ESIC MEDICAL COLLEGE AND PGIMSR, KK NAGAR, CHENNAI 600078

DEPARTMENT OF COMMUNITY MEDICINE

FINAL PROJECT REPORT

Title: Utilization and Economic Evaluation of Advanced Diagnostic and Therapeutic Healthcare Equipments in Public Healthcare Facilities of Tamil Nadu

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ADDRESS FOR CORRESPONDENCE

Dr. Yuvaraj Krishnamoorthy
Assistant Professor, Department of Community Medicine,
ESIC Medical College and PGIMSR, KK Nagar, Chennai 600078
email: yuvi.1130@gmail.com; Phone: 9551892665

PROJECT TEAM

Principal Investigator

Dr. Yuvaraj K, Assistant Professor, Department of Community Medicine, ESIC Medical College and PGIMSR, KK Nagar, Chennai 600078, Phone: 9551892665 Email: yuvi.1130@gmail.com

Co-Principal Investigators

1. Dr. Dhanajayan, Senior Resident, Department of Community Medicine, ESIC Medical College and PGIMSR, KK Nagar, Chennai 600078, Email: gdhanajayanj@gmail.com, Phone: 7904422741
2. Dr. Marie Gilbert Majella, Assistant Professor, Department of Community Medicine, Sri Venkateswaraa Medical College Hospital and Research Centre, Puducherry, email: gilbert2691@gmail.com, Phone: +91 9629584314
3. Dr Deivasigamani Kuberan, Professor and Head, Department of Community Medicine, ESIC Medical College and PGIMSR, KK Nagar, Chennai 600078, Email: dkuberan@gmail.com
4. Dr. Suthanthira Kannan, Assistant Professor, Department of Community Medicine, ESIC Medical College and PGIMSR, KK Nagar, Chennai 600078, Email: gurudixitkannan@gmail.com
5. Dr Venmathi, Assistant Professor, Department of Community Medicine, ESIC Medical College and PGIMSR, KK Nagar, Chennai 600078, Email: drvenmathielangovan@gmail.com
6. Dr. Arivarasan B, Assistant Professor, Department of Community Medicine, ESIC Medical College and PGIMSR, KK Nagar, Chennai 600078, Email: drarivarasan26@gmail.com

LIST OF ABBREVIATIONS

APC	Annual Percent Change
AAPC	Average Annual Percent Change
BIC	Bayesian Information Criterion
CHE	Catastrophic health expenditure
CMCHIS	Chief Minister's Comprehensive Health Insurance Scheme
CHC	Community health centers
CT	Computed Tomography
CI	Confidence interval
DEO	Data entry operator
DH	District hospitals
ESI	Employees' State Insurance
FA	Field Assistant
GH	Government Hospital
GMC	Government Medical Colleges
HDI	Human development index
INR	Indian Rupee
IT	Information technology
IQR	Interquartile range
LINAC	Linear accelerator
MMC	Madras Medical College
MRI	Magnetic resonance imaging
NCI	National Cancer Institute
OOPE	Out-of-pocket expenditures
OPD	Outpatient Department
OEE	Overall Equipment Effectiveness

PET	Positron emission tomography
PMJAY	Pradhan Mantri Jan Arogya Yojana
PHC	Primary health centers
RGGGH	Rajiv Gandhi Government General Hospital
RA	Research Assistant
STATA	Statistical software for data science
SC	Sub-centers
TNGMSSH	Tamil Nadu Government Multi-Super-Speciality Hospital
TNMSC	Tamil Nadu Medical Services Corporation
TEEP	Total Effective Equipment Performance
USA	United States of America
WHO	World Health Organization

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EXPLANATION AND PROBLEM STATEMENT

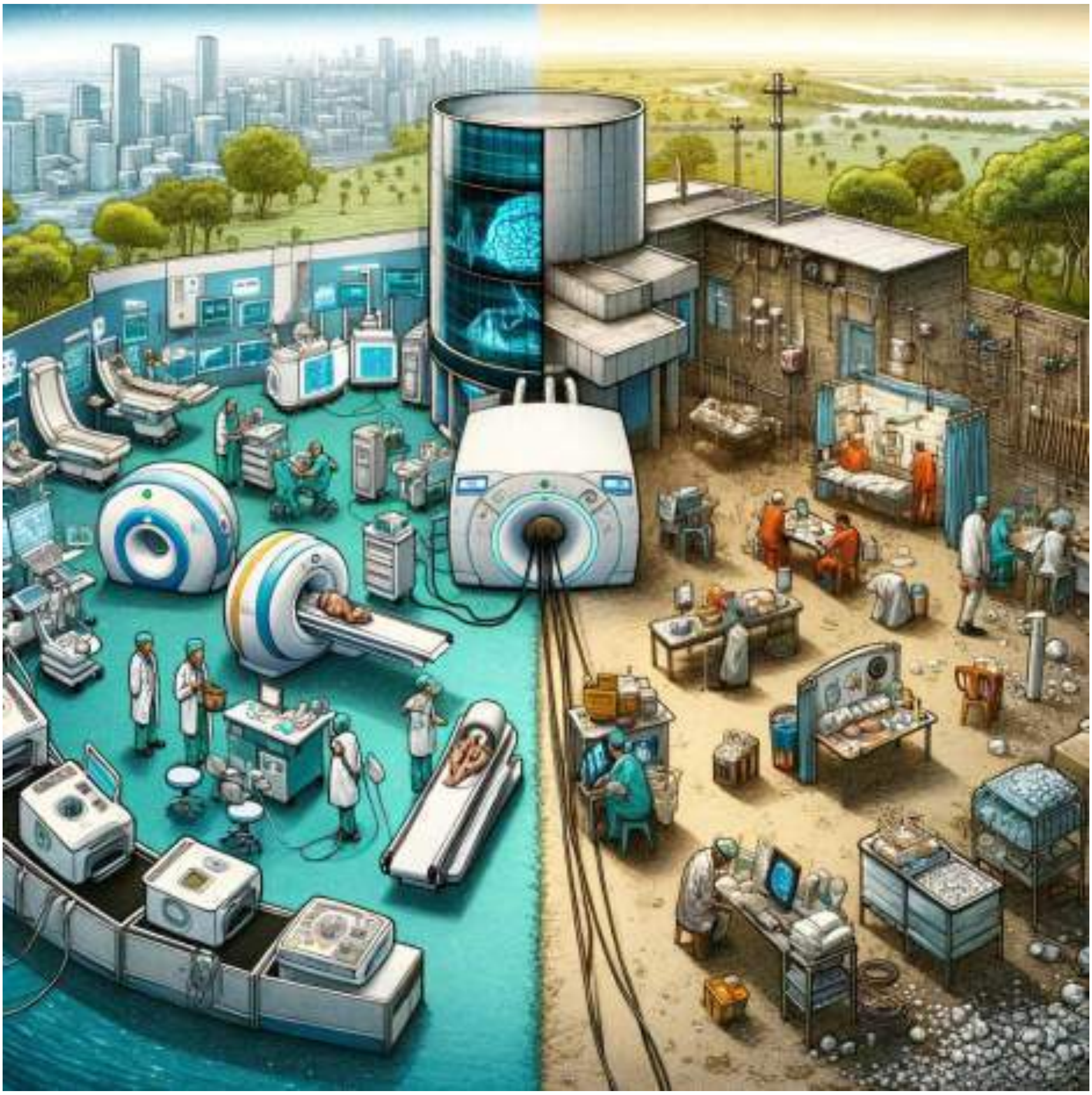
Global Healthcare Dynamics and Technological Disparity

World Health Organization (WHO) has reported that the use of medical devices and equipment is an essential component for maintaining the health system performance.[1] Diagnostic imaging, and intervention equipment consumes a significant portion of the annual healthcare budget across all the countries in the world.[1] In a global context, healthcare systems are increasingly reliant on advanced medical technologies and it is crucial to understand the varying degrees of access to medical technology.

In many developed countries, the healthcare systems are not only well-funded but also integrated with the latest advancements in medical technology. This integration enables these nations to offer a broad spectrum of advanced diagnostic and therapeutic options, ranging from precision medicine to minimally invasive surgical techniques. These technologies not only enhance the accuracy of diagnoses and effectiveness of treatments but also significantly improve patient outcomes and quality of life.[2]

In contrast, developing nations face challenges in adopting these technologies due to budget constraints and infrastructure limitations.[3] Limited budgets mean that investments in healthcare are frequently directed towards basic medical services and infrastructure, leaving little room for the acquisition of state-of-the-art medical equipment. Furthermore, the lack of skilled professionals who can operate and maintain such advanced equipment exacerbates the challenge. As a result, patients in these regions may not have access to the same level of diagnostic accuracy and treatment options available in more affluent countries.

This technological disparity also affects global efforts to combat infectious diseases and manage chronic conditions. Advanced diagnostics play a crucial role in early detection and management of diseases, which is a cornerstone of effective healthcare. Without access to these technologies, developing countries often face delays in diagnosis, leading to higher rates of morbidity and mortality.[4] Additionally, the lack of advanced therapeutic equipment limits the treatment options available for complex conditions, often resulting in suboptimal patient outcomes.



Moreover, the disparity in healthcare technology has implications for global health security. The COVID-19 pandemic highlighted the need for rapid and accurate diagnostic testing, which was a challenge for countries without the necessary technological infrastructure.[5] This not only impacts the ability to manage health crises within these countries but also poses a risk to global health, as delayed detection and response can contribute to the spread of infectious diseases across borders.[6]

Addressing this disparity requires a multifaceted approach. International cooperation and partnerships are vital in helping lower-income countries acquire and maintain advanced medical technologies. Additionally, initiatives to train healthcare professionals in these regions are essential to ensure the effective use of the equipment. Bridging the technological divide is not just a matter of equity;[7] it is a critical component in the global effort to improve healthcare outcomes and enhance health security worldwide.

Advanced medical imaging and therapeutic intervention equipment such as CT scan, MRI, PET scan, Echocardiography, Lithotripsy machine, Linear accelerator, Cobalt therapy unit, Brachytherapy contributes to accurate diagnosis of the disease condition and improved therapeutic treatment outcomes.[8] These equipments are utilized across various healthcare disciplines and provision of some of these modalities is inevitable for the medical diagnosis and treatment of patients with major disease conditions like cancer. However, this investment must be scrutinized for its effectiveness and efficiency, particularly in the public sector where resources are more constrained.

Challenges in Utilization of Advanced Medical Equipment in India

The healthcare landscape in India is particularly complex. The vast population of the country and diverse socio-economic strata present unique challenges in healthcare delivery. Public healthcare facilities, which cater to a large portion of the population, often struggle with resource allocation. This struggle is amplified in the realm of advanced medical equipment, where the need to balance cost with technological advancement is most acute. The Indian government has allocated nearly 5% of its healthcare expenditure on imaging services and equipment[9], which is a testament to the recognized importance of these technologies.

The rapid evolution of medical technology over the past few decades has significantly impacted healthcare delivery worldwide.[10,11] The development of more sophisticated diagnostic and therapeutic equipment has opened new frontiers in medical science, enabling the early detection and more effective treatment of various diseases. However, this technological advancement has also widened the gap between high-income and low-income regions. In many developing countries, including parts of India, access to state-of-the-art medical technology is limited, contributing to disparities in health outcomes.[12] The challenge for policymakers is to bridge this gap by facilitating the adoption of advanced technologies in a cost-effective manner, ensuring equitable healthcare access for all segments of the population.

The utilization of advanced medical imaging and therapeutic intervention equipment is not uniform across various healthcare disciplines. Some areas, like oncology, necessitate the frequent use of such equipment, while others may not. This uneven distribution and utilization can lead to inefficiencies in the healthcare system. For instance, the over-concentration of certain equipment in urban centres often leads to underutilization in rural or less populated areas. Conversely, the high demand in urban centres can lead to overutilization, straining both equipment and human resources, and potentially increasing the risk of diagnostic errors due to overwork and equipment wear.

Moreover, the effective utilization of these advanced technologies is not solely a matter of availability. It also encompasses aspects like the training and skill level of the healthcare professionals operating these machines, the maintenance and upkeep of the equipment, and the administrative policies governing their use. The lack of adequately trained personnel can lead to underutilization or incorrect utilization, impacting diagnostic accuracy and patient safety. Similarly, poor maintenance can reduce the lifespan of expensive equipment, necessitating more frequent replacements and thus impacting cost-effectiveness.[13]

The infrastructure of healthcare facilities plays a crucial role in the utilization of advanced medical equipment. In regions where healthcare infrastructure is underdeveloped, the integration and effective use of such equipment is hindered. This includes not only the physical aspects, such as space and power supply, but also the supportive elements like supply chains for parts and consumables, and IT systems for data management. In Tamil Nadu, the disparity in healthcare infrastructure between urban and rural areas influences the distribution and efficiency of advanced medical equipment. Enhancing the infrastructure, therefore, is key to improving the utilization rates of these technologies, ensuring that investments translate into tangible improvements in patient care and health outcomes.

TABLE 1: COMPARATIVE ANALYSIS OF HEALTHCARE SYSTEMS:

DEVELOPED COUNTRIES VS. DEVELOPING COUNTRIES (INDIAN FOCUS)

Characteristics	Developed Countries	Developing Countries (Focus on India)
Healthcare Budget Allocation	High; substantial investment in advanced medical technologies like MRI, CT scans, etc.	Limited; major portion directed towards basic medical services and infrastructure. Advanced medical technology investment is constrained.
Access to Advanced Technologies	Broad access to state-of-the-art medical equipment and facilities.	Limited access, especially in rural areas. Advanced equipment is more concentrated in urban centers.
Infrastructure	Well-developed infrastructure supporting advanced medical technologies.	In many areas, especially rural, infrastructure is underdeveloped, hindering the integration of advanced medical equipment.
Professional Training	High level of training in operating advanced medical equipment.	Varied levels of training; often a shortage of professionals skilled in advanced medical technologies.
Diagnostic and Treatment Options	Wide range of advanced diagnostic and treatment options available.	Limited options due to lack of advanced equipment, especially in remote and rural areas.
Health Outcomes	Improved patient outcomes due to early detection and effective treatment.	Potential delays in diagnosis and limited treatment options lead to varied health outcomes.
Impact of COVID-19	Rapid reallocation of resources; maintained regular services while managing the crisis.	Significant strain, often at the expense of regular diagnostic and therapeutic services. Highlighted the need for adaptable healthcare systems.
Policy Challenges	Focus on innovation and integration of cutting-edge technologies.	Need to bridge the technological gap and improve healthcare equity, especially in rural areas.

Understanding these factors will in turn provide knowledge to the policymakers about the possible under-utilization or over-utilization of these equipments. Both under-utilization and over-utilization has its own share of disadvantages.[8] Under-utilization of diagnostic equipment due to various factors in terms of performance, quality or availability can lead to under diagnosis of certain major disease condition, which in turn leads to high therapeutic costs to the government institutions because of late diagnosis. Underutilization of therapeutic equipment will lead to serious complications or even death of the patients who need the therapy, which in turn will indirectly cost the government in terms of loss of productivity.

Overutilization can also potentially harm the patients in terms of high radiation exposure or any other adverse reactions associated with the equipment and costs the government more than the expected amount.[8] In addition, inappropriate or inadequate selection and distribution of the advanced equipment can result in inefficiencies and waste, or hamper the quality of healthcare services, in serious situations like pandemic.[14] Hence, proper utilization of these equipment at appropriate level of healthcare facility is important for the government to ensure good and high-quality care for the patients.

Economic Implications and the Need for Resilient Healthcare Systems

The economic implications of these utilization patterns are profound. The direct costs associated with purchasing and maintaining this equipment are substantial, but the indirect costs, such as those stemming from late diagnoses or unnecessary treatments, can be even higher. Additionally, the opportunity cost of investing heavily in certain types of equipment at the expense of others, or other areas of healthcare, must be carefully considered. This necessitates a holistic economic evaluation of the utilization of these technologies in public healthcare facilities.

Lastly, the COVID-19 pandemic has underscored the importance of having a well-equipped and flexible healthcare system.[15] The pandemic has led to a significant reallocation of healthcare resources, often at the expense of regular diagnostic and therapeutic services. This has further complicated the landscape of equipment utilization, bringing to light the need for adaptable and resilient healthcare systems capable of handling such crises without compromising on regular healthcare services.

Furthermore, the integration of advanced medical technologies in public healthcare facilities is not just a matter of economic investment, but also a strategic move towards enhancing healthcare equity. In Tamil Nadu, where there is a diverse range of healthcare needs across different population segments, equitable access to high-quality healthcare services is essential. Advanced medical technologies, if utilized effectively, can bridge the gap in healthcare delivery between urban and rural areas, and between affluent and economically disadvantaged groups. This aspect of healthcare equity is crucial in the evaluation of economic implications.

The utilization and economic evaluation of advanced diagnostic and therapeutic healthcare equipment in public healthcare facilities in Tamil Nadu is a multifaceted issue. It requires a comprehensive understanding of the global and local healthcare contexts, technological advancements, utilization patterns, economic implications, and the impact of extraordinary events like pandemics. This understanding is crucial for policymakers to make informed decisions that optimize the use of these technologies for the betterment of public health.

RATIONALE OF THE STUDY

The commitment of Government of Tamil Nadu towards healthcare is evident in its robust healthcare system, which has set benchmarks in various health indices within India. However, despite these achievements, there are significant areas that require deeper exploration, particularly in the context of advanced medical technology. The state's investment in healthcare technology has been substantial, yet the actual impact of this investment on health outcomes and economic efficiency remains largely unquantified. This gap in understanding necessitates a comprehensive study to evaluate the efficacy and economic impact of these technologies.

The utilization of advanced medical equipment like CT scans, MRI, PET scans, LINAC, brachytherapy, cobalt therapy unit and lithotripsy plays a pivotal role in the early diagnosis and effective treatment of a wide array of medical conditions. These technologies, while being capital-intensive, offer unparalleled benefits in terms of precise diagnosis and targeted treatment, which are crucial for conditions like cancer, cardiovascular diseases, renal and neurological disorders. However, the allocation and utilization of such equipment in Tamil Nadu healthcare system seem to follow an uneven pattern, with a concentration in urban centers and tertiary care facilities, potentially leading to underutilization in secondary and rural healthcare setups.

Moreover, the economic aspect of utilizing these advanced technologies is a multi-faceted issue. The high costs associated with the acquisition, maintenance, and operation of such equipment raise questions about cost-effectiveness and return on investment. This is especially pertinent in a public healthcare setting where resource allocation must be balanced against a backdrop of budget constraints and the need to cater to a large and diverse population. The economic evaluation of these technologies will provide insights into their affordability, efficiency, and value for money, helping to inform future policy decisions.

Understanding the utilization patterns of these advanced technologies is crucial. It involves analyzing the frequency of their use, the types of conditions they are most commonly used for, and the demographics of the patient population benefiting from them. This analysis will reveal whether the current utilization aligns with the healthcare needs of the population or if there are gaps that need to be addressed.

Furthermore, the appropriateness of these technologies at different levels of healthcare delivery is another critical aspect. Assessing whether the right equipment is available at the right level of care, and whether healthcare professionals are adequately trained to use them, is essential. This also ties into the broader issue of healthcare equity - ensuring that advanced medical technologies are accessible not just in urban tertiary centers but also in secondary and rural healthcare facilities. In addition to these factors, the study will also consider the impact of external variables such as policy changes, demographic shifts, and emerging healthcare challenges, including those posed by recent events like the COVID-19 pandemic. The pandemic has significantly altered healthcare priorities and resource allocation, making it imperative to reassess the utilization and relevance of advanced medical equipment in this new context.

This study aims to fill the existing knowledge gap regarding the utilization and economic evaluation of advanced diagnostic and therapeutic healthcare equipment in Tamil Nadu's public healthcare facilities. By providing a comprehensive analysis of the current situation, this study will offer valuable insights to policymakers and healthcare administrators, aiding in the optimization of resource allocation and the enhancement of healthcare delivery across the state.

NOVELTY OF THE STUDY

This study introduces a novel approach to assessing healthcare technology in Tamil Nadu, setting it apart from previous research in several key ways. Firstly, the comprehensive scope of our evaluation, which encompasses both economic and utilization aspects of advanced medical technologies in public healthcare facilities, is a pioneering effort in the region. Most previous studies have focused either on the economic or clinical aspects of medical technology, but rarely both in an integrated manner. By combining these two critical dimensions, our research provides a more holistic understanding of the impact of these technologies.

Another innovative aspect of our study is the specific focus on public healthcare facilities. While private healthcare in India, and Tamil Nadu in particular, has been the subject of extensive research, public healthcare facilities[16] – which serve the majority of the population – have received less attention in terms of advanced medical technology utilization. Our study addresses this gap by specifically examining how these technologies are used in public settings, where resource constraints and patient demographics present unique challenges and opportunities.

Integration of Local Healthcare Context

The study also takes into consideration the unique healthcare context of Tamil Nadu, which includes its diverse demographic profile, varying levels of healthcare infrastructure across regions, and specific health challenges. This local focus is crucial, as the effective utilization of advanced medical technologies cannot be generalized from one region or country to another. The findings from this study will provide insights that are specifically tailored to the needs and constraints of Tamil Nadu, making them more relevant and actionable for local policymakers and healthcare administrators.

Evaluation of Equipment Across Different Levels of Care

Our research stands out in its evaluation of advanced medical equipment across different levels of healthcare delivery – from secondary to tertiary facilities. This layered approach allows for a more nuanced understanding of how these technologies are utilized at various points in the healthcare delivery chain, and how their usage differs based on the level of care. This is particularly important in a state like Tamil Nadu, where there is a significant disparity in healthcare infrastructure and access between urban and rural areas.[17]

Analysis of the Impact of COVID-19

The study also includes an analysis of how the COVID-19 pandemic has impacted the utilization of advanced medical technologies. This aspect of the study is particularly novel, as it explores a recent and ongoing global health crisis that has dramatically altered healthcare priorities and resource allocation. The findings will provide valuable insights into how such crises can affect the utilization of advanced medical equipment and how healthcare systems can adapt to these changes.

Exploration of Healthcare Equity and Access

Another novel aspect of this study is its exploration of healthcare equity in the context of advanced medical technology utilization. By examining how these technologies are accessed and used across different socio-economic groups and regions within Tamil Nadu, the study sheds light on issues of healthcare equity and access. This is a crucial area of investigation, as advanced medical technologies have the potential to either bridge or widen existing healthcare disparities.

Implications for Policy and Practice

Finally, the study is innovative in its potential implications for policy and practice. The findings will inform policymakers about the most effective and efficient ways to allocate resources for advanced medical technologies in public healthcare facilities. This could lead to more informed decision-making, better resource allocation, and ultimately, improved healthcare outcomes for the population of Tamil Nadu.

OBJECTIVES

Among the secondary and tertiary healthcare facilities in selected districts of Tamil Nadu,

- To determine the equipment utilization indices in terms of overall equipment effectiveness and total effective equipment performance for major healthcare equipment (CT scan, MRI, PET scan, Lithotripsy machine, Linear accelerator, Cobalt therapy unit, Brachytherapy)
- To assess the institute-level trends in utilization of advanced diagnostic and therapeutic healthcare equipment
- To perform economic evaluation for the advanced diagnostic and therapeutic healthcare equipment from health system and societal perspective

APPROACH AND METHODOLOGY

Study design and setting

We have conducted a facility based observational survey involving both primary (time and motion study) and secondary data collection (retrospective record review) to calculate the equipment utilization indices and perform economic evaluation.

Healthcare services in the state of Tamil Nadu are provided by a three-tier structure delivery system.[18] At the primary level, sub-centers (SCs) and primary health centers (PHCs) are responsible for provision of healthcare delivery. In secondary level, community health centers (CHCs) and district hospitals (DHs) are responsible for providing specialist secondary services and in tertiary level, medical colleges/hospitals are responsible for tertiary services.

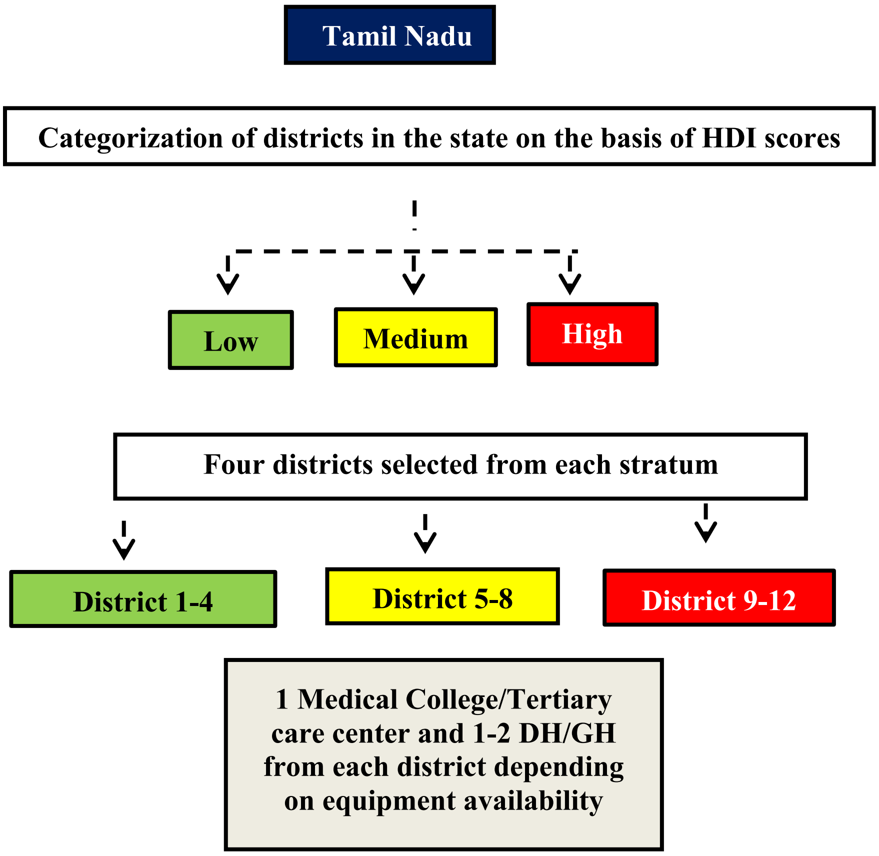
In Tamil Nadu, high-end healthcare equipment for the diagnosis and treatment of chronic health conditions such as CT scan, MRI, PET scan, Lithotripsy machine, brachytherapy, Linear accelerator, Cobalt therapy unit, are available majorly in tertiary care facilities like medical colleges/hospitals and in few secondary healthcare facilities like district hospitals.

Sampling strategy

Since these equipments are available mainly in the secondary and tertiary care facilities of Tamil Nadu, only these two levels of healthcare facilities will be sampled. A two-stage stratified random sampling was performed for the selection of public health facilities.

Stage 1: In the first stage, all the districts were stratified into three categories (low, medium and high) based on their human development index (HDI) scores.[19] The reason for choosing HDI to stratify the districts is that the indicators in HDI were representative of important demand side characteristics explaining the health status, healthcare seeking behavior and utilization of services. Four districts from each of these strata were selected and keeping in mind the geographical representation of the districts and the availability of the advanced medical equipment in the districts.

Figure 1: Sampling strategy for the selection of districts and facilities



Stage 2: In the second stage, 1 tertiary care hospitals/medical colleges and 1-2 DHs/GHs in each selected district were selected (depending on the availability of equipment), summing up to 23 public healthcare facilities (14 medical colleges and 9 GHs) in Tamil Nadu (**Table 1**). However, since Chennai has multiple medical colleges with advanced medical equipment, three medical colleges were selected. At present, TNMSC operates advanced medical equipment and devices in the following number of centres[20]:

- 124 CT scan equipment in 95 healthcare facilities;
- 34 MRI Scanners at 33 centres in Government Medical Institutions;
- 3 lithotripsy machines in 3 locations at RGGGH Chennai, Madurai, and Coimbatore

- 11 Linear Accelerator centres one each at Rajiv Gandhi Government General Hospital, Chennai, Government Rajaji Hospital, Madurai, Government Arignar Anna Cancer Institute, Karapettai, Kancheepuram (2 equipment), Government Medical College Hospital Thoothukudi, Government Medical College Hospital Tirunelveli, Government Medical College Hospital Coimbatore, Government Medical College Hospital Thanjavur, Government Royapettah Hospital, Chennai and TNGMSSH, Chennai, Govt. Mohan Kumaramangalam Medical College Hospital, Salem, Govt. Rajaji Hospital, Madurai;
- 15 Cobalt Therapy units one each at Rajiv Gandhi Government General Hospital, Chennai, Government Rajaji Hospital, Madurai, Government Arignar Anna Cancer Institute, Karapettai, Kancheepuram (2 equipment), Government Medical College Hospital Villupuram, Government Medical College Hospital Tirunelveli, Government Medical College Hospital Coimbatore, Government Medical College Hospital Thanjavur, Government Royapettah Hospital, Chennai, Government Medical College & Hospital, Dharmapuri, Govt. Mohan Kumaramangalam Medical College Hospital, Salem, Govt. Rajaji Hospital, Madurai, IOG, Chennai, Stanley Medical College, Chennai, Government Medical College & Hospital, Pudukottai;
- PET CT scan services under Public Private Partnership mode are established and functioning at Government Rajaji Hospital, Madurai and at Rajiv Gandhi Government General Hospital, Chennai
- 7 Brachytherapy units one each at Rajiv Gandhi Government General Hospital, Chennai, Government Rajaji Hospital, Madurai, Government Medical College Hospital Tirunelveli, Government Medical College Hospital Coimbatore, Government Medical College Hospital Thanjavur, Government Royapettah Hospital, Chennai, Govt. Rajaji Hospital, Madurai;

Keeping in mind the availability of machines, HDI stratification and geographical representation, the following districts and medical college institutions (GHs were selected after checking the availability of advanced medical equipment) were selected for this study:

TABLE 2: LIST OF DISTRICTS AND FACILITIES COVERED IN THE STUDY

District	HDI	Medical Colleges	Secondary Hospitals
CHENNAI	High	Rajiv Gandhi Government General Hospital, Government Stanley Medical College Hospital, Tamil Nadu Government Multi Super Speciality Hospital, Omandurar	Government Royapettah Hospital
COIMBATORE	High	Coimbatore Medical College Hospital	Nil
TIRUNELVELI	High	Tirunelveli Medical College Hospital	Nil
TRICHY	High	K.A.P. Viswanatham Government Medical College, Tiruchirapalli	Government Hospital, Srirangam
SALEM	Medium	Government Mohan Kumaramangalam Medical College and Hospital	Government Hospital, Mettur
MADURAI	Medium	Madurai Medical College Hospital	Government Hospital, Melur
THANJAVUR	Medium	Government Medical College Thanjavur	Government Hospital, Pattukottai
SIVAGANGAI	Medium	Government Sivagangai Medical College	Government Hospital, Karaikudi
VILLUPURAM	Low	Government Villupuram Medical College and Hospital	Government Hospital, Tindivanam
THENI	Low	Government Theni Medical College	Government Hospital, Periyakulam
TIRUVARUR	Low	Government Tiruvarur Medical College	Nil
THE NILGIRIS	Low	Government Medical College, The Nilgiris	Government Lawley Hospital, Coonoor

In total, 82 equipment were covered across these selected facilities. The stratification based on type of equipment is provided in ***Table-3.***

TABLE-3: DATA COLLECTION DETAILS ACROSS STUDY FACILITIES

Total number of districts covered	Total number of facilities covered	Total number of equipments covered	Stratification based on the type of equipment
12	23 (14 medical colleges & 9 GHs)	81	CT = 39 MRI = 16 LINAC = 7 Cobalt therapy = 8 Brachytherapy = 7 Lithotripsy = 2 PET = 2

Based on the availability of the total amount of equipment in Tamil Nadu, the number of equipment covered in our study are as follows:

- Brachytherapy – All the 7 equipment present throughout Tamil Nadu are covered.
- PET scan – 2 out of the available 2 equipment are covered.
- Lithotripsy – 2 out of 3 equipment are covered (1 other equipment in Coimbatore medical college could not be observed as it was currently non-functional due to lack of manpower; 1 lithotripsy equipment in Madurai Medical College is condemned)
- LINAC – 7 out of 11 equipment are covered.
- Cobalt therapy unit – 8 out of 15 equipment are covered.
- MRI – 16 out of 34 equipment are covered.
- CT – 39 out of 124 equipment are covered.

TABLE 4: LIST OF INSTITUTES AND EQUIPMENTS COVERED IN THE STUDY

Institute name	CT	MRI	PET	Lithotripsy	Cobalt	LINAC	Brachy	Total
1 (MMC)	4	2	1	1	0	1	1	10
2 (Stanley)	2	1	0	0	1	0	0	4
3 (Omandurar)	4	1	0	0	0	1	1	7
4 (Royapettah GH)	1	1	0	0	1	1	1	5
5 (Coimbatore Medical College)	3	1	0	0	1	1	1	7
6 (Madurai Medical College)	3	1	1	0	1	1	1	8
7 (Mellur GH)	1	0	0	0	0	0	0	1
8 (Tirunelveli Medical college)	2	1	0	1	1	1	1	7
9 (Trichy Medical College)	2	1	0	0	0	0	0	3
10 (Srirangam GH)	1	0	0	0	0	0	0	1
11 (Thanjavur Medical College)	2	1	0	0	1	1	1	6
12 (Pattukottai GH)	1	0	0	0	0	0	0	1

13 (Salem Medical College)	2	1	0	0	1	0	0	5
14 (Mettur GH)	1	0	0	0	0	0	0	1
15 (Sivagangai Medical College)	1	1	0	0	0	0	0	1
16 (Karaikudi GH)	1	0	0	0	0	0	0	1
17 (Villupuram Medical College)	2	1	0	0	1	0	0	4
18 (Tindivanam GH)	1	0	0	0	0	0	0	1
19 (Theni Medical College)	1	1	0	0	0	0	0	2
20 (Periyakulam GH)	1	0	0	0	0	0	0	1
21 (Nilgiris Medical College)	1	1	0	0	0	0	0	2
22 (Lawley GH)	1	0	0	0	0	0	0	1
23 (Tiruvarur Medical College)	1	1	0	0	0	0	0	2
Total	**39**	**16**	**2**	**2**	**8**	**7**	**7**	**81**

Study procedure

Training of data collectors

A team of investigators were recruited as data collectors for this survey. In total, 3 Research Assistants (RAs) were recruited. The RAs were responsible for retrieving the utilization data and conducting patient level survey for costing from the selected healthcare facilities. Each RA was responsible for four districts covering at least 8 facilities. Four Field Assistants (FAs) with bachelor's degree in radiology technician/radiography/radiation therapy were recruited to perform the time and motion observation of the equipment.

Before starting the data collection process, a week-long training was provided to familiarize them on data collection methods and tools. Piloting of the questionnaire and data collection tool was done in the parent institute of the Principal Investigator. Modifications were made based on the pilot survey findings. Finally, one data entry operator (DEO) was recruited for entering the time and motion data collected during the study. All the data collectors were monitored periodically by the Principal Investigator and Co-Investigators.

Equipment utilization

Equipment utilization in public healthcare facilities was assessed using a tool containing the set of indicators developed using literature search, standard guidelines, and expert opinions. The information required to be collected for each of the equipment during the primary data collection is given as follows:

Information to be collected for each of the equipment

CT scan

Number of CT scan conducted per year, age and gender distribution of patients undergoing CT scan on the day of data collection, Site of scan (Abdomen/Chest/Head/Spine), Purpose of scan (suspected diagnosis), Diagnosis based on CT scan, operating time per patient/day/month/year, scheduled time per patient/day/month/year, ideal cycle time per patient, number of poor-quality procedures, avoidable and unavoidable delays in procedure, number of persons undergoing the procedure who are covered by health insurance (if yes, public/private and name of the scheme), delay between procedure and reporting.

MRI

Number of MRI scan conducted per year, age and gender distribution of patients undergoing MRI scan on the day of data collection, Site of scan (Head/Spine), Purpose of scan (suspected diagnosis), Diagnosis based on MRI scan, operating time per patient/day/month/year, scheduled time per patient/day/month/year, ideal cycle time per patient, number of poor-quality procedures, avoidable and unavoidable delays in procedure, number of persons undergoing the procedure who are covered by health insurance (if yes, public/private and name of the scheme), delay between procedure and reporting

PET scan

Number of PET scan conducted per year, age and gender distribution of patients undergoing PET scan on the day of data collection, Site of PET scan, Purpose of scan (suspected diagnosis), Diagnosis based on echocardiography, operating time per patient/day/month/year, scheduled time per patient/day/month/year, ideal cycle time per patient, number of poor-quality procedures, avoidable and unavoidable delays in procedure, number of persons undergoing the procedure who are covered by health insurance (if yes, public/private and name of the scheme), delay between procedure and reporting

Lithotripsy machine

Number of times lithotripsy machine utilized per year, age and gender distribution of patients undergoing procedure on the day of data collection, Purpose of utilizing the machine, operating time per patient/day/month/year, scheduled time per patient/day/month/year, ideal cycle time per patient, number of poor-quality procedures, avoidable and unavoidable delays in procedure, number of persons undergoing the procedure who are covered by health insurance (if yes, public/private and name of the scheme).

LINAC

Number of times LINAC utilized per year, age and gender distribution of patients undergoing LINAC procedure, Purpose of utilizing LINAC, operating time per patient/day/month/year, scheduled time per patient/day/month/year, ideal cycle time per patient, number of poor-quality procedures, avoidable and unavoidable delays in procedure, number of persons undergoing the procedure who are covered by health insurance (if yes, public/private and name of the scheme).

Cobalt therapy unit

Number of times Cobalt therapy unit utilized per year, age and gender distribution of patients undergoing procedure on the day of data collection, Purpose of utilizing the unit, operating time per patient/day/month/year, scheduled time per patient/day/month/year, ideal cycle time per patient, number of poor-quality procedures, avoidable and unavoidable delays in procedure, number of persons undergoing the procedure who are covered by health insurance (if yes, public/private and name of the scheme).

Brachytherapy unit

Number of times brachytherapy unit utilized per year, age and gender distribution of patients undergoing procedure on the day of data collection, Purpose of utilizing the unit, operating time per patient/day/month/year, scheduled time per patient/day/month/year, ideal cycle time per patient, number of poor-quality procedures, avoidable and unavoidable delays in procedure, number of persons undergoing the procedure who are covered by health insurance (if yes, public/private and name of the scheme).

Table 5: Sample size for Time and Motion study and Costing Study

Serial Number	Name of the Equipment	No of the equipment	No of observations per equipment	Total no of time and motion observations	Total number of patients for costing data collection
1	CT	39	≅50	2056	1919
2	MRI	16	≅30	410	461
3	PET	2*	29	29	35
4	Lithotripsy	2	≅25	50	82
5	Cobalt therapy	8	≅35	280	146
6	LINAC	7	≅50	369	319
7	Brachy therapy	7#	≅5	37	35
TOTAL SAMPLE SIZE COVERED				**3231**	**2997**

*Permission to perform time and motion observation was given for only one equipment

#No time and motion observation was done in Tirunelveli Medical College Hospital as no patients underwent brachytherapy in the facility during the data collection period.

ANALYSIS PLAN (EQUIPMENT UTILIZATION INDICES)

LIST OF INDICATORS:

Total time interval scheduled for operating the equipment on the day of time and motion observation was recorded as ***scheduled time***.

Time interval between the actual start of the equipment till the end of utilizing the equipment on the day of time and motion observation was recorded as ***operating time***.

Total exam or procedure time was defined as the patient's door-to-door time. Sum of all the patient's door-to-door time on the day of time and motion observation was recorded as the ***functional time.***

Any interval during which the equipment remained unoccupied during normal hours
of operation was deemed to be ***idle time.***

1. Total equipment scheduled time (in minutes
2. Total equipment operating time (in minutes)
3. Total equipment functional time (in minutes)
4. ***Equipment utilization rate -*** Rate of utilization will be expressed per 1000 patients attending the hospital

Equipment utilization was assessed by determining the number of examinations done using each of these equipment and rates was generated based on calendar year.

5. ***Overall Equipment Effectiveness (OEE)***

OEE is a key performance indicator used to assess the equipment's ideal performance against its real performance. It is calculated by the product of three separate components[21]:

$$OEE = Availability \times Performance \times Quality$$

5.1.***Availability*** = percentage of scheduled time that the equipment is available to operate[22]

$$Availability = \frac{Operating\ time}{Scheduled\ time}$$

5.2.***Performance*** = speed at which the equipment runs against its designed speed

$$Performance = \frac{Procedure\ done * Ideal\ cycle\ time}{Operating\ time}$$

5.3.***Quality*** = percentage of appropriate quality diagnostic or therapeutic procedure against the total number of procedures done[21]

$$Quality = \frac{Procedure\ done - poor\ quality\ procedures}{Total\ procedures\ done}$$

Poor quality procedures for CT scan, MRI, PET scan (for diagnostic purposes) are defined as the poorer resolution of images generated using any of the scanning or diagnostic equipment assessed during this survey and necessitates the procedure to be done again. Source of data for poor quality images was the report from the technician.

Poor quality procedures for lithotripsy, Cobalt unit, and LINAC (for therapeutic purposes) are defined as the error due to defect in the equipment and necessitates the procedure to be done again.

6. Total Effective Equipment Performance (TEEP)

While OEE measures the efficiency based on the scheduled hours, TEEP measures efficiency against calendar hours i.e., 24 hours per day or 365 days per year. It is the product of OEE and loading.

$$TEEP = OEE \times Loading$$

6.1. ***Loading*** = percentage of time that the equipment is scheduled to operate against the total calendar time it is available[24]

$$Loading = \frac{Scheduled\ time}{Calendar\ time}$$

7. **Indicators for source of greatest losses in equipment utilization**:

We classified the indicators for source of greatest losses in equipment utilization into two factors: Avoidable delays and unavoidable delays

7.1. **Avoidable delays - Six big losses:** This determines the source of greatest losses and help to identify the area that need to be targeted for improving the performance. Identifying these measures will help in designing the counter measures and improve the overall OEE. These aspects can be identified under the three components of OEE.

7.1.1. Under Availability = Unplanned stops & Planned stops

7.1.2. Under Performance = Small Stops & Slow cycles

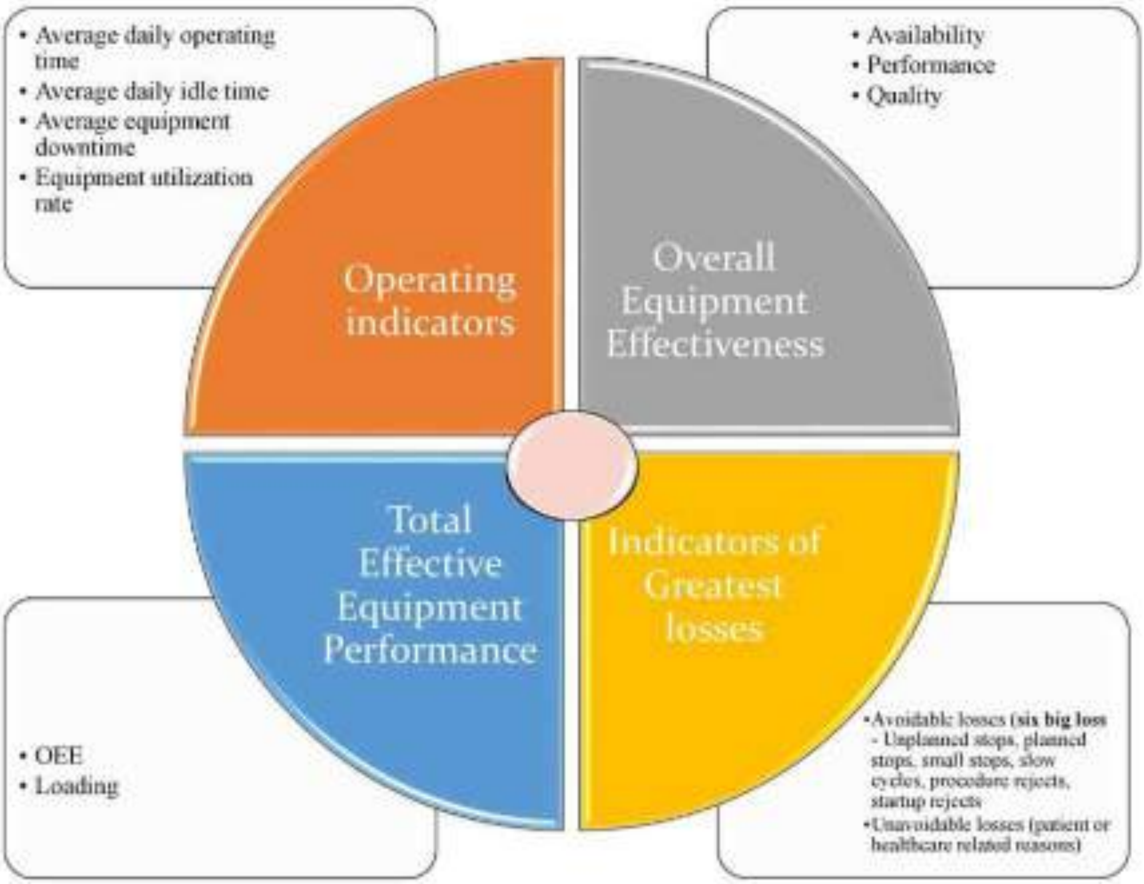
7.1.3. Under Quality = Procedures rejects & startup rejects

- Unplanned stops mean Equipment breakdown
- Planned stops mean setup and adjustments done to the equipment
- Small stops mean idling and minor stops
- Slow cycles mean speed loss
- Procedure rejects mean process defects
- Startup rejects mean reduced yield

However, since slow cycle incorporates various avoidable and unavoidable reasons within it, it was reported separately and avoidable stops consists of the other five parameters (unplanned stops, planned stops, small stops, procedure rejects and startup rejects).

7.2. **Unavoidable losses - Delay or cancellation in procedure due to unavoidable reasons**: We have also assessed the rate of delay or cancellation in procedures with respect to each of these equipment due to unavoidable circumstances (like patients' condition, absence of specialist due to unavoidable reasons etc.)

FIGURE 2: EQUIPMENT UTILIZATION INDICATORS



ANALYSIS PLAN (EQUIPMENT UTILIZATION RATE)

Data was retrieved in Microsoft Excel format and analysis was performed using STATA software version 14.2 (StataCorp, CollegeStation, TX, USA). All the equipment utilization indicators (outcome variables) was summarized descriptively as frequency and proportions.

Joinpoint regression:

First, the crude number of patients undergoing procedure for each of the seven equipment (CT, MRI, PET, Lithotripsy, Cobalt therapy, Brachytherapy) was obtained. This data was prepared for analysis by converting these absolute numbers into rates per 100,000 Outpatient Department (OPD) visits. This standardization was crucial for accurately assessing trends over time and making meaningful comparisons across different years. Both the absolute numbers and equipment utilization rate per 100,000 OPD visits were utilized for performing trend analysis using joinpoint regression.

The Joinpoint Regression Program (version 4.9.0) is a software developed by the United States (US) National Cancer Institute (NCI) to perform trend analysis for the incidence rates. It has been previously used to assess the trend of equipment utilization rates across several countries like USA and Canada.[25,26]

Joinpoint regression analysis involves fitting a series of connected linear segments to the data points. Each segment's slope, represented by the coefficient β, allows for the calculation of the Annual Percent Change (APC), given by the formula[27]:

$$APC = (\exp(\beta) - 1) \times 100$$

This measure quantifies the rate of change over a defined period of time.

In our analysis, the APC using joinpoint regression was used to examine the equipment utilization rate over the past decade (2013-2022). The best fitting point called "joinpoint" where a statistically significant change occurs was identified by joinpoint analysis.

The selection of the optimal number of joinpoints, indicative of significant changes in trend, was determined using the Weighted Bayesian Information Criterion (BIC). The BIC assesses the model fit, penalizing for the number of parameters to avoid overfitting. A lower BIC value indicates a better model fit. It was calculated using the formula[28]:

$$BIC = -2 \times ln(L) + k \times ln(n)$$

where L is the likelihood of the model,

k is the number of parameters, and

n is the number of observations.

Post identification of the joinpoints, the trends between these points were thoroughly analyzed. Furthermore, to encapsulate the overall trend direction and magnitude over the entire study period, we calculated the Average Annual Percent Change (AAPC). The AAPC is a summary measure that represents the average rate of change per year across all segments defined by the joinpoints, offering a comprehensive view of the long-term trend in equipment utilization.

This detailed analysis provided insights into how equipment utilization rates evolved over different periods, highlighting significant shifts and trends in healthcare service utilization. In the context of Tamil Nadu, this methodology was specifically applied to determine the changes in trend of equipment utilization rates at individual facilities surveyed. This analysis offered a localized understanding of equipment usage patterns, reflecting the healthcare dynamics specific to Tamil Nadu.

ANALYSIS PLAN (ECONOMIC EVALUATION)

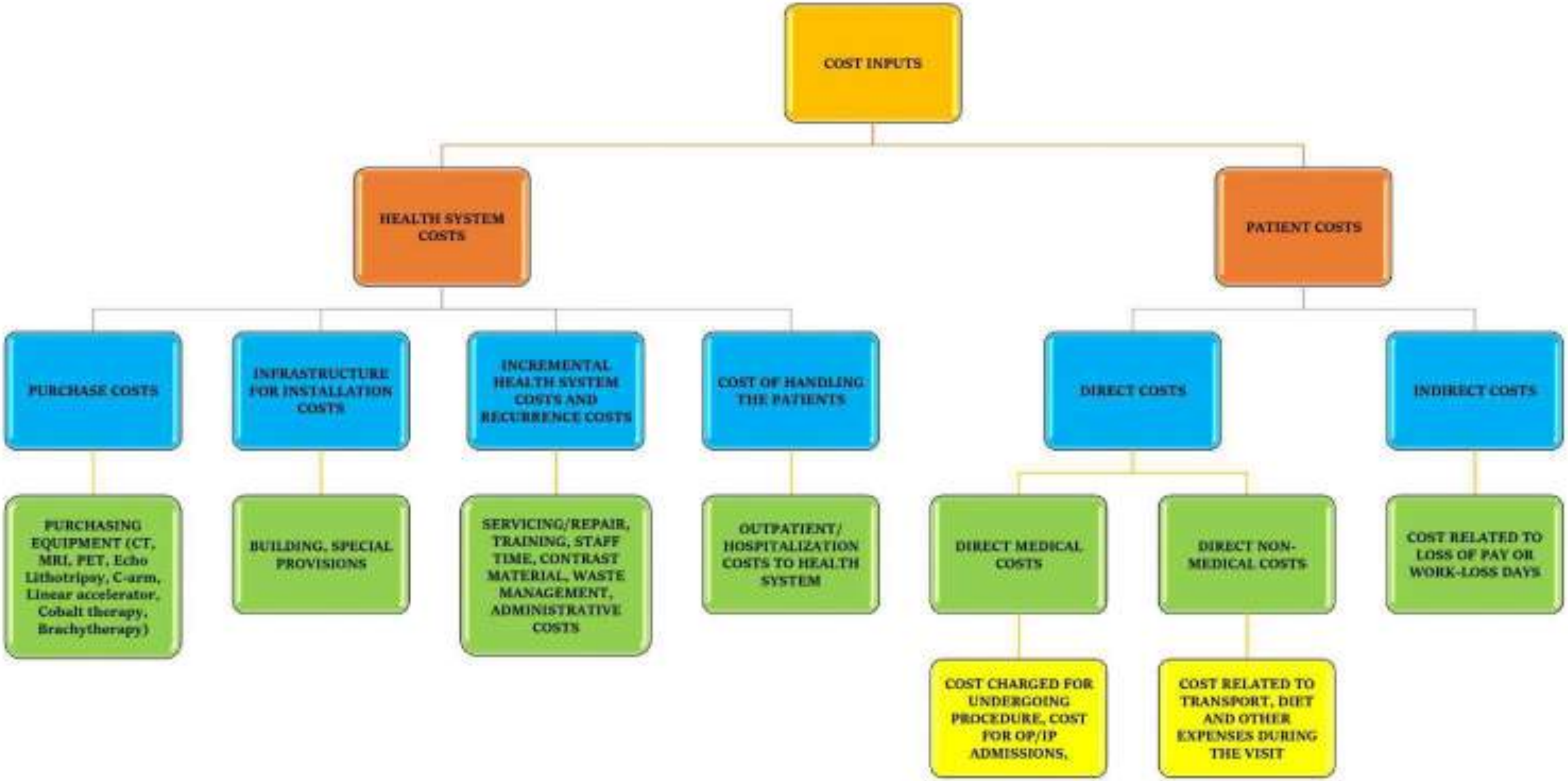
Equipment Costing Analysis:

We have performed a comprehensive costing analysis to understand the cost burden associated with each of the advanced diagnostic and therapeutic healthcare equipment from both health system and societal perspective.

Inputs required in the model from health system perspective were the costs related to equipment utilization such as cost of purchasing the healthcare equipment (CT scan, MRI, PET scan, Lithotripsy machine, Linear accelerator, Cobalt therapy unit, Brachytherapy), infrastructure for installation (building, special provisions), incremental health system and recurrence costs associated with healthcare equipment (additional cost in terms of servicing/repair of equipment, training, manpower or staff time, materials in terms of contrast materials or dyes, waste management and other administrative costs), and costs associated with handling of patients (outpatient or hospitalization [if necessary]).

For societal perspective, in addition to the above-mentioned parameters, the following parameters are required: Direct and indirect costs associated with patient expenses such as any cost charged from the patient for undergoing the procedure under healthcare equipment in the surveyed government facility, any fee associated with outpatient visit or hospitalization (if necessary) in surveyed government facility, cost associated with transport, diet and other direct non-medical costs associated with the visit and indirect costs related to loss of pay or work-loss days. These costs were obtained by interviewing the patients undergoing the procedure and observing the concerned experts during the procedure using time motion analysis.

FIGURE 3: TYPES OF COST DATA REQUIRED FOR ECONOMIC ANALYSIS OF ADVANCED DIAGNOSTIC AND THERAPEUTIC EQUIPMENT IN PUBLIC HEALTH FACILITIES OF TAMIL NADU



Patient Level Costing Analysis:

Our patient-level costing analysis aimed to understand the total cost per patient per procedure for seven different types of medical equipment: CT, MRI, PET, Lithotripsy, Cobalt therapy, LINAC, and Brachytherapy. The total cost per patient per procedure was calculated by incorporating all unit costs. This included direct medical costs, direct non-medical costs, and indirect costs. The comprehensive cost per procedure provided a detailed understanding of the financial burden borne by patients for each type of equipment.

Log-Linear Regression Model

The primary statistical method used in this analysis was log-linear regression. This approach is particularly suitable for modeling costs, as it can handle skewed cost data typically observed in health economics.

The general form of the log-linear regression model is[29]:

$$\ln(\mathrm{Yi}) = \beta 0 + \beta 1\mathrm{X1i} + \beta 2\mathrm{X2i} + \cdots + \beta \mathrm{kXki} + \epsilon\mathrm{i}$$

where ln(Yi) is the natural logarithm of the total cost for the i^{th} patient,

X1i,X2i,…,Xki are the independent variables (such as patient demographics, clinical characteristics, and other relevant factors),

β0,β1,…,βk are the coefficients to be estimated, and ϵiϵi is the error term.

In our analysis, the dependent variable was the logarithm of the total cost per patient per procedure. The independent variables included a range of characteristics such as residence (urban/rural), socioeconomic status (classified based on the latest modified BG Prasad classification 2023), insurance coverage (stratified into insured and utilized, insured and not-utilized and uninsured), distance travelled from home to hospital for the procedure (in kilometers [kms]), and waiting time after reaching hospital till the patient undergoes the procedure, depending on the equipment type. The coefficients obtained from the regression provide estimates of the percentage change in the total cost associated with a one-unit change in the independent variable, holding all other variables constant.

Model Fitting and Interpretation

Due to the limited sample size for PET scans, this equipment type was not included in a separate model. Furthermore, the three radiotherapy procedures (Cobalt therapy, LINAC, Brachytherapy) were combined into a single model, while CT, MRI, and Lithotripsy were each analyzed using separate models.

Each model was fitted separately for CT, MRI, and Lithotripsy, and a combined model for the three radiotherapy procedures. The models were assessed for their fit and explanatory power. The exponentiated coefficients from the log-linear models were interpreted as multiplicative effects on the total cost. A coefficient greater than one indicates an increase in the total cost associated with the independent variable, while a coefficient less than one indicates a decrease. Factors with p-value less than 0.20 in univariable analysis were included into multivariable analysis (adjusted model)

Statistical significance was determined based on P-values, with values less than 0.05 considered statistically significant. The models also included an assessment of potential multicollinearity among the independent variables.

RESULTS

Equipment Utilization Results

Time and motion observation findings

Table-6 encapsulates the findings from a detailed time and motion study conducted across 23 secondary and tertiary healthcare facilities in Tamil Nadu, focusing on the utilization of 81 different advanced diagnostic and therapeutic equipments. Over the course of 221 days, the study meticulously tracked the usage of these equipments, encompassing a total of 90,163 minutes of observation. During this period, the interactions and procedures involving 3,231 patients were analyzed, providing a comprehensive view of equipment utilization, patient flow, and operational efficiency within these healthcare settings.

Table 6: Details of the time and motion observation for advanced diagnostic and therapeutic equipment in secondary and tertiary healthcare facilities of Tamil Nadu

Category	Total
Total number of facilities observed	23
Total number of equipments observed	81
Total days of time and motion observations	221
Total number of patients observed	3231
Total minutes of time and motion observation	90163

Table 7 offers a detailed analysis of the time utilization for advanced diagnostic and therapeutic equipment in secondary and tertiary healthcare facilities of Tamil Nadu, incorporating both raw data and percentage values to enhance understanding. The total scheduled time for equipment observation was 90,163 minutes. Of this, the operation time, which accounts for the actual use of equipment, was 74,473 minutes, representing 82.6% of the scheduled time. The functional time, indicating when the equipment was actively used for procedures, was 60,310 minutes, or 66.9% of the scheduled time. In terms of downtime, the study identified unavoidable loss (such as no patient availability) totalling to 15,796 minutes, which is 17.5% of the scheduled time. Avoidable loss, consisting of five out of the six big losses, amounted to 3,020 minutes, making up 3.3% of the scheduled time. Additionally, slow cycles, which refer to periods when the equipment operated below its optimal speed, accounted for 15,213 minutes or 16.8% of the scheduled time. These percentages provide a nuanced perspective on equipment utilization, highlighting the efficiency and areas for improvement in operational practices within these healthcare facilities.

Table 7: Time and Motion Observation findings for advanced diagnostic and therapeutic equipment in secondary and tertiary healthcare facilities of Tamil Nadu

Category	Total in minutes (%)
Scheduled time	90163
Operation time	74473 (82.6% of scheduled time)
Functional time	60310 (66.9% of scheduled time)
Unavoidable loss	15796 (17.5% of scheduled time)
Slow cycle	15213 (16.8% of scheduled time)
Avoidable loss	3020 (3.3% of scheduled time)

Table 8 provides an in-depth equipment-wise analysis of time and motion observations across secondary and tertiary healthcare facilities in Tamil Nadu, detailing both the total minutes and their percentage distribution of the scheduled time.

CT scan:

For CT scan, the observed scheduled time was 41,383 minutes, with operation time at 36,378 minutes (87.9% of scheduled time) and functional time at 25,671 minutes (62.0%). Unavoidable loss accounted for 12,137 minutes (29.3%), avoidable loss for 1,703 minutes (4.1%), and slow cycles for 6,456 minutes (15.6%).

The high operational time (87.9%) indicates efficient usage, but the significant amount of unavoidable loss (29.3%) suggests external factors, possibly patient flow or scheduling issues, impacting utilization. The noticeable proportion of slow cycles (15.6%) could indicate occasional operational inefficiencies or maintenance needs.

MRI scan:

MRI machines had a observed scheduled time of 21,720 minutes, operation time of 19,549 minutes (90.0%), and functional time of 18,393 minutes (84.7%). Unavoidable and avoidable loss were 1,274 minutes (5.9%) and 442 minutes (2.0%), respectively, with slow cycles at 2,903 minutes (13.4%).

With an operation time of 90.0%, MRI machines demonstrate excellent usage efficiency. The relatively low avoidable loss (2.0%) suggests good operational management. However, the functional time (84.7%) compared to operation time indicates a potential gap in optimal usage during operation periods.

PET scan:

PET scanners, scheduled for 1,680 minutes, had an operation time of 971 minutes (57.8%) and functional time of 800 minutes (47.6%). They experienced 244 minutes of unavoidable losses (14.5%), no avoidable loss, and 200 minutes of slow cycles (11.9%).

The operation time (57.8%) is relatively low, which might reflect limited demand or scheduling challenges. The absence of avoidable stops is a positive indicator of operational efficiency, but the equipment seems underutilized, as indicated by the lower functional time (47.6%).

Lithotripsy:

Lithotripsy machines, with a observed scheduled time of 2,100 minutes, operated for 1,794 minutes (85.4%), were functional for 1,492 minutes (71.0%), had 262 minutes of unavoidable losses (12.5%), 65 minutes of avoidable losses (3.1%), and 547 minutes of slow cycles (26.0%). These figures show a potential gap balance between operation (85.4%) and functional times (71.0%). The high percentage of slow cycles (26.0%) suggests there might be technical issues or inefficiencies in procedure execution that need addressing.

LINAC:

LINAC equipment had 11,640 minutes scheduled, 9,963 minutes (85.6%) of operation time, and 9,040 minutes (77.7%) of functional time. Downtime included 394 minutes of unavoidable losses (3.4%), 700 minutes of avoidable losses (6.0%), and 1,718 minutes of slow cycles (14.8%). The close alignment of operation (85.6%) and functional times (77.7%) suggests efficient utilization. The avoidable losses (6.0%) are higher compared to other equipment, indicating room for improvement in operational protocols or maintenance schedules.

Cobalt therapy unit:

Cobalt therapy units, scheduled for 6,600 minutes, had an operation time of 3,554 minutes (53.8%) and functional time of 2,698 minutes (40.9%). Unavoidable losses were 1,093 minutes (16.6%), avoidable losses 80 minutes (1.2%), and slow cycles 1,613 minutes (24.4%).

These exhibit a lower operation time (53.8%) compared to scheduled time, which may point to underutilization or scheduling inefficiencies. The high percentage of slow cycles (24.4%) and unavoidable losses (16.6%) could also indicate technical issues or constraints in patient handling.

Brachytherapy:

Lastly, Brachytherapy equipment had a scheduled time of 5,040 minutes, with 2,264 minutes of operation time (44.9%), 2,216 minutes of functional time (44.0%), 392 minutes of unavoidable losses (7.8%), 30 minutes of avoidable losses (0.6%), and 1,776 minutes of slow cycles (35.2%).

The operation time (44.9%) and functional time (44.0%) are significantly lower than scheduled, suggesting underutilization. The high percentage of slow cycles (35.2%) is concerning and may point to technical inefficiencies or the need for improved operational management.

This comprehensive data, reflecting both total minutes and their relative percentages, provides a clear understanding of how each type of equipment is utilized, identifying specific operational inefficiencies and areas for improvement.

Table 8: Equipment-wise total minutes of time and motion observation findings along with percentage distribution of scheduled time across various utilization indices in secondary and tertiary healthcare facilities of Tamil Nadu

Equipment	Scheduled time	Operation time (% of scheduled time)	Functional time (% of scheduled time)	Unavoidable loss (% of scheduled time)	Avoidable loss (% of scheduled time)	Slow cycles (% of scheduled time)
CT	41383	36378 (87.9)	25671 (62.0)	12137 (29.3)	1703 (4.1)	6456 (15.6)
MRI	21720	19549 (90.0)	18393 (84.7)	1274 (5.9)	442 (2.0)	2903 (13.4)
PET	1680	971 (57.8)	800 (47.6)	244 (14.5)	0 (0)	200 (11.9)
Lithotripsy	2100	1794 (85.4)	1492 (71.0)	262 (12.5)	65 (3.1)	547 (26.0)
LINAC	11640	9963 (85.6)	9040 (77.7)	394 (3.4)	700 (6.0)	1718 (14.8)
Cobalt	6600	3554 (53.8)	2698 (40.9)	1093 (16.6)	80 (1.2)	1613 (24.4)
Brachytherapy	5040	2264 (44.9)	2216 (44.0)	392 (7.8)	30 (0.6)	1776 (35.2)

Table 9 provides an in-depth institute-wise analysis of time and motion observations for CT scan equipment across secondary and tertiary healthcare facilities in Tamil Nadu, detailing both the total minutes and their percentage distribution of the scheduled time.

Rajiv Gandhi Government General Hospital (RGGGH):

The CT scan utilization at RGGGH shows exceptional operational efficiency, with the operation time at 99.9% of the scheduled time. A high functional time of 85.8% suggests effective patient management and equipment usage. However, unavoidable losses accounting for 13.4% indicate external factors, possibly related to patient flow, impacting usage. The avoidable loss and slow cycles are relatively minimal at 2.2% and 3.9%, respectively, indicating a well-managed operation with minor areas for improvement in efficiency.

Government Stanley Medical College Hospital:

The operation time exceeding the scheduled time (100.4%) is an unusual but positive indicator, possibly reflecting efficient handling of patient overflow or effective scheduling. However, the functional time is lower at 64.6%, suggesting gaps in optimal equipment usage during operational hours. The high unavoidable loss of 30.5% could indicate significant external constraints, possibly patient-related delays. The avoidable loss is notable at 6.3%, suggesting some operational inefficiencies. The negative percentage in slow cycles (-3.0%) might be due to data inconsistencies or exceptional operational efficiency that needs further investigation.

Government Medical College, Omandurar:

Here, the CT scan operation time is 89.3% of the scheduled time, which is efficient but indicates some room for improvement. The functional time of 59.5% suggests that a significant portion of the operation time is not translating into effective equipment usage, possibly due to procedural or scheduling delays.

Unavoidable losses are relatively high at 38.4%, pointing to external factors significantly affecting equipment utilization. Avoidable losses and slow cycles are at 1.9% and 10.7% respectively, indicating some inefficiencies in equipment operation and potential areas for streamlining processes.

Government Royapettah Hospital:

The CT scan utilization at Government Royapettah Hospital shows good operational efficiency, with operation time accounting for 95.1% of the scheduled time. The functional time is reasonably high at 66.7%, indicating effective use of the equipment for patient care. However, unavoidable losses at 25.9% suggest external challenges, possibly including patient-related delays or scheduling issues, impacting utilization.

The avoidable loss is relatively low at 2.6%, indicating good operational management. The negative percentage in slow cycles (-2.8%) may point towards exceptional operational performance as the equipment cycle is performing even better than the ideal cycle.

Coimbatore Medical College Hospital:

At this facility, the operation time for CT scans is 86.0% of the scheduled time, indicating some room for optimization. The functional time is lower at 54.4%, suggesting that a significant portion of operation time is not being translated into active scanning, which might be due to procedural inefficiencies or patient preparation times.

Unavoidable losses are noticeable at 33.6%, indicating external factors significantly affecting the utilization of the equipment. The avoidable loss at 5.0% and slow cycles at 0.8% point towards minor operational inefficiencies that could be improved.

Madurai Medical College Hospital:

Here, the CT scan operation time is notably lower at 67.5% of the scheduled time, highlighting a significant underutilization of the equipment. The functional time stands at 49.5%, indicating that less than half of the scheduled time is used for actual patient scanning, suggesting inefficiencies in scheduling or procedural delays.

Unavoidable losses account for 27.5%, which is considerable and may reflect external challenges such as patient availability or scheduling conflicts. The avoidable loss at 2.2% and slow cycles at 5.4% are areas where operational improvements could enhance efficiency.

Government Hospital, Melur:

The CT scan utilization at Government Hospital, Melur, shows a unique scenario where the operation time is significantly higher than scheduled, at 115.4%. This might indicate efficient handling of additional cases or extended operation hours. However, the functional time is relatively low at 39.3%, suggesting that despite the extended operation time, the actual scanning time is limited.

The unavoidable loss is high at 34.7%, and the avoidable loss is notably substantial at 50.0%, indicating major operational inefficiencies or scheduling challenges. The slow cycles percentage at 23.6% further points towards periods of reduced operational speed, possibly due to equipment issues or procedural delays.

Government Tirunelveli Medical College and Hospital:

Here, the operation time for CT scans is 74.0% of the scheduled time, indicating underutilization. The functional time at 49.9% suggests that almost half of the scheduled time is effectively used for scanning, but there's still scope for improvement.

Unavoidable losses amount to 25.4%, indicating significant external constraints affecting equipment utilization. Avoidable losses are relatively lower at 4.6%, and slow cycles at 12.4% suggest some inefficiencies in equipment operation that could be addressed for better utilization.

KAP Vishwanathan Government Medical College and Hospital, Trichy:

This facility shows a high operation time at 86.7% of the scheduled time, matched exactly by the functional time, indicating highly efficient use of the CT scanner with minimal downtime. The unavoidable loss is modest at 9.6%. However, the avoidable loss at 3.1% and particularly high slow cycles at 39.8% suggest that while the scanner is frequently in use, there are periods where it operates below optimal speed, indicating potential technical issues or procedural inefficiencies that should be explored.

Government Hospital, Srirangam:

At Government Hospital, Srirangam, the operation time for CT scans is 69.8% of the scheduled time, indicating moderate utilization. The functional time is lower at 46.8%, suggesting that a significant portion of the operation time is not being used for actual scanning, which might be due to procedural delays or patient preparation. The unavoidable loss is relatively high at 20.9%, hinting at external factors affecting the operation. However, avoidable losses are minimal at 2.1%. Notably, slow cycles are high at 27.4%, suggesting periods where the equipment operates below optimal capacity, possibly due to technical issues or inefficient operational practices.

Government Medical College Hospital, Thanjavur:

This facility shows strong operational efficiency with an operation time of 88.6% of the scheduled time and an even more impressive functional time of 83.1%, indicating effective and consistent use of the CT scanner. The low unavoidable loss of 16.2% and minimal avoidable loss of 0.7% are indicative of well-managed operations. The slow cycles at 10.2% suggest some periods of reduced operational efficiency, but overall, the facility demonstrates high utilization and operational effectiveness.

Government Hospital, Pattukottai:

The operation time at Government Hospital, Pattukottai, is high at 96.7% of the scheduled time, showing excellent utilization of the CT scanner. However, the functional time is significantly lower at 42.9%, indicating that while the scanner is frequently operational, the actual time spent on scanning is relatively limited, pointing towards inefficiencies in patient throughput or procedural delays. The high unavoidable loss of 52.0% is a major concern, significantly impacting equipment utilization. Avoidable losses are low at 1.8%, but the slow cycles at 15.1% indicate periods of reduced efficiency, which might be due to operational or technical issues.

Government Mohan Kumaramangalam Medical College and Hospital, Salem:

This facility demonstrates high efficiency in CT scan utilization, with operation time at 91.5% of the scheduled time. The functional time is also substantial at 75.7%, indicating effective patient scanning operations. The facility manages to avoid any avoidable losses (0%), which is commendable. However, unavoidable losses account for 21.8%, possibly due to external factors like patient scheduling or availability. The slow cycles at 21.5% suggest some periods of reduced operational speed, which could be due to equipment maintenance needs or procedural delays.

Government Headquarters Hospital, Mettur:

The operation time here is 90.3% of the scheduled time, showing good equipment utilization. However, the functional time is lower at 62.0%, indicating that a significant portion of the operation time is not being used for actual scanning, which might be due to patient preparation or scheduling inefficiencies. Unavoidable losses are relatively high at 30.1%, impacting utilization. The facility experiences a considerable amount of slow cycles at 46.3%, which is a significant area of concern, potentially indicating technical issues or operational inefficiencies.

Government Sivagangai Medical College and Hospital:

The operation time at this facility is 79.4% of the scheduled time, suggesting room for improvement in equipment utilization. The functional time is relatively high at 72.4%, which is a positive indicator of effective scanning operations. Like the Salem facility, there are no avoidable losses, reflecting efficient operational management.

Unavoidable losses stand at 27.6%, which could be due to external factors. However, the high percentage of slow cycles (45.3%) is a critical area for investigation, as it suggests significant periods where the equipment is not operating at optimal capacity.

Government Hospital, Karaikudi:

At Government Hospital, Karaikudi, the CT scan operation time is 75.6% of the scheduled time, indicating moderate utilization. However, the functional time is significantly lower at 36.7%, suggesting that the equipment is not being used for actual scanning for a substantial part of the operation time, which could be due to scheduling inefficiencies or procedural delays.

The facility has no avoidable losses, which is a positive aspect of its operation. However, the unavoidable losses are notably high at 63.3%, indicating significant external challenges. Slow cycles account for 23.6% of the scheduled time, suggesting periods of reduced scanning efficiency.

Government Villupuram Medical College and Hospital:

This facility shows good utilization with an operation time of 81.5% of the scheduled time and an even higher functional time of 77.1%, indicating effective use of the CT scanner. However, both unavoidable and avoidable losses are present, each accounting for 8.9% of the scheduled time. This suggests some external challenges and operational inefficiencies that could be addressed. The slow cycles at 30.7% are a considerable factor, indicating periods where the equipment operates below optimal capacity, possibly due to technical issues or procedural inefficiencies.

Government Hospital, Tindivanam:

The operation time here is 71.5% of the scheduled time, showing room for improvement in utilization. The functional time is quite low at 32.8%, pointing towards significant inefficiencies in the actual scanning process or patient handling. Unavoidable losses are high at 46.8%, indicating external factors significantly impacting the operation. Avoidable losses at 6.7% and slow cycles at 20.3% suggest operational inefficiencies that could be targeted for improvement.

Government Theni Medical College and Hospital:

This facility exhibits outstanding operational efficiency in CT scan utilization, with both operation time and functional time at 100.0% and 98.4% of the scheduled time, respectively. This indicates that the CT scanner is almost continuously in use for patient scanning during operational hours, reflecting excellent management and scheduling. The negligible unavoidable loss of 1.6% is an exemplary achievement. However, the high percentage of slow cycles at 51.6% is a point of concern, suggesting that despite the high usage, there are significant periods where the equipment operates at a reduced capacity, potentially due to technical issues or procedural inefficiencies.

Government Hospital, Periyakulam:

The operation time at this facility is high at 97.3% of the scheduled time, indicating good utilization of the CT scanner. However, the functional time is much lower at 31.7%, suggesting that a large portion of the operation time is not being used for actual scanning. This could be due to inefficient scheduling, patient preparation, or procedural delays.

The unavoidable loss is notably high at 63.3%, significantly impacting the utilization. Additionally, the facility experiences a substantial amount of slow cycles at 59.2%, indicating frequent periods of reduced operational efficiency.

Government Medical College, Nilgiris:

Here, the operation time for CT scans is 110.8% of the scheduled time, showing excellent equipment utilization. However, the functional time is relatively low at 29.3%, indicating inefficiencies in converting operation time into actual scanning time.

The high unavoidable loss of 63.0% and the avoidable loss of 9.2% suggest both external challenges and operational inefficiencies affecting equipment utilization. The slow cycles at 8.1% further point towards periods of reduced scanning efficiency, which could be due to technical issues or operational practices.

Lawley Government Hospital, Coonoor:

The CT scan operation time at Lawley Government Hospital is 110.8% of the scheduled time, indicating an outstanding level of utilization. However, the functional time is notably low at 20.3%, suggesting that the scanner is underutilized for actual patient scanning. This low functional time could be a result of long patient preparation times, scheduling issues, or procedural delays.

A significant concern is the high unavoidable loss of 79.7%, which severely impacts the scanner's availability for use. The absence of avoidable losses (0%) is a positive aspect, but the slow cycles at 18.2% indicate periods of reduced scanning efficiency that need to be addressed.

Government Thiruvarur Medical College:

This facility demonstrates excellent operational efficiency with an operation time of 99.1% of the scheduled time. The functional time is also high at 79.9%, indicating effective and consistent use of the CT scanner for patient care.

The unavoidable loss is relatively low at 20.1%, suggesting that external factors do not significantly impede the scanner's operation. There are no avoidable losses, which is commendable and indicative of efficient management. Slow cycles, at 7.0%, are minimal, pointing to a well-maintained and efficiently operated CT scanner.

Table 9: Institute-wise total minutes of time and motion observation findings for CT scan and percentage distribution out of the scheduled time across various utilization indices in secondary and tertiary healthcare facilities of Tamil Nadu

Institute Name	Scheduled time	Operation time (% of scheduled time)	Functional time (% of scheduled time)	Unavoidable loss (% of scheduled time)	Avoidable loss (% of scheduled time)	Slow cycles (% of scheduled time)
Rajiv Gandhi Government General Hospital (RGGGH)	3540	3538 (99.9)	3039 (85.8)	473 (13.4)	80 (2.2)	139 (3.9)
Government Stanley Medical College Hospital	2880	2892 (100.4)	1862 (64.6)	878 (30.5)	182 (6.3)	-88 (-3.0)
Government Medical College, Omandurar	4920	4394 (89.3)	2926 (59.5)	1890 (38.4)	95 (1.9)	526 (10.7)
Government Royapettah Hospital	1438	1367 (95.1)	959 (66.7)	373 (25.9)	38 (2.6)	-41 (-2.8)

Coimbatore Medical College Hospital	2520	2168 (86.0)	1370 (54.4)	847 (33.6)	125 (5.0)	20 (0.8)
Madurai Medical College Hospital	3105	2097 (67.5)	1538 (49.5)	854 (27.5)	68 (2.2)	168 (5.4)
Government Hospital, Melur	960	1108 (115.4)	377 (39.3)	333 (34.7)	480 (50.0)	227 (23.6)
Government Tirunelveli Medical College and Hospital	2400	1777 (74.0)	1199 (49.9)	611 (25.4)	110 (4.6)	299 (12.4)
KAP Vishwanathan Government Medical College and Hospital, Trichy	1920	1665 (86.7)	1665 (86.7)	185 (9.6)	60 (3.1)	765 (39.8)
Government Hospital, Srirangam	1440	1005 (69.8)	674 (46.8)	301 (20.9)	30 (2.1)	394 (27.4)

Government Medical College Hospital, Thanjavur	1440	1276 (88.6)	1197 (83.1)	233 (16.2)	10 (0.7)	147 (10.2)
Government Hospital, Pattukottai	1080	1045 (96.7)	463 (42.9)	562 (52.0)	20 (1.8)	163 (15.1)
Government Mohan Kumaramangalam Medical College and Hospital, Salem	2400	2197 (91.5)	1817 (75.7)	523 (21.8)	0 (0)	517 (21.5)
Government Headquarters Hospital, Mettur	1080	975 (90.3)	670 (62.0)	325 (30.1)	35 (3.2)	500 (46.3)
Government Sivagangai Medical College and Hospital	960	762 (79.4)	695 (72.4)	265 (27.6)	0 (0)	435 (45.3)
Government Hospital, Karaikudi	960	726 (75.6)	352 (36.7)	608 (63.3)	0 (0)	227 (23.6)

Government Villupuram Medical College and Hospital	2100	1711 (81.5)	1619 (77.1)	188 (8.9)	188 (8.9)	644 (30.7)
Government Hospital, Tindivanam	1200	858 (71.5)	394 (32.8)	562 (46.8)	80 (6.7)	244 (20.3)
Government Theni Medical College and Hospital	960	960 (100.0)	945 (98.4)	15 (1.6)	0 (0)	495 (51.6)
Government Hospital, Periyakulam	600	584 (97.3)	190 (31.7)	380 (63.3)	14 (2.3)	355 (59.2)
Government Medical College, Nilgiris	960	1064 (110.8)	281 (29.3)	605 (63.0)	88 (9.2)	78 (8.1)
Lawley Government Hospital, Coonoor	960	1064 (110.8)	195 (20.3)	765 (79.7)	0 (0)	175 (18.2)
Government Thiruvarur Medical College	960	951 (99.1)	767 (79.9)	193 (20.1)	0 (0)	67 (7.0)

Table 10 provides an in-depth institute-wise analysis of time and motion observations for MRI scan equipment across secondary and tertiary healthcare facilities in Tamil Nadu, detailing both the total minutes and their percentage distribution of the scheduled time.

Rajiv Gandhi Government General Hospital (RGGGH):

For MRI scans, RGGGH demonstrates strong operational efficiency with an operation time of 89.4% and a functional time of 85.7% of the scheduled time. These percentages indicate effective use of the MRI scanner, with a high proportion of operation time being utilized for actual scanning.

However, unavoidable losses are minimal at 2.0%, and avoidable losses are slightly higher at 2.3%, suggesting some room for improvement in managing operational interruptions. The percentage of slow cycles at 14.4% points to periods of reduced operational speed that could be due to equipment maintenance or procedural inefficiencies.

Government Stanley Medical College Hospital:

This facility shows an operation time exceeding the scheduled time (112.3%), which is an exceptional case, likely reflecting efficient handling of patient overflow or extended operation hours. The functional time is also high at 102.0%, indicating that the MRI scanner is almost continuously in use. The unavoidable loss is moderate at 9.4%, and avoidable loss is relatively low at 2.6%. However, the slow cycles at 18.7% suggest there are significant periods where the equipment is not operating at its optimal speed, which could be a focus area for improvement.

Government Medical College, Omandurar:

The MRI scan operation time here is 87.3% of the scheduled time, with a very close functional time of 84.4%, suggesting efficient utilization of the equipment for patient scans. Notably, there are no unavoidable losses, which is an excellent indicator of operational efficiency.

The avoidable losses are at 5.0%, indicating some areas of operational inefficiency that could be addressed. Slow cycles are minimal at 1.0%, suggesting that the equipment operates at near-optimal speed for most of the time.

Government Royapettah Hospital:

The MRI scan operation time at Government Royapettah Hospital is 80.3% of the scheduled time, showing a moderate level of utilization. The functional time is relatively lower at 61.6%, indicating some inefficiency in translating operation time into actual scanning time.

Unavoidable losses are notable at 25.9%, but there are no avoidable losses, reflecting effective management. The negative percentage in slow cycles (-11.3%) suggests an operation speed better than the ideal cycle time, which could indicate efficient procedural execution.

Coimbatore Medical College Hospital:

Here, the operation time for MRI scans is 63.7% of the scheduled time, indicating underutilization of the scanner. Interestingly, the functional time is higher than the operation time at 65.9%, which is unusual and might reflect efficient patient handling during the operational hours or discrepancies in time recording.

There are no unavoidable losses, which is positive, but the avoidable loss is minimal at 0.8%. Similar to Government Royapettah Hospital, the negative slow cycles (-9.1%) indicate a higher than expected operation speed, suggesting efficient processing.

Madurai Medical College Hospital:

This facility demonstrates exceptional operational efficiency, with both operation time and functional time at 100% of the scheduled time. This indicates that the MRI scanner is continuously used for patient scans during operational hours. There are no unavoidable losses, which is an exemplary achievement. However, the avoidable losses are slightly higher at 2.1%, indicating minor operational inefficiencies. The slow cycles at 33.3% are a significant concern, suggesting that despite continuous operation, there are considerable periods where the equipment operates below optimal speed, potentially due to technical issues or procedural delays.

Government Tirunelveli Medical College and Hospital:

This facility shows a moderate level of MRI scan operation time at 66.7% of the scheduled time, which is mirrored in the functional time. The absence of unavoidable losses (0%) indicates no external interruptions in the operation. However, the avoidable loss is minimal at 2.1%. Notably, the facility has a negative slow cycle percentage of -16.7%, suggesting operation speeds better than ideal cycle time, which may indicate highly efficient procedures.

KAP Vishwanathan Government Medical College and Hospital, Trichy:

The operation time is impressively high at 99.3% of the scheduled time, with an even higher functional time of 100.6%, indicating that the MRI scanner is used more effectively than scheduled. This could be due to efficient patient scheduling or extended operational hours. There are no unavoidable losses, and avoidable losses are minimal at 1.0%. However, the facility has a high percentage of slow cycles at 39.1%, suggesting significant periods of reduced operational speed that could be attributed to technical issues or operational inefficiencies.

Government Medical College Hospital, Thanjavur:

The facility exhibits strong operational efficiency, with operation time at 92.8% and functional time even higher at 96.3% of the scheduled time. This indicates effective utilization of the MRI scanner, with a high proportion of operation time being utilized for actual scanning. Both unavoidable and avoidable losses are at 0%, which is commendable. However, similar to KAP Vishwanathan Government Medical College and Hospital, the high slow cycle percentage at 40.8% points to periods where the equipment operates below its optimal speed, suggesting areas for potential improvement.

Government Mohan Kumaramangalam Medical College and Hospital, Salem:

This facility showcases strong operational efficiency in MRI scan utilization with an operation time of 96.6% and a functional time of 94.0% of the scheduled time. These high percentages indicate effective use of the MRI scanner, with most of the operation time being utilized for actual patient scans. The unavoidable and avoidable losses are notably low at 1.3% and 1.2% respectively, suggesting efficient management of operational interruptions. However, the slow cycles at 12.8% point to some periods of reduced operational speed, indicating room for improvement in maintaining consistent operational efficiency.

Government Sivagangai Medical College and Hospital:

The operation time for MRI scans at this facility is commendable at 91.4%, and the functional time is also high at 87.7%, indicating efficient utilization of the equipment. The facility manages to avoid any avoidable losses, reflecting effective operational control.

However, the unavoidable loss is somewhat significant at 12.3%, hinting at external factors affecting the scanning process. The slow cycles at 6.4% suggest occasional periods where the equipment operates below optimal capacity.

Government Villupuram Medical College and Hospital:

This facility demonstrates good utilization with an operation time of 90.2% and an almost matching functional time of 89.2%, indicating effective and consistent use of the MRI scanner. The facility experiences minimal unavoidable losses (0.8%), which is a positive aspect of its operation.

However, avoidable losses are higher at 4.2%, indicating some operational inefficiencies that could be targeted for improvement. The percentage of slow cycles at 26.7% is considerable and points towards periods of reduced scanning efficiency, potentially due to equipment maintenance needs or procedural delays.

Government Medical College, Nilgiris:

At this facility, the MRI scan operation time is good at 81.2% of the scheduled time, indicating efficient use of the scanner. The functional time is notably higher at 97.8%, suggesting exceptional utilization where the actual scanning time exceeds the operation time, which could be due to efficient scheduling or rapid patient processing.

The unavoidable loss is minimal at 2.2%, but the avoidable loss is slightly higher at 5.1%, pointing to some operational inefficiencies that could be optimized. The slow cycles at 21.4% are significant and indicate periods where the equipment operates below optimal capacity, potentially impacting the overall throughput efficiency.

Government Thiruvarur Medical College:

The operation time for MRI scans at this facility is high at 96.4% of the scheduled time, showcasing good utilization. However, the functional time is lower at 75.8%, indicating that not all operation time is effectively used for patient scanning, possibly due to procedural delays or inefficiencies. There are considerable unavoidable losses at 22.9%, suggesting external factors significantly affect the operation. Interestingly, this facility reports negative slow cycles at -5.4%, indicating operation speeds better than the ideal cycle time, which is an unusual but positive scenario, suggesting highly efficient operation.

Table 10: Institute-wise total minutes of time and motion observation findings for MRI scan and percentage distribution out of the scheduled time across various utilization indices in secondary and tertiary healthcare facilities of Tamil Nadu

Institute Name	Scheduled time	Operation time (% of scheduled time)	Functional time (% of scheduled time)	Unavoidable loss (% of scheduled time)	Avoidable loss (% of scheduled time)	Slow cycles (% of scheduled time)
Rajiv Gandhi Government General Hospital (RGGGH)	4080	3649 (89.4)	3499 (85.7)	80 (2.0)	95 (2.3)	589 (14.4)
Government Stanley Medical College Hospital	1440	1618 (112.3)	1469 (102.0)	135 (9.4)	37 (2.6)	269 (18.7)
Government Medical College, Omandurar	1440	1257 (87.3)	1215 (84.4)	0 (0)	72 (5.0)	15 (1.0)
Government Royapettah Hospital	1440	1157 (80.3)	887 (61.6)	373 (25.9)	0 (0)	-163 (-11.3)
Coimbatore Medical College Hospital	1440	918 (63.7)	949 (65.9)	0 (0)	11 (0.8)	-131 (-9.1)

Madurai Medical College Hospital	1440	1440 (100)	1440 (100)	0 (0)	30 (2.1)	480 (33.3)
Government Tirunelveli Medical College and Hospital	1440	960 (66.7)	960 (66.7)	0 (0)	30 (2.1)	-240 (16.7)
KAP Vishwanathan Government Medical College and Hospital, Trichy	1560	1550 (99.3)	1570 (100.6)	0 (0)	15 (1.0)	610 (39.1)
Government Medical College Hospital, Thanjavur	1440	1337 (92.8)	1387 (96.3)	0 (0)	0 (0)	587 (40.8)
Government Mohan Kumaramangalam Medical College and Hospital, Salem	1440	1391 (96.6)	1354 (94.0)	19 (1.3)	18 (1.2)	184 (12.8)
Government Sivagangai Medical College and Hospital	960	878 (91.4)	842 (87.7)	118 (12.3)	0 (0)	62 (6.4)

Government Villupuram Medical College and Hospital	1440	1299 (90.2)	1285 (89.2)	11 (0.8)	60 (4.2)	385 (26.7)
Government Medical College, Nilgiris	1440	1169 (81.2)	1409 (97.8)	31 (2.2)	74 (5.1)	308 (21.4)
Government Thiruvarur Medical College	960	926 (96.4)	728 (75.8)	220 (22.9)	0 (0)	-52 (-5.4)

Table 11 provides an in-depth institute-wise analysis of time and motion observations for PET scan and lithotripsy equipment across secondary and tertiary healthcare facilities in Tamil Nadu, detailing both the total minutes and their percentage distribution of the scheduled time.

PET Scan (Madurai Medical College Hospital):

The PET scan facility at Madurai Medical College Hospital shows moderate utilization, with an operation time accounting for 57.8% of the scheduled 1680 minutes. The functional time, at 47.6%, suggests that while the scanner is moderately utilized, there's a notable gap in achieving its full potential. Unavoidable losses, constituting 14.5%, hint at external factors such as patient availability impacting the scanner's use. Notably, there are no avoidable losses, indicating efficient operational management. However, the presence of slow cycles at 11.9% points towards periods where the scanner operates below its optimal capacity.

Lithotripsy Equipment at Rajiv Gandhi Government General Hospital (RGGGH):

The lithotripsy equipment at RGGGH demonstrates good operational efficiency within its 1260 minutes of scheduled time, with an 83.2% operation time. The functional time is impressive at 74.0%, indicating that a significant portion of the operation time is effectively utilized for treatments. Unavoidable losses are relatively low at 6.4%, suggesting well-managed external factors. However, avoidable losses, although small at 2.8%, and slow cycles at a high 31.2% indicate areas where operational efficiency could be further improved.

Lithotripsy Equipment at Government Tirunelveli Medical College and Hospital:

This facility exhibits efficient utilization of its lithotripsy equipment, with an 88.7% operation time out of the scheduled 840 minutes. The functional time stands at 66.5%, showing effective use but also highlighting a gap in maximizing operational efficiency.

Unavoidable losses are somewhat high at 21.5%, indicating significant external operational challenges. The facility has a small percentage of avoidable losses (3.6%), but the presence of slow cycles at 18.3% suggests opportunities for improving the equipment's operational speed and efficiency.

Table 11: Institute-wise total minutes of time and motion observation findings for PET scan and lithotripsy equipment and percentage distribution out of the scheduled time across various utilization indices in secondary and tertiary healthcare facilities of Tamil Nadu

Institute Name	Scheduled time	Operation time (% of scheduled time)	Functional time (% of scheduled time)	Unavoidable loss (% of scheduled time)	Avoidable loss (% of scheduled time)	Slow cycles (% of scheduled time)
PET SCAN						
Madurai Medical College Hospital	1680	971 (57.8)	800 (47.6)	244 (14.5)	0 (0)	200 (11.9)
LITHOTRIPSY EQUIPMENT						
Rajiv Gandhi Government General Hospital (RGGGH)	1260	1049 (83.2)	933 (74.0)	81 (6.4)	35 (2.8)	393 (31.2)
Government Tirunelveli Medical College and Hospital	840	745 (88.7)	559 (66.5)	181 (21.5)	30 (3.6)	154(18.3)

Table 12 provides an in-depth institute-wise analysis of time and motion observations for LINAC equipment across secondary and tertiary healthcare facilities in Tamil Nadu, detailing both the total minutes and their percentage distribution of the scheduled time.

Rajiv Gandhi Government General Hospital (RGGGH):

The LINAC utilization at RGGGH is exemplary, with an operation time surpassing the scheduled time at 101.7%, indicating efficient management and possibly extended operation hours. The functional time is impressively high at 99.2% of the scheduled 2640 minutes, suggesting that the equipment is almost continuously in use for patient treatment. This facility effectively manages to avoid any unavoidable losses, which is a significant achievement. However, avoidable losses are present at 2.4%, indicating some scope for operational improvement. The slow cycles at 19.7% suggest periods where the equipment operates below optimal capacity, which could be due to technical reasons or procedural inefficiencies.

Government Medical College, Omandurar:

This facility shows strong operational efficiency with an operation time of 98.9% of the scheduled 1920 minutes observed. The functional time is also high at 94.4%, indicating effective use of the LINAC equipment for patient treatments. Unavoidable losses are minimal at 1.3%, but avoidable losses are slightly higher at 3.9%, suggesting room for improvement in operational management. Notably, the slow cycles are quite high at 43.3%, indicating significant periods of reduced efficiency, which could be an area of focus for technical improvements or procedural optimization.

Government Royapettah Hospital:

The LINAC operation time at this facility is 88.9% of the scheduled 1800 minutes, showing moderate utilization. The functional time is also moderate at 83.7%, suggesting some inefficiency in translating operation time into effective treatment time.

Unavoidable losses are relatively low at 2.5%, but avoidable losses are higher at 4.8%, indicating potential areas for operational improvements. Slow cycles account for 5.9%, suggesting occasional periods of reduced operational efficiency that could be optimized.

Coimbatore Medical College Hospital:

At Coimbatore Medical College Hospital, the LINAC equipment shows a moderate level of utilization with an operation time of 66.7% of the scheduled 1440 minutes. The functional time is somewhat lower at 55.5%, indicating a gap between the equipment being operational and its actual use for patient treatments.

Unavoidable losses are minimal at 2.1%, but avoidable losses are relatively high at 8.9%, suggesting areas where operational efficiency can be improved. Interestingly, the facility reports negative slow cycles at -2.8%, implying operational speeds better than the ideal cycle time, which might suggest efficient procedural execution.

Madurai Medical College Hospital:

The LINAC utilization at this facility indicates room for improvement, with an operation time of 60.6 % of the scheduled 1440 minutes. The functional time, however, is slightly higher at 61.7%, unusual as it exceeds the operation time, possibly due to efficient patient handling during operational hours or data discrepancies. There are no unavoidable losses, which is a positive aspect of the facility's operation. However, avoidable losses are present at 1.3%, indicating some minor operational inefficiencies. The slow cycles are notably high at 38.3%, suggesting significant periods where the equipment operates below optimal capacity.

Government Tirunelveli Medical College and Hospital:

This facility demonstrates a moderate level of LINAC utilization, with an operation time of 65.2% of the scheduled 960 minutes. The functional time is closely aligned at 62.3%, suggesting a good translation of operation time into effective patient treatment. However, there is still room for increasing this efficiency. Unavoidable losses are noticeable at 11.7%, indicating some impact of external factors on the operation. The absence of avoidable losses is a positive aspect, showing effective operational management. Slow cycles account for 20.0%, pointing to periods where the equipment operates below optimal capacity, which could be an area for improvement.

Government Medical College Hospital, Thanjavur:

This facility exhibits a high level of operational efficiency with an operation time of 91.7% of the scheduled 1440 minutes. However, the functional time is notably lower at 56.6%, indicating a significant gap in maximizing the operational time for actual patient treatments. Unavoidable losses are moderate at 12.5%, but avoidable losses are relatively high at 22.6%, suggesting substantial room for improvement in operational management. The percentage of slow cycles at 10.1% indicates some periods of reduced operational efficiency.

Table 12: Institute-wise total minutes of time and motion observation findings for LINAC and percentage distribution out of scheduled time across various utilization indices in secondary and tertiary healthcare facilities of Tamil Nadu

Institute Name	Scheduled time observed	Operation time (% of scheduled time)	Functional time (% of scheduled time)	Unavoidable loss (% of scheduled time)	Avoidable loss (% of scheduled time)	Slow cycles (% of scheduled time)
Rajiv Gandhi Government General Hospital (RGGGH)	2640	2684 (101.7)	2620 (99.2)	0 (0)	64 (2.4)	520 (19.7)
Government Medical College, Omandurar	1920	1900 (98.9)	1812 (94.4)	26 (1.3)	76 (3.9)	832 (43.3)
Government Royapettah Hospital	1800	1600 (88.9)	1507 (83.7)	45 (2.5)	87 (4.8)	107 (5.9)
Coimbatore Medical College Hospital	1440	960 (66.7)	800 (55.5)	31 (2.1)	129 (8.9)	-40 (-2.8)

Madurai Medical College Hospital	1440	873 (60.6)	888 (61.7)	0 (0)	19 (1.3)	552 (38.3)
Government Tirunelveli Medical College and Hospital	960	626 (65.2)	598 (62.3)	112 (11.7)	0 (0)	192 (20.0)
Government Medical College Hospital, Thanjavur	1440	1320 (91.7)	815 (56.6)	180 (12.5)	325 (22.6)	145 (10.1)

Table 13 provides an in-depth institute-wise analysis of time and motion observations for Cobalt therapy equipment across secondary and tertiary healthcare facilities in Tamil Nadu, detailing both the total minutes and their percentage distribution of the scheduled time.

Government Stanley Medical College Hospital:

This facility displays a high level of operational efficiency in its use of Cobalt therapy. The operation time is 84.4% of the scheduled 480 minutes, indicating good utilization. The functional time is slightly lower at 73.3%, suggesting that most of the operational time is effectively used for patient treatments. Unavoidable losses are moderate at 11.0%, reflecting external factors affecting the operation, but there are no avoidable losses, indicating efficient operational management. The slow cycles are negligible at 0.4%, pointing to a high level of technical efficiency in the equipment's operation.

Government Royapettah Hospital:

The Cobalt therapy operation at this facility shows an exceptionally high operation time of 166.1% of the scheduled 720 minutes, indicating extended operation hours and possibly efficient handling of patient overflow. The functional time exceeds the scheduled time at 116.1%, suggesting that the equipment is used extensively for patient treatments. However, unavoidable losses are significantly high at 58.3%, indicating substantial external constraints impacting operation. Avoidable losses are minimal at 1.9%. The slow cycles at 28.6% suggest periods of reduced operational speed, potentially due to technical issues or operational inefficiencies.

Coimbatore Medical College Hospital:

The utilization of Cobalt therapy at Coimbatore Medical College Hospital indicates a low level of operation with an operation time constituting only 10.5% of the scheduled 960 minutes. The functional time is similarly low at 17.8%, suggesting that the equipment is underutilized for actual patient treatments. Unavoidable losses are minimal at 1.1%, indicating that external factors do not significantly impact operation. There are no avoidable losses, reflecting effective operational control. However, the slow cycles at 12.6% indicate periods of reduced operational efficiency, which could be due to technical or procedural inefficiencies.

Madurai Medical College Hospital:

The operation time for Cobalt therapy at this facility is notably low at 8.7% of the scheduled 1260 minutes, indicating significant underutilization of the equipment. The functional time is even lower at 9.1%, underscoring the gap in effectively using the available operation time for patient treatments. Unavoidable losses are small at 2.4%, but the presence of negative slow cycles at -0.8% suggests operational speeds better than the ideal cycle time, which is an unusual but positive occurrence, potentially indicating efficient procedural execution.

Government Tirunelveli Medical College and Hospital:

The utilization of Cobalt therapy at this facility indicates a low level of operation, with an operation time of 20.0% out of the scheduled 1440 minutes. The functional time is slightly lower at 18.9%, suggesting that the equipment is not fully utilized for patient treatments during its operational hours. Unavoidable losses are moderate at 7.9%, indicating some external constraints impacting operation. The absence of avoidable losses indicates efficient operational management. The slow cycles, at 6.4%, suggest occasional periods of reduced efficiency, which could be optimized for better utilization.

Government Medical College Hospital, Thanjavur:

This facility demonstrates a higher level of operational efficiency in Cobalt therapy utilization with an operation time of 86.0% of the scheduled 720 minutes. However, the functional time is significantly lower at 53.0%, indicating a gap in converting operation time into effective treatment time. Unavoidable losses are relatively high at 25.3%, pointing towards external factors significantly affecting operation. Avoidable losses are present at 7.6%, suggesting some areas for operational improvement. The percentage of slow cycles at 28.0% is considerable, indicating periods of reduced operational speed that could be targeted for improvement.

Government Mohan Kumaramangalam Medical College and Hospital, Salem:

This facility shows a high level of operational efficiency in Cobalt therapy utilization with an operation time of 81.2% of the scheduled 480 minutes. The functional time is also quite high at 75.4%, indicating effective use of the equipment for patient treatments. Unavoidable losses are modest at 5.8%, suggesting some impact of external factors on the operation but are well managed. The absence of avoidable losses indicates efficient operational management. However, the high percentage of slow cycles at 46.2% suggests significant periods where the equipment operates below its optimal capacity, which could be an area for technical improvement.

Government Villupuram Medical College Hospital:

The utilization of Cobalt therapy indicates efficient operation with an operation time of 82.4% out of scheduled 540 minutes. However, functional time is notably lower at 38.3%, suggesting that a considerable portion of the operation time is not being effectively used for patient treatments. Unavoidable losses are high at 47.6%, indicating substantial external constraints impacting operation. Avoidable losses are minimal at 2.0%. The slow cycles, at 32.8%, point towards periods of reduced operational efficiency, which could be targeted for improvement.

Table 13: Institute-wise total minutes of time and motion observation findings for Cobalt therapy and percentage distribution out of total scheduled time across the various utilization indices in secondary and tertiary healthcare facilities of Tamil Nadu

Institute Name	Scheduled time	Operation time (% of scheduled time)	Functional time (% of scheduled time)	Unavoidable loss (% of scheduled time)	Avoidable loss (% of scheduled time)	Slow cycles (% of scheduled time)
Government Stanley Medical College Hospital	480	405 (84.4)	352 (73.3)	53 (11.0)	0 (0)	2 (0.4)
Government Royapettah Hospital	720	1196 (166.1)	836 (116.1)	420 (58.3)	14 (1.9)	206 (28.6)
Coimbatore Medical College Hospital	960	101 (10.5)	171 (17.8)	11 (1.1)	0 (0)	121 (12.6)
Madurai Medical College Hospital	1260	110 (8.7)	115 (9.1)	30 (2.4)	0 (0)	-10 (-0.8)

Government Tirunelveli Medical College and Hospital	1440	288 (20.0)	273 (18.9)	112 (7.9)	0 (0)	93 (6.4)
Government Medical College Hospital, Thanjavur	720	619 (86.0)	382 (53.0)	182 (25.3)	55 (7.6)	202 (28.0)
Government Mohan Kumaramangalam Medical College and Hospital, Salem	480	390 (81.2)	362 (75.4)	28 (5.8)	0 (0)	222 (46.2)
Government Villupuram Medical College Hospital	540	445 (82.4)	207 (38.3)	257 (47.6)	11 (2.0)	177 (32.8)

Table 14 provides an in-depth institute-wise analysis of time and motion observations for brachytherapy equipment across secondary and tertiary healthcare facilities in Tamil Nadu, detailing both the total minutes and their percentage distribution of the scheduled time.

Rajiv Gandhi Government General Hospital (RGGGH):

The brachytherapy facility at RGGGH exhibits high operational efficiency, with an operation time of 92.0% of the scheduled 840 minutes. However, the functional time is moderately lower at 59.6%, suggesting that while the equipment is frequently operational, the actual time used for patient treatments could be improved. Notably, there are no avoidable losses, indicating effective management. However, unavoidable losses are significant at 32.4%, pointing towards external factors like patient scheduling impacting utilization. The percentage of slow cycles is high at 50.1%, indicating substantial periods of reduced operational efficiency.

Government Medical College, Omandurar:

This facility shows moderate utilization of brachytherapy with an operation time of 66.8% out of the scheduled 600 minutes. The functional time is closely aligned at 65.2%, suggesting effective use of operational hours for patient treatments. The facility has no unavoidable losses, which is a positive aspect of its operation. However, avoidable losses, although minimal at 1.7%, suggest some room for improvement in operational efficiency. The slow cycles are notably high at 51.8%, indicating considerable periods where the equipment operates below its optimal capacity.

Government Royapettah Hospital:

The brachytherapy operation at Government Royapettah Hospital shows moderate utilization, with an operation time of 55.0% of the scheduled 960 minutes. The functional time is closely aligned at 51.8%, indicating effective use of the operational hours for patient treatments. The absence of unavoidable losses is a positive aspect, suggesting no significant external constraints on operation. However, there are minimal avoidable losses at 2.1%, indicating slight room for improvement in operational management. The slow cycles are relatively high at 43.4%, pointing towards periods of reduced operational efficiency which could be targeted for technical or procedural optimization.

Coimbatore Medical College Hospital:

This facility exhibits significantly low utilization of brachytherapy equipment, with both operation time and functional time at merely 4.7% of the scheduled 960 minutes. This low utilization indicates that the equipment is largely underutilized. The absence of both unavoidable and avoidable losses suggests that external factors or operational inefficiencies are not impacting the operation, which further highlights the underutilization issue. Slow cycles are minimal at 0.5%, aligning with the low operational and functional times.

Madurai Medical College Hospital:

The brachytherapy facility at Madurai Medical College Hospital shows a low level of utilization with an operation time of 13.8% of the scheduled 960 minutes. Notably, the functional time exactly matches the operation time, indicating that all available operation time is utilized for patient treatments. This facility does not report any unavoidable or avoidable losses, which is positive and suggests no significant external or internal constraints on operation. However, the slow cycles are relatively high at 33.5%, indicating periods of reduced operational efficiency, which could be due to technical issues or procedural inefficiencies.

Government Medical College Hospital, Thanjavur:

This facility demonstrates a moderate level of utilization for brachytherapy, with an operation time of 53.5% out of the scheduled 720 minutes. The functional time is moderately lower at 58.3%, suggesting some inefficiencies in maximizing the operational time for patient treatments. Unavoidable losses are notable at 16.7%, indicating external factors impacting operation. There are no avoidable losses, which reflects effective operational management. The percentage of slow cycles at 41.7% is considerable and points towards periods of reduced efficiency, suggesting a need for technical improvements or operational refinements.

Government Tirunelveli Medical College and Hospital:

No time and motion observations were made for brachytherapy services at this facility as there were no patients utilizing the services during the data collection visit. This absence of data indicates either very low demand for brachytherapy services at the facility or potential scheduling and availability issues that need to be addressed to ensure the service is utilized effectively.

Table 14: Institute-wise total minutes of time and motion observation findings for Brachytherapy and percentage distribution out of scheduled time across various utilization indices in secondary and tertiary healthcare facilities of Tamil Nadu

Institute Name	Scheduled time	Operation time (% of scheduled time)	Functional time (% of scheduled time)	Unavoidable loss (% of scheduled time)	Avoidable loss (% of scheduled time)	Slow cycles (% of scheduled time)
Rajiv Gandhi Government General Hospital (RGGGH)	840	773 (92.0)	501 (59.6)	272 (32.4)	0 (0)	421 (50.1)
Government Medical College, Omandurar	600	401 (66.8)	391 (65.2)	0 (0)	10 (1.7)	311 (51.8)
Government Royapettah Hospital	960	528 (55.0)	497 (51.8)	0 (0)	20 (2.1)	417 (43.4)
Coimbatore Medical College Hospital	960	45 (4.7)	45 (4.7)	0 (0)	0 (0)	5 (0.5)

Madurai Medical College Hospital	960	132 (13.8)	362 (37.7)	0 (0)	0 (0)	322 (33.5)
Government Medical College Hospital, Thanjavur	720	385 (53.5)	420 (58.3)	120 (16.7)	0 (0)	300 (41.7)
Government Tirunelveli Medical College and Hospital	No time and motion observations were made as there was no patients utilized the brachytherapy services during the visit to the facility for data collection.					

Table 15 provides an in-depth equipment-wise analysis of time and motion observations for factors associated with avoidable losses in utilization across secondary and tertiary healthcare facilities in Tamil Nadu.

The analysis of avoidable losses across various medical equipments in secondary and tertiary healthcare facilities in Tamil Nadu reveals insightful patterns:

CT Equipment:

The total avoidable loss was 1703 minutes. The majority of these losses were due to unplanned stops (60.1%), indicating equipment breakdowns as a significant contributor. Planned stops accounted for 27.9%, while short stops and procedure repeats were relatively minimal, each constituting less than 9% of the avoidable losses.

MRI Equipment:

Avoidable losses totaled 442 minutes. Here, the distribution is more balanced, with short stops being the highest at 28.3%, closely followed by unplanned stops at 26.9% and procedure repeats at 13.6%. This suggests a combination of equipment breakdowns and minor idling stops as primary contributors to downtime.

PET Equipment:

Remarkably, there were no avoidable losses recorded for PET scans, indicating exemplary operational efficiency or potentially underreported data.

Lithotripsy Equipment:

The total avoidable loss was 65 minutes, entirely attributed to short stops (100%). This indicates that minor idling or breaks are the sole contributors to downtime for lithotripsy.

LINAC Equipment:

Out of a total of 700 minutes of avoidable losses, a significant portion was due to planned stops (64.3%), suggesting that setup and adjustments are the main factors. Unplanned stops and procedure repeats also contributed to the losses.

Cobalt Therapy:

The avoidable losses amounted to 80 minutes, predominantly due to unplanned stops (76.3%). This suggests that equipment breakdown is a major contributor to downtime in cobalt therapy.

Brachytherapy Equipment:

With a total of 30 minutes of avoidable losses, all were due to planned stops (100%), indicating that setup and adjustments are the sole factors contributing to downtime.

This analysis provides a nuanced understanding of the factors contributing to avoidable losses across different medical equipments. While some equipments like PET scans show no avoidable losses, others like CT, MRI, and LINAC have diverse factors contributing to downtime, ranging from equipment breakdowns to setup and adjustment times. These insights can be instrumental in formulating targeted strategies to minimize avoidable losses and enhance operational efficiency.

Table 15: Equipment-wise total minutes of factors contributing to avoidable losses in secondary and tertiary healthcare facilities of Tamil Nadu

Equipment	Avoidable loss	Planned Stops (% of avoidable loss)	Unplanned stops (% of avoidable loss)	Short stops (% of avoidable loss)	Startup rejects (% of avoidable loss)	Procedure repeats (% of avoidable loss)
CT	1703	475 (27.9)	1024 (60.1)	143 (8.4)	31 (1.8)	30 (1.8)
MRI	442	77 (17.4)	119 (26.9)	125 (28.3)	61 (13.8)	60 (13.6)
PET	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Lithotripsy	65	0 (0)	0 (0)	65 (100)	0 (0)	0 (0)
LINAC	700	450 (64.3)	183 (26.1)	0 (0)	4 (0.6)	63 (9.0)
Cobalt	80	19 (23.7)	61 (76.3)	0 (0)	0 (0)	0 (0)
Brachytherapy	30	30 (100)	0 (0)	0 (0)	0 (0)	0 (0)

Table 16 provides an in-depth institute-wise analysis of time and motion observations for factors associated with avoidable losses in CT equipment utilization across secondary and tertiary healthcare facilities in Tamil Nadu.

Rajiv Gandhi Government General Hospital (RGGGH):

The CT scan equipment at RGGGH experienced a total of 80 minutes of avoidable losses. A significant portion of these losses, 68.7%, were due to planned stops, which generally involve setup and adjustments. Short stops, which include minor idling or breaks, contributed 25.0% to the avoidable losses, while procedure repeats accounted for 6.3%. Notably, there were no instances of unplanned stops or startup rejects, indicating that equipment breakdowns and reduced yield at startup did not contribute to the losses.

Government Stanley Medical College Hospital:

This facility reported 182 minutes of avoidable losses in CT scan equipment. The majority of these losses, at 80.8%, were attributed to planned stops, suggesting that equipment setup and adjustments were the primary factors. Short stops constituted 19.2% of the losses, but there were no contributions from unplanned stops, startup rejects, or procedure repeats. This pattern suggests effective operational management, with the main area for improvement being in the management of planned stops.

Government Medical College, Omandurar:

The total avoidable loss here was 95 minutes, with a more diverse distribution across categories. Unplanned stops, indicating equipment breakdowns, were the largest contributor, accounting for 36.8% of the losses. This was closely followed by short stops at 25.3% and planned stops at 24.2%.

Startup rejects and procedure repeats contributed 8.4% and 5.3%, respectively. This distribution indicates that a combination of equipment-related issues and operational inefficiencies are the primary contributors to the downtime in CT scan services at this facility.

Government Royapettah Hospital:

In this facility, the CT scan equipment experienced 38 minutes of avoidable losses. The majority of these losses were due to procedure repeats, which accounted for 52.6% of the avoidable losses, indicating instances where scans had to be redone. Startup rejects, which involve reduced yield at startup, contributed 31.6%. Interestingly, there were no unplanned stops or short stops reported, and planned stops contributed only a small portion (15.8%) to the losses.

Coimbatore Medical College Hospital:

The facility reported a total of 125 minutes of avoidable losses. A significant portion of these losses, 82.4%, were due to unplanned stops, indicating equipment breakdowns as a major contributor to downtime. Planned stops contributed 17.6% to the avoidable losses, but there were no instances of short stops, startup rejects, or procedure repeats. This pattern suggests that equipment reliability is a primary concern at this facility.

Madurai Medical College Hospital:

The total avoidable loss in this facility was 68 minutes, with unplanned stops contributing 55.9%, suggesting equipment breakdowns are a significant factor. Short stops accounted for 44.1% of the losses, indicating minor idling or breaks as another contributor to downtime. There were no reported losses due to planned stops, startup rejects, or procedure repeats.

Government Hospital, Melur:

This facility reported a total of 480 minutes of avoidable losses in CT scan equipment, all of which were attributed to unplanned stops (100%). This indicates that equipment breakdowns are the sole factor contributing to the downtime in CT scan services at this hospital. The absence of losses due to planned stops, short stops, startup rejects, or procedure repeats suggests that operational processes outside of equipment failures are managed efficiently.

Government Tirunelveli Medical College and Hospital:

Similar to Government Hospital, Melur, this facility also reported avoidable losses totaling 110 minutes, exclusively due to unplanned stops (100%). This pattern indicates that the primary challenge faced by the facility is related to equipment reliability and breakdowns, with no contributions from other operational inefficiencies such as procedural delays or setup times.

KAP Vishwanathan Government Medical College and Hospital, Trichy:

The facility experienced 60 minutes of avoidable losses, all of which were due to planned stops (100%). This suggests that the primary source of downtime in CT scan services at this hospital is related to equipment setup and adjustments. Unlike the other two facilities, KAP Vishwanathan Government Medical College and Hospital, Trichy does not face challenges with equipment breakdowns or operational inefficiencies during scans.

Government Hospital, Srirangam:

In this facility, the CT scan equipment experienced a total of 30 minutes of avoidable losses. Remarkably, all these losses were due to unplanned stops (100%), which typically indicate equipment breakdowns. The absence of planned stops, short stops, startup rejects, or procedure repeats suggests that, aside from equipment reliability issues, the operational processes at this facility are managed efficiently.

Government Medical College Hospital, Thanjavur:

The facility reported a minimal total of 10 minutes in avoidable losses, which were entirely due to planned stops (100%). This indicates that the primary source of downtime in their CT scan services is related to equipment setup and adjustments. The fact that there are no losses attributed to unplanned stops, short stops, startup rejects, or procedure repeats indicates that other aspects of CT scan operation are well-managed.

Government Hospital, Pattukottai:

Similar to Government Medical College Hospital, Thanjavur, this facility also experienced avoidable losses totaling 20 minutes, solely due to planned stops (100%). This pattern suggests that the main operational challenge in CT scan services here is managing the time required for equipment setup and adjustments. The lack of other types of avoidable losses indicates effective management of the operational process once the equipment is ready for use.

Government Headquarters Hospital, Mettur:

This facility experienced a total of 35 minutes of avoidable losses in CT scan equipment. A significant portion of these losses, 71.4%, was due to short stops, indicating minor idling or breaks during operation. Planned stops contributed 28.6% to the avoidable losses, involving setup and adjustments of the equipment. Notably, there were no unplanned stops, startup rejects, or procedure repeats, suggesting that the primary areas of focus for improvement should be minimizing short stops and enhancing the efficiency of planned stops.

Government Villupuram Medical College and Hospital:

The facility reported a total of 188 minutes of avoidable losses, with the majority being planned stops (50.0%) and unplanned stops (39.4%). This indicates that both equipment setup and breakdowns are significant contributors to downtime. Short stops and startup rejects also contributed to the losses, accounting for 4.8% and 5.8%, respectively. The distribution of these losses suggests that a comprehensive approach addressing both equipment reliability and operational efficiency could significantly reduce downtime in CT scan services.

Government Hospital, Tindivanam:

The facility faced 80 minutes of avoidable losses, all attributed to unplanned stops (100%). This pattern points to equipment breakdowns as the sole factor contributing to downtime. The absence of planned stops, short stops, startup rejects, or procedure repeats is a positive aspect, indicating that once operational, the CT scan services are managed efficiently. The focus here should be on improving equipment maintenance and reliability to reduce the occurrence of unplanned stops.

Government Hospital, Periyakulam:

This facility recorded a total of 14 minutes of avoidable losses in CT scan equipment, all attributed to planned stops (100%). These planned stops typically involve setup and adjustments to the equipment. The absence of unplanned stops, short stops, startup rejects, or procedure repeats suggests that, aside from the time required for setup, the operational processes are efficiently managed. Focusing on reducing the duration of these planned stops could further enhance the overall efficiency of CT scan services at this hospital.

Government Medical College, Nilgiris:

The facility reported a total of 88 minutes of avoidable losses. The majority of these losses, 84.1%, were due to unplanned stops, which are generally indicative of equipment breakdowns. This suggests that equipment reliability and maintenance are the primary areas needing attention. Planned stops accounted for a smaller portion of the losses (15.9%), with no contributions from short stops, startup rejects, or procedure repeats. This distribution indicates that while the equipment setup process is relatively efficient, improving equipment reliability could significantly reduce downtime in CT scan operations.

Lawley Government Hospital, Coonoor, Government Thiruvarur Medical College, Government Theni Medical College and Hospital, Government Sivagangai Medical College and Hospital, Government Hospital, Karaikudi and Government Mohan Kumaramangalam Medical College and Hospital, Salem did not have any avoidable losses during our time and motion observations.

Table 16: Institute-wise total minutes of factors contributing to avoidable losses in CT scan equipment across secondary and tertiary healthcare facilities of Tamil Nadu

Institute Name	Avoidable loss	Planned Stops (% of avoidable loss)	Unplanned stops (% of avoidable loss)	Short stops (% of avoidable loss)	Startup rejects (% of avoidable loss)	Procedure repeats (% of avoidable loss)
Rajiv Gandhi Government General Hospital (RGGGH)	80	55 (68.7)	0 (0)	20 (25.0)	0 (0)	5 (6.3)
Government Stanley Medical College Hospital	182	147 (80.8)	0 (0)	35 (19.2)	0 (0)	0 (0)
Government Medical College, Omandurar	95	23 (24.2)	35 (36.8)	24 (25.3)	8 (8.4)	5 (5.3)
Government Royapettah Hospital	38	6 (15.8)	0 (0)	0 (0)	12 (31.6)	20 (52.6)
Coimbatore Medical College Hospital	125	22 (17.6)	103 (82.4)	0 (0)	0 (0)	0 (0)

Madurai Medical College Hospital	68	0 (0)	38 (55.9)	30 (44.1)	0 (0)	0 (0)
Government Hospital, Melur	480	0 (0)	480 (100)	0 (0)	0 (0)	0 (0)
Government Tirunelveli Medical College and Hospital	110	0 (0)	110 (100)	0 (0)	0 (0)	0 (0)
KAP Vishwanathan Government Medical College and Hospital, Trichy	60	60 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Government Hospital, Srirangam	30	0 (0)	30 (100)	0 (0)	0 (0)	0 (0)

Government Medical College Hospital, Thanjavur	10	10 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Government Hospital, Pattukottai	20	20 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Government Mohan Kumaramangalam Medical College and Hospital, Salem	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Government Headquarters Hospital, Mettur	35	10 (28.6)	0 (0)	25 (71.4)	0 (0)	0 (0)
Government Sivagangai Medical College and Hospital	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Government Hospital, Karaikudi	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Government Villupuram Medical College and Hospital	188	94 (50.0)	74 (39.4)	9 (4.8)	11 (5.8)	0 (0)
Government Hospital, Tindivanam	80	0 (0)	80 (100)	0 (0)	0 (0)	0 (0)
Government Theni Medical College and Hospital	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Government Hospital, Periyakulam	14	14 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Government Medical College, Nilgiris	88	14 (15.9)	74 (84.1)	0 (0)	0 (0)	0 (0)
Lawley Government Hospital, Coonoor	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Government Thiruvarur Medical College	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Table 17 provides an in-depth institute-wise analysis of time and motion observations for factors associated with avoidable losses in MRI equipment utilization across secondary and tertiary healthcare facilities in Tamil Nadu.

Rajiv Gandhi Government General Hospital (RGGGH):

The MRI scan equipment at RGGGH experienced 95 minutes of avoidable losses, all of which were attributed to short stops (100%). Short stops typically involve minor idling or breaks, suggesting that operational inefficiencies, possibly related to patient flow or staff coordination, are the primary contributors to downtime in MRI services at this facility.

Government Stanley Medical College Hospital:

This facility reported a total of 37 minutes of avoidable losses in its MRI scan equipment. Planned stops, which include setup and adjustments, contributed 25 minutes of these losses. Additionally, 12 minutes were due to startup rejects, which involve reduced yield at startup. The absence of losses due to unplanned stops, short stops, or procedure repeats indicates that the main areas of improvement are in the setup and initial operation of the equipment.

Government Medical College, Omandurar:

The MRI scan equipment at this facility faced a total of 72 minutes of avoidable losses. The majority of these losses were due to unplanned stops (48.6%), indicating equipment breakdowns as a significant factor. Startup rejects contributed 9.7% to the losses, and procedure repeats accounted for 41.7%, suggesting issues with process defects and the need for rescans. The absence of planned stops and short stops indicates that setup and minor idling are not major contributors to the downtime.

Coimbatore Medical College Hospital:

In this facility, MRI scan equipment faced a total of 11 minutes of avoidable losses, which were entirely due to startup rejects (100%). Startup rejects typically involve reduced yield at the beginning of the operation, suggesting issues in the initial operational phase of the MRI equipment. The absence of losses due to planned stops, unplanned stops, short stops, or procedure repeats is notable, indicating that once operational, the equipment runs efficiently.

Madurai Medical College Hospital:

This facility reported 30 minutes of avoidable losses in MRI scan equipment, all attributed to short stops (100%). Short stops generally involve minor idling or breaks, indicating that operational inefficiencies, possibly related to patient handling or staff coordination, are the primary factors contributing to downtime in MRI services at this hospital.

Government Tirunelveli Medical College and Hospital:

The MRI scan equipment at this facility experienced 30 minutes of avoidable losses, exclusively due to procedure repeats (100%). Procedure repeats often occur due to process defects or the need for rescans, suggesting that improving the quality of initial scans could significantly reduce these types of avoidable losses at the facility.

KAP Vishwanathan Government Medical College and Hospital, Trichy:

This facility encountered 15 minutes of avoidable losses in MRI scan equipment, entirely due to planned stops (100%). These planned stops typically involve equipment setup and adjustments, suggesting that optimizing the setup process could help reduce downtime in MRI services at this hospital.

Government Mohan Kumaramangalam Medical College and Hospital, Salem:

The facility faced a total of 18 minutes of avoidable losses. The majority of these losses, 83.3%, were due to planned stops, while the remaining 16.7% were attributed to startup rejects. This indicates that the primary areas for improvement include the initial setup of the equipment and optimizing the startup phase to minimize reduced yield at the beginning of operations.

Government Villupuram Medical College and Hospital:

This facility reported a total of 60 minutes of avoidable losses, with a diverse distribution. Startup rejects were the largest contributor at 46.7%, followed by planned stops at 24.4% and unplanned stops at 16.7%. The high percentage of startup rejects suggests that focusing on improving the initial operational efficiency of the MRI equipment could significantly reduce downtime.

Government Medical College, Nilgiris:

The MRI scan equipment at this facility experienced 74 minutes of avoidable losses, all attributed to unplanned stops (100%). Unplanned stops generally indicate equipment breakdowns, suggesting that enhancing maintenance protocols or addressing equipment reliability issues could help minimize these types of losses.

Government Thiruvarur Medical College, Government Sivagangai Medical College and Hospital, Government Medical College Hospital, and Thanjavur Government Royapettah Hospital had no avoidable losses during the days of time and motion observations for MRI.

Table 17: Institute-wise total minutes of factors contributing to avoidable losses in MRI scan equipment across secondary and tertiary healthcare facilities of Tamil Nadu

Institute Name	Avoidable losses	Planned Stops (% of avoidable loss)	Unplanned stops (% of avoidable loss)	Short stops (% of avoidable loss)	Startup rejects (% of avoidable loss)	Procedure repeats (% of avoidable loss)
Rajiv Gandhi Government General Hospital (RGGGH)	95	0 (0)	0 (0)	95 (100)	0 (0)	0 (0)
Government Stanley Medical College Hospital	37	25	0 (0)	0 (0)	12	0 (0)
Government Medical College, Omandurar	72	0 (0)	35 (48.6)	0 (0)	7 (9.7)	30 (41.7)
Government Royapettah Hospital	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Coimbatore Medical College Hospital	11	0 (0)	0 (0)	0 (0)	11 (100)	0 (0)
Madurai Medical College Hospital	30	0 (0)	0 (0)	30 (100)	0 (0)	0 (0)

Government Tirunelveli Medical College and Hospital	30	0 (0)	0 (0)	0 (0)	0 (0)	30 (100)
KAP Vishwanathan Government Medical College and Hospital, Trichy	15	15 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Government Medical College Hospital, Thanjavur	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Government Mohan Kumaramangalam Medical College and Hospital, Salem	18	15 (83.3)	0 (0)	0 (0)	3 (16.7)	0 (0)
Government Sivagangai Medical College and Hospital	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Government Villupuram Medical College and Hospital	60	22 (24.4)	10 (16.7)	0 (0)	28 (46.7)	0 (0)

Government Medical College, Nilgiris	74	0 (0)	74 (100)	0 (0)	0 (0)	0 (0)
Government Thiruvarur Medical College	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Table 18 provides an in-depth institute-wise analysis of time and motion observations for factors associated with avoidable losses in PET scan and lithotripsy equipment utilization across secondary and tertiary healthcare facilities in Tamil Nadu.

PET Scan Equipment at Madurai Medical College Hospital:

Avoidable Losses: Remarkably, there were no avoidable losses recorded in the PET scan equipment at Madurai Medical College Hospital. This indicates exemplary operational efficiency, with no recorded instances of planned stops, unplanned stops, short stops, start-up rejects, or procedure repeats. This level of operational excellence suggests highly effective management and maintenance of the PET scan equipment at this facility.

Lithotripsy Equipment:

Rajiv Gandhi Government General Hospital (RGGGH):

A total of 35 minutes of avoidable losses were reported, all attributed to short stops (100%). Short stops typically involve minor idling or breaks during operation, suggesting that operational inefficiencies, are the primary factors contributing to downtime in lithotripsy services.

Government Tirunelveli Medical College and Hospital:

Similar to RGGGH, this facility reported 30 minutes of avoidable losses, exclusively due to short stops (100%). This pattern indicates that operational management, particularly in minimizing idling and enhancing patient throughput, is a key area for improvement to reduce downtime in lithotripsy services.

Table 18: Institute-wise total minutes of factors contributing to avoidable losses in PET scan and lithotripsy equipment across secondary and tertiary healthcare facilities of Tamil Nadu

Institute Name	Avoidable losses	Planned Stops (% of avoidable loss)	Unplanned stops (% of avoidable loss)	Short stops (% of avoidable loss)	Startup rejects (% of avoidable loss)	Procedure repeats (% of avoidable loss)
PET SCAN						
Madurai Medical College Hospital	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
LITHOTRIPSY EQUIPMENT						
Rajiv Gandhi Government General Hospital (RGGGH)	35	0 (0)	0 (0)	35 (100)	0 (0)	0 (0)
Government Tirunelveli Medical College and Hospital	30	0 (0)	0 (0)	30 (100)	0 (0)	0 (0)

Table 19 provides an in-depth institute-wise analysis of time and motion observations for factors associated with avoidable losses in LINAC equipment utilization across secondary and tertiary healthcare facilities in Tamil Nadu.

Rajiv Gandhi Government General Hospital (RGGGH):

The facility reported 64 minutes of avoidable losses in its LINAC equipment, all attributed to planned stops (100%). This suggests that the primary area for improvement is in the setup and adjustment phase of the equipment, which, if optimized, could significantly enhance operational efficiency.

Government Medical College, Omandurar:

A total of 76 minutes of avoidable losses were reported, with the majority being due to planned stops (65.8%). Unplanned stops contributed 10.5% of the losses, indicating occasional equipment breakdowns. Additionally, startup rejects accounted for 5.3%, and procedure repeats contributed 18.4%. This diverse distribution of losses suggests that several areas, including equipment setup, maintenance, and operational processes, need attention to minimize downtime.

Government Royapettah Hospital:

The facility experienced 87 minutes of avoidable losses. Planned stops were the primary contributor at 51.7%, followed closely by procedure repeats at 48.3%. The absence of losses from unplanned stops and short stops is positive, but the high percentage of procedure repeats suggests a need for improvements in the quality of procedures to avoid the need for rescans.

Coimbatore Medical College Hospital:

The facility reported a total of 129 minutes of avoidable losses in LINAC equipment, exclusively due to planned stops (100%). This indicates that the entire downtime is attributed to equipment setup and adjustments. The absence of unplanned stops, short stops, startup rejects, or procedure repeats suggests that the operational processes, once the equipment is ready, are efficient. However, there is a significant opportunity to reduce the duration of planned stops to enhance overall operational efficiency.

Madurai Medical College Hospital:

A total of 19 minutes of avoidable losses were reported, with the majority (63.1%) due to planned stops. Additionally, procedure repeats accounted for 36.9% of the losses. The absence of unplanned stops, short stops, and startup rejects is positive. However, addressing the issues leading to procedure repeats and optimizing planned stops could further improve the efficiency of LINAC services.

Government Medical College Hospital, Thanjavur:

The facility experienced 325 minutes of avoidable losses, with a nearly even distribution between planned stops (46.1%) and unplanned stops (53.9%). This pattern indicates that both equipment setup and breakdowns are significant contributors to downtime. Focusing on reducing both types of stops through improved operational management and maintenance could greatly enhance the availability and reliability of LINAC services.

Government Tirunelveli Medical College and Hospital did not have any avoidable losses.

Table 19: Institute-wise total minutes of factors contributing to avoidable losses in LINAC equipment across secondary and tertiary healthcare facilities of Tamil Nadu

Institute Name	Avoidable losses	Planned Stops (% of avoidable loss)	Unplanned stops (% of avoidable loss)	Short stops (% of avoidable loss)	Startup rejects (% of avoidable loss)	Procedure repeats (% of avoidable loss)
Rajiv Gandhi Government General Hospital (RGGGH)	64	64 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Government Medical College, Omandurar	76	50 (65.8)	8 (10.5)	0 (0)	4 (5.3)	14 (18.4)
Government Royapettah Hospital	87	45 (51.7)	0 (0)	0 (0)	0 (0)	42 (48.3)
Coimbatore Medical College Hospital	129	129 (100)	0 (0)	0 (0)	0 (0)	0 (0)

Madurai Medical College Hospital	19	12 (63.1)	0 (0)	0 (0)	0 (0)	7 (36.9)
Government Tirunelveli Medical College and Hospital	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Government Medical College Hospital, Thanjavur	325	150 (46.1)	175 (53.9)	0 (0)	0 (0)	0 (0)

Table 20 provides an in-depth institute-wise analysis of time and motion observations for factors associated with avoidable losses in Cobalt therapy equipment utilization across secondary and tertiary healthcare facilities in Tamil Nadu.

G**overnment Royapettah Hospital**:

The facility reported 14 minutes of avoidable losses in cobalt therapy equipment, exclusively attributed to planned stops (100%). This indicates that the primary area of improvement is in reducing the time spent on equipment setup and adjustments. The absence of losses from unplanned stops, short stops, start-up rejects, or procedure repeats suggests that other operational aspects are managed efficiently.

Government Medical College Hospital, Thanjavur:

The facility faced a total of 55 minutes of avoidable losses, all due to unplanned stops (100%). This points to equipment breakdowns as the sole contributor to downtime. Addressing equipment reliability and maintenance could significantly improve operational efficiency and reduce these types of losses.

Government Villupuram Medical College Hospital:

A total of 11 minutes of avoidable losses were reported, with a nearly even distribution between planned stops (45.4%) and unplanned stops (54.6%). This indicates that both equipment setup and breakdowns are significant factors contributing to downtime. Focusing on both improving the efficiency of planned stops and enhancing equipment maintenance could greatly benefit the operational efficiency of cobalt therapy services at this hospital.

Rest of the facilities did not have any avoidable losses.

Table 20: Institute-wise total minutes of factors contributing to avoidable losses in Cobalt therapy equipment across secondary and tertiary healthcare facilities of Tamil Nadu

Institute Name	Avoidable losses	Planned Stops (% of avoidable loss)	Unplanned stops (% of avoidable loss)	Short stops (% of avoidable loss)	Startup rejects (% of avoidable loss)	Procedure repeats (% of avoidable loss)
Government Stanley Medical College Hospital	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Government Royapettah Hospital	14	14 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Coimbatore Medical College Hospital	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Madurai Medical College Hospital	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Government Tirunelveli Medical College and Hospital	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Government Medical College Hospital, Thanjavur	55	0 (0)	55 (100)	0 (0)	0 (0)	0 (0)
Government Mohan Kumaramangalam Medical College and Hospital, Salem	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Government Villupuram Medical College Hospital	11	5 (45.4)	6 (54.6)	0 (0)	0 (0)	0 (0)

Table 21 provides an in-depth institute-wise analysis of time and motion observations for factors associated with avoidable losses in Brachytherapy equipment utilization across secondary and tertiary healthcare facilities in Tamil Nadu.

The analysis of avoidable losses in Brachytherapy equipment across various secondary and tertiary healthcare facilities in Tamil Nadu presents a varied picture of operational efficiency:

Rajiv Gandhi Government General Hospital (RGGGH), **Coimbatore Medical College Hospital**, **Madurai Medical College Hospital**, and **Government Medical College Hospital, Thanjavur**:

These facilities reported zero avoidable losses in their Brachytherapy services. This exceptional performance indicates highly efficient operational management, with no recorded instances of operational time losses, functional time losses, unavoidable losses, avoidable losses, or slow cycles. Such efficiency sets a high standard for Brachytherapy operations, suggesting that these facilities have effectively streamlined their processes, maintained their equipment optimally, and managed patient care efficiently.

Government Medical College, Omandurar and **Government Royapettah Hospital**:

Both these facilities reported minimal avoidable losses (10 and 20 minutes, respectively), exclusively due to operational time losses. This indicates that while their Brachytherapy services are generally efficient, there are small margins for improvement in managing their operational processes. The absence of functional time losses, unavoidable losses, and slow cycles in these facilities is commendable and points towards a high level of operational efficiency.

Government Tirunelveli Medical College and Hospital:

This facility did not have any time and motion observations for Brachytherapy services as no patients utilized these services during the data collection period. The absence of data highlights a potential gap in service demand or availability, which may warrant further investigation to ensure effective utilization of the Brachytherapy services.

Majority of the facilities demonstrate excellent operational management in their Brachytherapy services, with no significant avoidable losses. The few facilities that reported minimal losses primarily need to focus on optimizing their operational time. The absence of patient utilization in one facility indicates a need for further assessment to understand the underlying reasons and ensure that services are aligned with patient needs.

Table 21: Institute-wise total minutes of factors contributing to avoidable losses in Brachytherapy equipment across secondary and tertiary healthcare facilities of Tamil Nadu

Institute Name	Avoidable losses	Operation time (% of scheduled time)	Functional time (% of scheduled time)	Unavoidable loss (% of scheduled time)	Avoidable loss (% of scheduled time)	Slow cycles (% of scheduled time)
Rajiv Gandhi Government General Hospital (RGGGH)	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Government Medical College, Omandurar	10	10 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Government Royapettah Hospital	20	20 (100)	0 (0)	0 (0)	0 (0)	0 (0)
Coimbatore Medical College Hospital	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

Madurai Medical College Hospital	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Government Medical College Hospital, Thanjavur	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Government Tirunelveli Medical College and Hospital	No time and motion observations were made as there was no patients utilized the brachytherapy services during the visit to the facility for data collection.					

Table 22 provides an in-depth equipment-wise analysis of time and motion observations for utilization indicators across secondary and tertiary healthcare facilities in Tamil Nadu.

CT Scan Equipment:

Availability: The CT scan equipment shows high availability at 88.5%, indicating it is operational and accessible for most of its scheduled time. This high availability is crucial for meeting the diagnostic needs of the patients.

Performance: However, the performance level is considerably lower at 45.6%. This suggests that the actual speed at which the CT scans are conducted is significantly below the equipment's designed capacity, potentially due to operational delays or inefficiencies.

Quality: The quality of CT scans is exceptionally high at 99.9%, indicating that the vast majority of procedures conducted meet the required standards and rarely necessitate repetition due to poor image quality.

Overall Equipment Effectiveness (OEE): At 40.7%, the OEE for CT equipment, which is a composite measure of availability, performance, and quality, is moderate. This indicates room for improvement, particularly in the aspect of performance.

Total Effective Equipment Performance (TEEP): With a TEEP of 16.0%, the efficiency of the CT equipment against the total calendar time is relatively low. This suggests that while the equipment is available, its usage is not maximized throughout the year.

MRI Equipment:

Availability: Availability is high at 90.3%, similar to the CT scan equipment, which implies that the MRI equipment is mostly operational during its scheduled times.

Performance: Significantly higher than CT scans, the performance of MRI equipment is 81.0%. This indicates that MRI scans are conducted closer to the equipment's designed speed, suggesting more efficient operational processes than those observed in CT scan operations.

Quality: The quality of MRI procedures is also high at 99.6%, ensuring that nearly all scans are conducted effectively the first time, with minimal need for repetitions.

OEE: The OEE for MRI equipment stands at 70.7%, which is considerably higher than that of CT scans. This reflects a better balance between availability, performance, and quality, indicating more efficient utilization of MRI equipment.

TEEP: At 32.7%, the TEEP for MRI equipment is significantly higher than that of CT scans, suggesting that MRI equipment is utilized more effectively throughout the year.

PET Scan Equipment:

Availability: The availability of PET scan equipment is moderately high at 57.8%. This suggests that the equipment is operational for over half of its scheduled time, indicating potential room for increased availability.

Performance: The performance level is at 61.8%, which, while not optimal, indicates that the PET scans are conducted reasonably close to the equipment's designed operational speed.

Quality: Outstandingly, the quality metric stands at 100%, showing that all PET scan procedures conducted meet the required standards without the need for repetition due to quality issues.

OEE: The OEE for PET scan equipment is 35.7%, reflecting the combined impact of moderate availability and performance, offset by excellent quality. This suggests that while the quality of scans is high, there is potential to improve both the availability and performance.

TEEP: With a TEEP of 20.8%, the efficiency of PET scan equipment against total calendar time is reasonable but indicates opportunities for better utilization throughout the year.

Lithotripsy Equipment:

Availability: The availability is high at 86.0%, suggesting that the equipment is operational for a significant portion of its scheduled time, which is beneficial for meeting patient treatment needs.

Performance: However, the performance is lower at 43.9%. This implies that the speed at which lithotripsy treatments are conducted is below the equipment's ideal capacity, possibly due to operational delays or inefficiencies.

Quality: Similar to PET scans, lithotripsy equipment boasts a perfect quality score of 100%, indicating that all procedures are of appropriate therapeutic quality with no need for repetitions due to poor outcomes.

OEE: The OEE stands at 37.5%, which is moderate and primarily impacted by the lower performance rate. Despite high availability and quality, improving performance could significantly enhance overall equipment effectiveness.

TEEP: The TEEP is relatively low at 11.0%, indicating that while the equipment is available and of high quality, its overall utilization throughout the year could be improved.

LINAC Equipment:

Availability: The LINAC equipment shows high availability at 82.0%, indicating it is operational for a significant portion of its scheduled time, which is beneficial for providing consistent therapeutic services.

Performance: The performance level is also high at 71.9%. This suggests that the LINAC treatments are conducted close to the equipment's designed operational speed, reflecting efficient operational processes.

Quality: The quality of procedures is excellent at 99.1%, ensuring that nearly all LINAC procedures meet the required therapeutic standards with minimal need for repetitions.

OEE: The OEE for LINAC equipment stands at 54.5%, which is a robust figure. This high OEE is a result of the balance between high availability, strong performance, and exceptional quality.

TEEP: With a TEEP of 36.0%, the LINAC equipment shows a good level of utilization over the entire calendar year, suggesting effective management and use of the equipment.

Cobalt therapy Equipment:

Availability: The availability of Cobalt therapy equipment is moderate at 67.4%. This indicates room for improvement in making the equipment more consistently available for treatments.

Performance: Performance is lower at 48.3%, suggesting that the operational speed of Cobalt treatments is below the equipment's ideal capacity, possibly due to procedural delays or operational inefficiencies.

Quality: The quality metric is perfect at 100%, demonstrating that all Cobalt therapy procedures are of appropriate therapeutic quality, with no need for repetitions due to poor outcomes.

OEE: The OEE for Cobalt equipment is 20.6%, which is relatively low. This reflects the combined impact of moderate availability and performance, despite the excellent quality of treatments.

TEEP: The TEEP stands at 6.4%, indicating that the overall utilization of Cobalt therapy equipment against the total calendar time is quite low. This suggests potential for significantly better utilization throughout the year.

Brachytherapy Equipment:

Availability: The availability of Brachytherapy equipment is moderate at 47.6%. This indicates that the equipment is operational for nearly half of its scheduled time. The relatively lower availability compared to other equipment types like LINAC suggests potential room for improvement in scheduling and equipment readiness.

Performance: The performance level is significantly lower at 32.6%. This suggests that the actual operational speed of Brachytherapy treatments is considerably below the equipment's designed capacity. This lower performance might be attributed to various factors such as operational delays, procedural intricacies, or patient-specific considerations.

Quality: The quality metric stands at a perfect 100%, indicating that all Brachytherapy procedures conducted meet the required therapeutic standards with no instances of poor quality necessitating repeats.

OEE: The OEE for Brachytherapy equipment is relatively low at 9.4%. Despite the high quality of procedures, the overall effectiveness is significantly impacted by the lower availability and performance.

TEEP: The TEEP is only 2.4%, which is quite low. This metric indicates that the overall utilization of Brachytherapy equipment against the total calendar time is minimal. This low figure suggests that there is substantial potential for increasing the utilization of Brachytherapy equipment throughout the year.

Table 22: Equipment-wise utilization indicators in secondary and tertiary healthcare facilities of Tamil Nadu

Equipment	Availability (%)	Performance (%)	Quality (%)	OEE (%)	TEEP (%)
CT	88.5	45.6	99.9	40.7	16.0
MRI	90.3	81.0	99.6	70.7	32.7
PET	57.8	61.8	100	35.7	20.8
Lithotripsy	86.0	43.9	100	37.5	11.0
LINAC	82.0	71.9	99.1	54.5	36.0
Cobalt	67.4	48.3	100	20.6	6.4
Brachytherapy	47.6	32.6	100	9.4	2.4

Table 23 provides an in-depth institute-wise analysis of time and motion observations for CT scan utilization indicators across secondary and tertiary healthcare facilities in Tamil Nadu.

Rajiv Gandhi Government General Hospital (RGGGH):

Availability: Exceptionally high at 99.9%, indicating that the CT scan equipment is almost always operational during its scheduled times. This high availability is crucial for meeting the diagnostic needs of the patients efficiently.

Performance: The performance is also high at 82.0%, suggesting that the CT scans are conducted close to the equipment's designed operational speed, reflecting efficient operational processes.

Quality: Near-perfect quality at 99.8%, ensuring that almost all CT scans meet the required diagnostic standards.

OEE: The OEE is significantly high at 81.8%, reflecting the balance between excellent availability, strong performance, and high quality.

TEEP: At 40.2%, the TEEP indicates a good level of utilization over the entire calendar year, suggesting effective management and use of the CT scan equipment.

Government Stanley Medical College Hospital:

Availability: Surprisingly, availability exceeds 100% at 100.4%, indicating that the CT scan equipment is used beyond the scheduled operational times. This can occur due to extended operation hours to accommodate patient demand.

Performance: Lower than RGGGH at 67.4%, suggesting operational speed is somewhat below the equipment's ideal capacity.

Quality: Perfect score at 100%, indicating all CT scan procedures are conducted effectively without the need for repetitions.

OEE: The OEE stands at 67.7%, which is commendable but lower than RGGGH, mainly due to the lesser performance rate.

TEEP: At 33.9%, the TEEP is reasonably good but indicates room for improving the equipment’s utilization throughout the year.

Government Medical College, Omandurar:

Availability: High at 89.3%, indicating that the CT scan equipment is operational for most of its scheduled time.

Performance: The performance level is moderate at 54.6%, suggesting that the operational speed is below the equipment's designed capacity.

Quality: Near-perfect quality at 99.8%, ensuring that almost all CT scans are of appropriate diagnostic quality.

OEE: The OEE is moderate at 48.7%, impacted by the moderate performance despite high availability and quality.

TEEP: At 18.5%, the TEEP suggests that there is room for improvement in utilizing the CT scan equipment more effectively throughout the entire year.

Government Royapettah Hospital:

Availability: Very high at 95.1%, showing that the equipment is mostly operational during its scheduled times.

Performance: Better than Government Medical College, Omandurar, at 73.2%, indicating more efficient operational processes.

Quality: Slightly lower at 98.0%, but still high, ensuring most CT scans are conducted effectively.

OEE: Higher at 68.2%, reflecting better overall equipment efficiency.

TEEP: At 34.0%, it shows more effective year-round utilization of the CT scan equipment.

Coimbatore Medical College Hospital:

Availability: The availability is high at 86.0%, suggesting that the equipment is operational for a significant portion of its scheduled time.

Performance: The performance is moderate at 62.3%, indicating some room for improvement in operational speed.

Quality: Perfect at 100%, showing that all CT scan procedures meet the required standards.

OEE: The OEE stands at 53.6%, which is reasonable but indicates potential for improvement, especially in performance.

TEEP: At 15.6%, the TEEP is on the lower side, suggesting that the equipment's utilization could be maximized further throughout the year.

Madurai Medical College Hospital:

Availability: The availability of CT scan equipment is moderate at 67.5%, indicating that it is operational for about two-thirds of its scheduled time. This suggests potential room for increased availability.

Performance: The performance level is relatively high at 65.3%, suggesting that operational speed is close to the equipment's designed capacity.

Quality: Perfect quality at 100%, indicating that all CT scan procedures meet the required diagnostic standards without the need for repetition.

OEE: The OEE stands at 44.1%, which is a reflection of the balance between moderate availability, good performance, and excellent quality.

TEEP: At 15.9%, the TEEP suggests that while the quality and performance are high, there is room for improvement in maximizing the equipment’s utilization throughout the year.

Government Hospital, Melur:

Availability: Unusually high at 115.4%, suggesting that the CT scan equipment is used beyond the scheduled operational times, likely due to high demand or extended operation hours.

Performance: Significantly lower at 13.5%, indicating that the operational speed is much below the equipment's ideal capacity. This could be due to operational delays or inefficiencies.

Quality: Maintains a perfect score of 100%, ensuring all procedures meet the required quality standards.

OEE: The OEE is low at 15.6%, mainly impacted by the very low performance rate despite the excessively high availability.

TEEP: The TEEP, standing at 5.2%, is quite low, indicating that despite the extended use of the equipment, its overall utilization over the calendar year remains limited, possibly due to the significantly reduced operational speed.

Government Tirunelveli Medical College and Hospital:

Availability: The availability of CT scan equipment is fairly high at 74.0%, indicating that it is operational for a significant portion of its scheduled time. This level of availability is beneficial for meeting patient diagnostic needs.

Performance: Performance stands at 50.6%, suggesting that the CT scans are conducted at about half the equipment's ideal operational speed. This indicates potential room for improvement in operational efficiency.

Quality: Maintains a perfect quality score of 100%, ensuring that all CT scan procedures are conducted effectively without the need for repetitions due to poor quality.

OEE: The OEE is moderately high at 37.5%, reflecting the balance between fairly high availability, moderate performance, and excellent quality.

TEEP: With a TEEP of 20.8%, the efficiency of the CT equipment against the total calendar time is reasonable, suggesting effective utilization but with room for improvement.

KAP Vishwanathan Government Medical College and Hospital, Trichy:

Availability: The availability is high at 86.7%, showing that the equipment is mostly operational during its scheduled times, which is advantageous for patient care.

Performance: Performance is moderately high at 54.1%, indicating that the equipment operates closer to its designed capacity, but still has potential for improvement.

Quality: Perfect at 100%, indicating all CT scan procedures meet the required standards with high quality.

OEE: The OEE stands at 46.9%, which is a good figure, suggesting a better balance between availability, performance, and quality.

TEEP: At 15.6%, the TEEP, is still indicative of a reasonable level of year-round utilization.

Government Hospital, Srirangam:

Availability: The availability of CT scan equipment at Government Hospital, Srirangam, is moderate at 69.8%. This suggests that the equipment is operational for a good portion of its scheduled time but still has room for increased availability to better meet patient needs.

Performance: The performance level is relatively low at 27.9%. This indicates that the operational speed of CT scans is significantly below the equipment's designed capacity. This lower performance might be due to various factors such as operational delays, procedural complexities, or patient-specific factors.

Quality: The quality of CT scan procedures maintains a perfect score of 100%, indicating that all scans conducted meet the required diagnostic standards with no need for repetitions due to poor image quality.

OEE: The OEE for the CT scan equipment at Government Hospital, Srirangam, stands at 19.4%. This figure is on the lower side, reflecting the impact of moderate availability and relatively low performance, despite the excellent quality of the scans.

TEEP: The TEEP is 6.5%, which is quite low. This metric indicates that the overall utilization of the CT scan equipment against the total calendar time is limited. This low TEEP suggests that there is considerable potential for increasing the utilization of the CT scan equipment throughout the year.

Government Medical College Hospital, Thanjavur:

Availability: High at 88.6%, indicating that the CT scan equipment is operational for most of its scheduled time, which is beneficial for patient care and diagnostics.

Performance: The performance level is impressive at 82.3%, suggesting that the CT scans are conducted close to the equipment's designed operational speed. This indicates efficient operational processes and effective use of the equipment.

Quality: Maintains a perfect quality score of 100%, ensuring that all CT scan procedures are of appropriate diagnostic quality.

OEE: The OEE stands at a high 72.9%, reflecting the balance between excellent availability, strong performance, and high-quality scans. This high OEE suggests that the equipment is used efficiently and effectively.

TEEP: At 24.3%, the TEEP indicates a good level of utilization over the entire calendar year, showing effective management and utilization of the CT scan equipment.

Government Hospital, Pattukottai:

Availability: Very high at 96.8%, showing that the CT scan equipment is operational for most of the scheduled time, often beyond the standard operational hours.

Performance: However, the performance is much lower at 28.7%, indicating that the operational speed is significantly below the equipment's ideal capacity. This could be due to operational delays or inefficiencies in the scanning process.

Quality: Like the previous facility, the quality is perfect at 100%, indicating high standards in scan quality.

OEE: The OEE is moderately low at 27.8%, impacted by the low performance rate despite the high availability. This suggests that while the equipment is available, its effective use is hampered by operational speed issues.

TEEP: The TEEP, at 10.4%, is relatively low, indicating that the overall utilization of the equipment over the calendar year is limited, primarily due to reduced operational speed.

Government Mohan Kumaramangalam Medical College and Hospital, Salem:

Availability: Very high at 91.5%, indicating the CT scan equipment is frequently operational and available during its scheduled time. This high availability is crucial for meeting patient diagnostic needs effectively.

Performance: The performance is moderate at 59.2%. While better than some facilities, it suggests that the operational speed of CT scans is somewhat below the equipment's ideal capacity.

Quality: Maintains a perfect quality score of 100%, ensuring that all CT scan procedures are conducted effectively with no need for repetitions due to poor quality.

OEE: The OEE stands at 54.2%, which is relatively high but indicates room for improvement, particularly in enhancing performance.

TEEP: At 22.6%, the TEEP suggests effective utilization of the CT scan equipment over the entire calendar year, though there is potential for further improvement.

Government Headquarters Hospital, Mettur:

Availability: Similarly high at 90.3%, showing that the CT scan equipment is mostly operational during its scheduled hours, which benefits patient care.

Performance: However, the performance is significantly lower at 17.4%, indicating that the operational speed is far below the equipment's designed capacity, likely contributing to operational delays and inefficiencies.

Quality: Like the previous facility, the quality is perfect at 100%, indicating that the scans conducted meet the required standards.

OEE: Low at 15.7%, primarily due to the very low performance, despite the high availability.

TEEP: The TEEP, standing at 5.9%, is quite low, suggesting that the overall year-round utilization of the equipment is limited, mainly due to the reduced operational speed.

Government Sivagangai Medical College and Hospital:

Availability: The availability of CT scan equipment is reasonably high at 79.4%, indicating that it is operational for a significant part of its scheduled time. This level of availability is beneficial for patient diagnostics but suggests some room for improvement.

Performance: The performance level stands at 34.1%, which is relatively low. This indicates that the operational speed of CT scans is considerably below the equipment's ideal capacity, potentially due to operational delays or other inefficiencies.

Quality: The quality score is perfect at 100%, ensuring all CT scan procedures meet the required diagnostic standards without the need for repetition due to poor quality.

OEE: The OEE for the CT equipment is 27.1%, which is moderately low. The lower OEE is primarily impacted by the reduced performance, despite the high availability and quality.

TEEP: At 9.0%, the TEEP indicates that the overall utilization of the equipment against the total calendar time is limited, suggesting potential for improved utilization.

Government Hospital, Karaikudi:

Availability: The availability is slightly lower at 75.6%, indicating that the equipment is operational for most of its scheduled time, but with some room for increased availability.

Performance: Performance is significantly lower at 17.2%, suggesting major operational inefficiencies. This low performance rate indicates that the CT scans are conducted much slower than the ideal operational speed.

Quality: Maintains a perfect quality score of 100%, indicating high standards in diagnostic accuracy and the effectiveness of scans.

OEE: The OEE is quite low at 13.0%, impacted significantly by the very low performance rate, despite the relatively high availability.

TEEP: With a TEEP of 4.3%, the year-round utilization of the equipment is quite low, suggesting that the CT scan services could be better utilized throughout the year.

Government Villupuram Medical College and Hospital:

Availability: The CT scan equipment shows a high availability of 81.5%, indicating it is operational for a significant portion of its scheduled time, which is beneficial for meeting the diagnostic needs of patients.

Performance: The performance level is moderately high at 57.0%. This suggests that the operational speed of CT scans is above average but still has room for improvement to reach the equipment's designed capacity.

Quality: The quality of CT scans is excellent, scoring 100%, ensuring that all procedures meet the required diagnostic standards.

OEE: The OEE for the CT equipment is reasonably high at 46.4%, reflecting a balance between good availability, moderate performance, and excellent quality.

TEEP: At 16.9%, the TEEP indicates that the overall utilization of the equipment against the total calendar time is fairly good, suggesting effective management and utilization of the CT scan equipment.

Government Hospital, Tindivanam:

Availability: The availability is moderate at 71.5%, suggesting that the equipment is operational for most of its scheduled time but with noticeable room for improvement.

Performance: Performance is significantly lower at 17.5%, indicating that the operational speed of CT scans is much below the equipment's ideal capacity, likely contributing to operational delays and inefficiencies.

Quality: Maintains a perfect quality score of 100%, ensuring that all procedures are of appropriate diagnostic quality.

OEE: The OEE is quite low at 12.5%, mainly due to the very low performance rate despite the moderate availability.

TEEP: With a TEEP of 5.2%, the year-round utilization of the equipment is low, indicating that the CT scan services could be better utilized throughout the year.

Government Theni Medical College and Hospital:

Availability: The CT scan equipment exhibits exceptional availability at 100%, indicating that it is operational during all its scheduled times. This level of availability is ideal for meeting patient diagnostic needs.

Performance: The performance level, however, is moderate at 46.9%. This suggests that the operational speed of CT scans is below the equipment's designed capacity, indicating room for improvement in operational efficiency.

Quality: Perfect quality at 100% indicates that all CT scan procedures meet the required diagnostic standards, with no repetitions due to poor image quality.

OEE: The OEE is 46.9%, which is moderate. While the high availability and quality are positive aspects, the overall effectiveness is limited by the moderate performance level.

TEEP: With a TEEP of 15.6%, the utilization of CT scan equipment over the calendar year is reasonably good, but there is potential for improved utilization.

Government Hospital, Periyakulam:

Availability: The availability is high at 98.5%, showing that the equipment is operational for most of its scheduled time. This high availability ensures that patient needs are largely met.

Performance: The performance is lower at 35.5%, indicating that the CT scans are conducted at a speed significantly below the equipment's ideal operational capacity.

Quality: Maintains a perfect quality score of 100%, ensuring that all procedures meet the required diagnostic standards.

OEE: The OEE stands at 35.0%, which is on the lower side, primarily impacted by the reduced performance despite the high availability.

TEEP: At 13.1%, the TEEP indicates that the year-round utilization of the equipment is moderate, suggesting room for improvement in maximizing the equipment’s utilization throughout the year.

Government Medical College, Nilgiris:

Availability: The availability is extremely high at 99.5%, indicating the CT scan equipment is almost always operational during its scheduled time.

Performance: However, the performance level is notably low at 26.3%, suggesting operational inefficiencies where the CT scans are conducted much slower than the equipment's ideal capacity.

Quality: Maintains a perfect quality score of 100%, ensuring all procedures meet the necessary diagnostic standards.

OEE: Despite the high availability and quality, the OEE is only 25.9% due to the significantly low performance level.

TEEP: At 9.7%, the TEEP is moderate, indicating room for improvement in maximizing the equipment’s utilization throughout the year.

Lawley Government Hospital, Coonoor:

Availability: High availability at 81.0%, showing that the equipment is operational for a significant portion of its scheduled time.

Performance: The performance is extremely low at 2.6%, indicating major operational delays and inefficiencies.

Quality: Like the other facilities, the quality is perfect at 100%.

OEE: OEE is very low at 2.1%, predominantly impacted by the extremely low performance rate.

TEEP: The TEEP, standing at just 0.7%, is very low, suggesting that the overall year-round utilization of the equipment is minimal, largely due to the reduced operational speed.

Government Thiruvarur Medical College:

Availability: Very high at 99.1%, indicating the CT scan equipment is consistently operational during its scheduled times.

Performance: High performance at 73.6%, suggesting efficient operational processes close to the equipment's designed capacity.

Quality: Perfect quality score at 100%, indicating high standards in scan quality.

OEE: The OEE is high at 72.9%, reflecting a balance between excellent availability, strong performance, and high-quality scans.

TEEP: At 24.3%, the TEEP is reasonably good, indicating effective utilization of the CT scan equipment over the calendar year.

Table 23: Institute-wise utilization performance indicators of CT scan equipment across secondary and tertiary healthcare facilities of Tamil Nadu

Institute Name	Availability (%)	Performance (%)	Quality (%)	OEE (%)	TEEP (%)
Rajiv Gandhi Government General Hospital (RGGGH)	99.9	82.0	99.8	81.8	40.2
Government Stanley Medical College Hospital	100.4	67.4	100	67.7	33.9
Government Medical College, Omandurar	89.3	54.6	99.8	48.7	18.5
Government Royapettah Hospital	95.1	73.2	98.0	68.2	34.0
Coimbatore Medical College Hospital	86.0	62.3	100	53.6	15.6

Madurai Medical College Hospital	67.5	65.3	100	44.1	15.9
Government Hospital, Melur	115.4	13.5	100	15.6	5.2
Government Tirunelveli Medical College and Hospital	74.0	50.6	100	37.5	20.8
KAP Vishwanathan Government Medical College and Hospital, Trichy	86.7	54.1	100	46.9	15.6
Government Hospital, Srirangam	69.8	27.9	100	19.4	6.5

Government Medical College Hospital, Thanjavur	88.6	82.3	100	72.9	24.3
Government Hospital, Pattukottai	96.8	28.7	100	27.8	10.4
Government Mohan Kumaramangalam Medical College and Hospital, Salem	91.5	59.2	100	54.2	22.6
Government Headquarters Hospital, Mettur	90.3	17.4	100	15.7	5.9
Government Sivagangai Medical College and Hospital	79.4	34.1	100	27.1	9.0
Government Hospital, Karaikudi	75.6	17.2	100	13.0	4.3

Government Villupuram Medical College and Hospital	81.5	57.0	100	46.4	16.9
Government Hospital, Tindivanam	71.5	17.5	100	12.5	5.2
Government Theni Medical College and Hospital	100	46.9	100	46.9	15.6
Government Hospital, Periyakulam	98.5	35.5	100	35.0	13.1
Government Medical College, Nilgiris	99.5	26.3	100	25.9	9.7
Lawley Government Hospital, Coonoor	81.0	2.6	100	2.1	0.7
Government Thiruvarur Medical College	99.1	73.6	100	72.9	24.3

Table 24 provides an in-depth institute-wise analysis of time and motion observations for MRI scan utilization indicators across secondary and tertiary healthcare facilities in Tamil Nadu.

Rajiv Gandhi Government General Hospital (RGGGH):

Availability: The availability of MRI scan equipment is high at 89.4%, indicating it is operational for a significant portion of its scheduled time. This level is conducive to meeting patient diagnostic needs effectively.

Performance: The performance is also high at 79.7%, suggesting that MRI scans are conducted close to the equipment's designed operational speed.

Quality: Maintains a perfect quality score of 100%, ensuring that all MRI procedures are conducted effectively without the need for repetitions due to poor quality.

OEE: The OEE stands at 71.3%, which is a strong indicator of efficient utilization, balancing availability, performance, and quality.

TEEP: At 25.3%, the TEEP suggests a good level of year-round utilization, though there's potential for maximizing the equipment's use throughout the year.

Government Stanley Medical College Hospital:

Availability: Exceptionally high at 112.4%, suggesting that the MRI equipment is used beyond its scheduled operational times, likely to accommodate a high patient load.

Performance: Performance is slightly lower than RGGGH at 74.2%, indicating a slightly reduced operational speed but still within a high-efficiency range.

Quality: Like RGGGH, it has a perfect quality score of 100%, reflecting high standards in imaging and diagnostic accuracy.

OEE: The OEE is exceptionally high at 83.3%, one of the highest among the facilities, indicating superior effectiveness in equipment utilization.

TEEP: At 41.7%, the TEEP is notably high, suggesting that the MRI equipment is utilized very effectively throughout the year, much better than RGGGH.

Government Medical College, Omandurar:

Availability: High at 87.3%, indicating that the MRI equipment is frequently operational and available for use during its scheduled times.

Performance: Exceptionally high at 95.5%, suggesting that MRI scans are conducted very close to or at the equipment's designed operational speed, showcasing efficient operational processes.

Quality: The quality of MRI procedures is high at 97.5%, indicating that the majority of procedures are of suitable quality, with a small margin for improvement.

OEE: The OEE is notably high at 81.2%, reflecting an excellent balance between high availability, strong performance, and good quality.

TEEP: At 40.6%, the TEEP indicates a strong level of utilization over the entire calendar year, suggesting effective management and use of the MRI equipment.

Government Royapettah Hospital:

Availability: Moderately high at 80.3%, showing that the MRI equipment is operational for a significant portion of its scheduled time, but with potential for improvement.

Performance: Very high at 90.7%, indicating efficient operational processes where MRI scans are conducted close to the equipment's designed capacity.

Quality: Perfect quality score at 100%, ensuring all MRI procedures meet the highest standards.

OEE: The OEE is high at 72.9%, suggesting effective overall utilization, balancing availability, performance, and quality.

TEEP: At 36.5%, the TEEP is quite good, indicating effective utilization of the MRI equipment throughout the year, though slightly lower than Government Medical College, Omandurar.

Coimbatore Medical College Hospital:

Availability: The availability of MRI scan equipment is moderate at 63.3%, indicating it is operational for a significant portion of its scheduled time, but there's room for improvement.

Performance: Exceptionally high at 117.6%, suggesting that MRI scans are conducted at a speed exceeding the equipment's designed operational capacity. This could indicate efficient operational processes or shorter-than-expected scan durations.

Quality: Maintains a perfect quality score of 100%, ensuring all MRI procedures meet the highest standards.

OEE: The OEE is very high at 75%, reflecting a combination of moderate availability, extremely high performance, and excellent quality.

TEEP: At 37.5%, the TEEP indicates a good level of year-round utilization, suggesting effective management and utilization of the MRI equipment.

Madurai Medical College Hospital:

Availability: Exceptionally high at 100%, showing that the MRI equipment is consistently operational during its scheduled times.

Performance: The performance is moderate at 66.7%, indicating that operational speed is somewhat below the equipment's ideal capacity.

Quality: Perfect quality score at 100%, indicating that all MRI procedures meet the necessary diagnostic standards.

OEE: The OEE stands at 66.7%, which is a strong figure, reflecting a balance between perfect availability, moderate performance, and high-quality scans.

TEEP: At 33.3%, the TEEP is reasonably good, indicating effective utilization of the MRI equipment throughout the year, though slightly lower than Coimbatore Medical College Hospital.

Government Tirunelveli Medical College and Hospital:

Availability: The availability of MRI scan equipment is moderate at 66.7%, suggesting the equipment is operational for two-thirds of its scheduled time.

Performance: Exceptionally high at 125.0%, indicating that MRI scans are conducted significantly faster than the equipment's designed operational capacity. This could reflect highly efficient operational processes or shorter-than-anticipated scan durations.

Quality: Maintains a perfect quality score of 100%, ensuring all MRI procedures meet the highest standards without the need for repetition.

OEE: The OEE is very high at 81.2%, reflecting the combination of moderate availability, extremely high performance, and excellent quality.

TEEP: At 40.6%, the TEEP indicates strong utilization of the MRI equipment over the entire calendar year, suggesting effective management and utilization.

KAP Vishwanathan Government Medical College and Hospital, Trichy:

Availability: Very high at 99.4%, showing that the MRI equipment is consistently operational during its scheduled times, which is excellent for patient care.

Performance: Moderate at 61.9%, indicating that the operational speed of MRI scans is somewhat below the equipment's ideal capacity.

Quality: Perfect quality score at 100%, indicating that all MRI procedures meet the required diagnostic standards.

OEE: The OEE stands at 61.5%, which is strong, reflecting a balance between high availability, moderate performance, and excellent quality.

TEEP: At 33.3%, the TEEP is good, indicating effective utilization of the MRI equipment throughout the year, though slightly lower than Government Tirunelveli Medical College and Hospital.

Government Medical College Hospital, Thanjavur:

Availability: High at 92.8%, indicating that the MRI equipment is operational for most of its scheduled time, which is beneficial for accommodating patient needs.

Performance: Good performance at 71.8%, suggesting that MRI scans are conducted relatively close to the equipment's designed operational speed.

Quality: Perfect quality score of 100%, ensuring all MRI procedures meet the highest diagnostic standards.

OEE: The OEE is strong at 66.7%, reflecting a balance between high availability, good performance, and excellent quality.

TEEP: At 33.3%, the TEEP indicates a good level of year-round utilization, suggesting effective management and utilization of the MRI equipment.

Government Mohan Kumaramangalam Medical College and Hospital, Salem:

Availability: Very high at 96.6%, showing that the MRI equipment is consistently operational during its scheduled times.

Performance: The performance is notably high at 84.1%, indicating efficient operational processes and the equipment operating close to its ideal capacity.

Quality: Maintains a perfect quality score of 100%, reflecting high standards in imaging and diagnostic accuracy.

OEE: The OEE is very high at 81.2%, indicating superior effectiveness in the utilization of MRI equipment.

TEEP: At 40.6%, the TEEP is strong, suggesting that the MRI equipment is utilized very effectively throughout the year, indicating excellent operational management.

Government Sivagangai Medical College and Hospital:

Availability: High at 91.5%, indicating that the MRI equipment is frequently operational and available for use during its scheduled times.

Performance: Very high at 88.8%, suggesting that MRI scans are conducted close to or at the equipment's designed operational speed, showcasing efficient operational processes.

Quality: Perfect quality score of 100%, ensuring all MRI procedures are conducted effectively without the need for repetitions due to poor quality.

OEE: The OEE is notably high at 81.3%, reflecting an excellent balance between high availability, strong performance, and good quality.

TEEP: At 27.1%, the TEEP indicates a strong level of utilization over the entire calendar year, suggesting effective management and use of the MRI equipment.

Government Villupuram Medical College and Hospital:

Availability: Also high at 90.2%, showing that the MRI equipment is operational for most of its scheduled time, which is beneficial for patient care.

Performance: Good performance at 69.2%, indicating efficient operational processes, though there is room for improvement to achieve the ideal operational speed.

Quality: Maintains a perfect quality score of 100%, ensuring all MRI procedures meet the required diagnostic standards.

OEE: The OEE stands at 62.5%, which is strong, reflecting a balance between high availability, good performance, and excellent quality.

TEEP: At 31.2%, the TEEP is quite good, indicating effective utilization of the MRI equipment throughout the year.

Government Medical College, Nilgiris:

Availability: Very high at 97.4%, indicating that the MRI equipment is operational and available for use during most of its scheduled times.

Performance: However, the performance level is quite low at 23.9%. This suggests significant operational inefficiencies, where MRI scans are conducted much slower than the equipment's designed capacity.

Quality: Maintains a perfect quality score of 100%, ensuring all MRI procedures are conducted effectively and meet the required diagnostic standards.

OEE: The OEE is low at 23.3%, primarily impacted by the low performance despite the high availability.

TEEP: At 9.7%, the TEEP indicates limited utilization of the MRI equipment over the entire calendar year, suggesting significant room for improvement.

Government Thiruvarur Medical College:

Availability: Also very high at 96.5%, showing that the MRI equipment is consistently operational during its scheduled times.

Performance: Excellent performance at 84.2%, indicating efficient operational processes close to the equipment's ideal capacity.

Quality: Perfect quality score of 100%, indicating all MRI procedures meet the highest standards.

OEE: OEE is very high at 81.2%, reflecting superior effectiveness in the utilization of MRI equipment.

TEEP: At 27.1%, the TEEP is strong, suggesting that the MRI equipment is utilized effectively throughout the year, indicating excellent operational management.

Table 24: Institute-wise utilization indicators of MRI scan in secondary and tertiary healthcare facilities of Tamil Nadu

Institute Name	Availability (%)	Performance (%)	Quality (%)	OEE (%)	TEEP (%)
Rajiv Gandhi Government General Hospital (RGGGH)	89.4	79.7	100	71.3	25.3
Government Stanley Medical College Hospital	112.4	74.2	100	83.3	41.7
Government Medical College, Omandurar	87.3	95.5	97.5	81.2	40.6
Government Royapettah Hospital	80.3	90.7	100	72.9	36.5
Coimbatore Medical College Hospital	63.3	117.6	100	75	37.5
Madurai Medical College Hospital	100	66.7	100	66.7	33.3

Government Tirunelveli Medical College and Hospital	66.7	125.0	100	81.2	40.6
KAP Vishwanathan Government Medical College and Hospital, Trichy	99.4	61.9	100	61.5	33.3
Government Medical College Hospital, Thanjavur	92.8	71.8	100	66.7	33.3
Government Mohan Kumaramangalam Medical College and Hospital, Salem	96.6	84.1	100	81.2	40.6
Government Sivagangai Medical College and Hospital	91.5	88.8	100	81.3	27.1
Government Villupuram Medical College and Hospital	90.2	69.2	100	62.5	31.2

Government Medical College, Nilgiris	97.4	23.9	100	23.3	9.7
Government Thiruvarur Medical College	96.5	84.2	100	81.2	27.1

Table 25 provides an in-depth institute-wise analysis of time and motion observations for PET scan and lithotripsy equipment utilization indicators across secondary and tertiary healthcare facilities in Tamil Nadu.

PET Scan at Madurai Medical College Hospital:

Availability: Moderately high at 57.8%, indicating that the PET scan equipment is operational for over half of its scheduled time.

Performance: The performance level is moderate at 61.8%, suggesting operational speed is somewhat below the equipment's designed capacity.

Quality: Perfect score at 100%, showing that all PET scan procedures meet the required quality standards.

OEE: The OEE for PET scan equipment is 35.7%, reflecting the balance between moderate availability and performance, offset by excellent quality.

TEEP: At 20.8%, the efficiency of PET scan equipment against total calendar time is reasonable, suggesting potential for better utilization.

Lithotripsy Equipment at Rajiv Gandhi Government General Hospital (RGGGH):

Availability: High at 83.2%, suggesting that the equipment is operational for a significant portion of its scheduled time.

Performance: Moderate performance at 51.4%, indicating that the equipment operates below its ideal speed.

Quality: Maintains a perfect quality score of 100%, ensuring effective therapeutic procedures.

OEE: The OEE is reasonably good at 42.8%, reflecting a combination of high availability, moderate performance, and high quality.

TEEP: At 12.5%, the TEEP indicates that while the availability and quality are high, the overall utilization of lithotripsy equipment over the year could be improved.

Lithotripsy Equipment at Government Tirunelveli Medical College and Hospital:

Availability: Very high at 88.7%, indicating that the equipment is mostly operational during its scheduled hours.

Performance: Lower at 36.2%, suggesting significant room for improvement in operational speed.

Quality: Perfect quality at 100%, indicating the procedures meet therapeutic standards.

OEE: The OEE is moderate at 32.1%, primarily impacted by the lower performance despite the high availability.

TEEP: At 9.4%, TEEP suggests that there is considerable potential to increase the utilization of the equipment throughout the year.

Table 25: Institute-wise utilization performance indicators of PET scan and lithotripsy equipment in secondary and tertiary healthcare facilities of Tamil Nadu

Institute Name	Availability (%)	Performance (%)	Quality (%)	OEE (%)	TEEP (%)
PET SCAN					
Madurai Medical College Hospital	57.8	61.8	100	35.7	20.8
LITHOTRIPSY EQUIPMENT					
Rajiv Gandhi Government General Hospital (RGGGH)	83.2	51.4	100	42.8	12.5
Government Tirunelveli Medical College and Hospital	88.7	36.2	100	32.1	9.4

Table 26 provides an in-depth institute-wise analysis of time and motion observations for LINAC equipment utilization indicators across secondary and tertiary healthcare facilities in Tamil Nadu.

Rajiv Gandhi Government General Hospital (RGGGH):

Availability: Exceptionally high at 101.7%, indicating that the LINAC equipment is used beyond its scheduled operational times. This could reflect high demand and efficient utilization of the equipment.

Performance: The performance is high at 78.2%, suggesting efficient operational processes and the equipment operating close to its ideal capacity.

Quality: Perfect score of 100%, indicating all LINAC procedures meet the required therapeutic standards.

OEE: The OEE is very high at 79.5%, reflecting a combination of excellent availability, strong performance, and high quality.

TEEP: At 72.9%, the TEEP is notably high, suggesting that the LINAC equipment is utilized very effectively throughout the year.

Government Medical College, Omandurar:

Availability: High at 98.9%, showing that the LINAC equipment is consistently operational during its scheduled times.

Performance: Moderate at 51.6%, indicating that the operational speed of LINAC treatments is somewhat below the equipment's ideal capacity.

Quality: Slightly lower at 98.6%, but still high, ensuring most LINAC procedures are conducted effectively.

OEE: The OEE is moderate at 50.3%, impacted primarily by the moderate performance, despite high availability.

TEEP: At 33.5%, the TEEP suggests that there is room for improvement in the year-round utilization of the LINAC equipment.

Government Royapettah Hospital:

Availability: High at 88.9%, indicating that the LINAC equipment is operational for a significant portion of its scheduled time.

Performance: Very high at 87.5%, suggesting that LINAC treatments are conducted close to the equipment's designed operational speed, reflecting efficient operational processes.

Quality: Slightly lower at 97.0%, but still high, ensuring most LINAC procedures are of appropriate therapeutic quality.

OEE: The OEE is high at 75.4%, reflecting a combination of high availability, strong performance, and good quality.

TEEP: At 47.2%, the TEEP is quite good, indicating that the LINAC equipment is utilized effectively throughout the year.

Coimbatore Medical College Hospital:

Availability: Moderate at 66.7%, suggesting that the LINAC equipment is operational for two-thirds of its scheduled time.

Performance: High at 87.5%, indicating efficient operational processes similar to Government Royapettah Hospital, despite the lower availability.

Quality: Perfect score of 100%, ensuring all LINAC procedures meet the highest therapeutic standards.

OEE: The OEE is moderate at 58.3%, reflecting the balance between moderate availability, high performance, and excellent quality.

TEEP: At 29.2%, the TEEP suggests that while the performance and quality are high, the overall utilization of LINAC equipment over the year could be improved.

Madurai Medical College Hospital:

Availability: Moderate at 60.6%, suggesting that the LINAC equipment is operational for a little over half of its scheduled time.

Performance: Relatively low at 38.5%, indicating operational inefficiencies where LINAC treatments are conducted below the equipment's designed operational speed.

Quality: Good quality at 97.9%, ensuring that most LINAC procedures meet the required therapeutic standards.

OEE: The OEE is low at 22.8%, impacted by both moderate availability and low performance.

TEEP: At 11.4%, the TEEP is quite low, indicating limited utilization of the LINAC equipment throughout the year.

Government Tirunelveli Medical College and Hospital:

Availability: Slightly higher at 65.2%, showing that the LINAC equipment is operational for about two-thirds of its scheduled time.

Performance: Much better at 64.9%, suggesting more efficient operational processes compared to Madurai Medical College Hospital.

Quality: Perfect score of 100%, indicating that all LINAC procedures meet the highest therapeutic standards.

OEE: The OEE is moderate at 42.3%, reflecting a balance between decent availability, strong performance, and excellent quality.

TEEP: At 14.1%, the TEEP is somewhat higher than Madurai Medical College Hospital, indicating better utilization of LINAC equipment throughout the year.

Government Medical College Hospital, Thanjavur

Availability: The LINAC equipment at Government Medical College Hospital, Thanjavur, shows very high availability at 91.7%. This indicates that the equipment is operational for most of its scheduled time, providing ample opportunity for patient treatment.

Performance: Exceptionally high at 95.5%, suggesting that the LINAC treatments are conducted very close to the equipment's designed operational speed. This high performance indicates efficient operational processes and skilled handling of the equipment.

Quality: Maintains a perfect quality score of 100%, ensuring that all LINAC procedures conducted meet the required therapeutic standards without the need for repetition due to poor outcomes.

OEE: The OEE is outstanding at 87.5%, one of the highest among the surveyed facilities. This high OEE reflects the efficient utilization of LINAC equipment, balancing excellent availability, strong performance, and perfect quality.

TEEP: With a TEEP of 43.8%, the LINAC equipment at Government Medical College Hospital, Thanjavur, shows a high level of utilization over the entire calendar year. This score suggests that the facility is effectively managing and maximizing the use of its LINAC equipment throughout the year.

Table 26: Institute-wise utilization performance indicators of LINAC equipment in secondary and tertiary healthcare facilities of Tamil Nadu

Institute Name	Availability (%)	Performance (%)	Quality (%)	OEE (%)	TEEP (%)
Rajiv Gandhi Government General Hospital (RGGGH)	101.7	78.2	100	79.5	72.9
Government Medical College, Omandurar	98.9	51.6	98.6	50.3	33.5
Government Royapettah Hospital	88.9	87.5	97.0	75.4	47.2
Coimbatore Medical College Hospital	66.7	87.5	100	58.3	29.2
Madurai Medical College Hospital	60.6	38.5	97.9	22.8	11.4
Government Tirunelveli Medical College and Hospital	65.2	64.9	100	42.3	14.1
Government Medical College Hospital, Thanjavur	91.7	95.5	100	87.5	43.8

Table 27 provides an in-depth institute-wise analysis of time and motion observations for Cobalt therapy equipment utilization indicators across secondary and tertiary healthcare facilities in Tamil Nadu.

Government Stanley Medical College Hospital:

Availability: High at 84.4%, indicating that the Cobalt therapy equipment is operational for a significant portion of its scheduled time.

Performance: Very good performance at 86.4%, suggesting that treatments are conducted close to the equipment's designed operational speed.

Quality: Perfect quality score of 100%, ensuring all Cobalt therapy procedures meet the required therapeutic standards.

OEE: The OEE is high at 72.9%, reflecting efficient utilization of Cobalt therapy equipment, balancing availability, performance, and quality.

TEEP: At 24.3%, the TEEP indicates good utilization of the equipment over the entire calendar year, though there is potential for further improvement.

Government Royapettah Hospital:

Availability: Exceptionally high at 166.1%, suggesting that the Cobalt therapy equipment is used extensively, potentially beyond its scheduled operational times.

Performance: Significantly low at 2.5%, indicating major operational inefficiencies where treatments are conducted far below the equipment's ideal capacity.

Quality: Maintains a perfect quality score of 100%, indicating effective therapeutic procedures despite the low performance.

OEE: The OEE is very low at 4.2%, primarily due to the extremely low performance rate.

TEEP: At 1.0%, the TEEP is minimal, suggesting that despite the over-availability, the actual year-round utilization of the equipment is very limited.

Coimbatore Medical College Hospital:

Availability: Very low at 10.5%, indicating that the Cobalt therapy equipment is operational for only a small fraction of its scheduled time. This low availability could be due to equipment downtime or limited patient demand.

Performance: Moderate at 49.5%, suggesting that when operational, the equipment performs below its ideal capacity. This could be due to operational inefficiencies or technical challenges.

Quality: Perfect quality score of 100%, ensuring that all Cobalt therapy procedures meet the required therapeutic standards despite the low performance and availability.

OEE: The OEE is very low at 5.2%, significantly impacted by the low availability and moderate performance.

TEEP: At 1.7%, the TEEP indicates minimal utilization of the equipment over the entire calendar year, highlighting a significant underutilization of this therapeutic resource.

Madurai Medical College Hospital:

Availability: Similarly low at 8.7%, suggesting that the equipment is seldom used. This could point to issues like low patient load, scheduling inefficiencies, or equipment maintenance and downtime.

Performance: Exceptionally high at 113.6%, indicating that when operational, the Cobalt therapy treatments are conducted at a speed exceeding the equipment's designed capacity. This high performance might be a response to the low availability, attempting to compensate by increasing throughput during operational periods.

Quality: Maintains a perfect quality score of 100%, indicating high standards in therapeutic effectiveness.

OEE: The OEE, though better than Coimbatore Medical College Hospital, is still low at 9.9%, reflecting the imbalance between low availability and high performance.

TEEP: At 2.9%, the TEEP is slightly better than Coimbatore Medical College Hospital but still indicates underutilization of the equipment throughout the year.

Government Tirunelveli Medical College and Hospital:

Availability: Significantly low at 20.0%, indicating that the Cobalt therapy equipment is operational for only a small portion of its scheduled time. This could reflect limited patient demand or extended periods of equipment downtime.

Performance: Moderate at 62.5%, suggesting that the equipment, when operational, performs below its ideal operational capacity.

Quality: Maintains a perfect quality score of 100%, ensuring that all Cobalt therapy procedures are conducted effectively and meet the required therapeutic standards.

OEE: The OEE is low at 12.5%, primarily due to the limited availability, even though the performance is moderate.

TEEP: At 4.2%, the TEEP indicates minimal utilization of the equipment over the entire calendar year, highlighting significant underutilization.

Government Medical College Hospital, Thanjavur:

Availability: Quite high at 86.0%, showing that the Cobalt therapy equipment is operational for a large portion of its scheduled time.

Performance: However, performance is low at 21.1%, indicating operational inefficiencies where treatments are conducted much slower than the equipment's ideal capacity.

Quality: Like Government Tirunelveli Medical College and Hospital, it has a perfect quality score of 100%.

OEE: The OEE is moderately low at 25.0%, impacted by the low performance rate despite the high availability.

TEEP: At 6.3%, the TEEP suggests that while the availability is high, the overall year-round utilization of the equipment is still limited, primarily due to the reduced operational speed.

Government Mohan Kumaramangalam Medical College and Hospital, Salem:

Availability: High at 81.3%, indicating that the Cobalt therapy equipment is operational for a significant portion of its scheduled time.

Performance: Moderate at 35.9%, suggesting that the equipment operates below its ideal capacity. This indicates potential room for improvement in operational speed and efficiency.

Quality: Perfect quality score of 100%, ensuring all Cobalt therapy procedures meet the required therapeutic standards.

OEE: The OEE is moderately low at 29.2%, reflecting a balance between high availability and moderate performance.

TEEP: At 9.7%, TEEP suggests that year-round utilization of the equipment could be improved.

Government Villupuram Medical College Hospital:

Availability: Similarly high at 82.4%, showing that the Cobalt therapy equipment is operational for most of its scheduled time.

Performance: Significantly low at 6.7%, indicating major operational inefficiencies. This could be due to factors like procedural delays, technical issues, or suboptimal patient throughput.

Quality: Maintains a perfect quality score of 100%, indicating effective therapeutic procedures.

OEE: OEE is very low at 5.6%, predominantly impacted by the extremely low performance rate.

TEEP: At 1.0%, the TEEP is minimal, suggesting that the overall year-round utilization of the equipment is very limited, which is concerning given the high availability.

Table 27: Institute-wise utilization performance indicators of Cobalt therapy equipment in secondary and tertiary healthcare facilities of Tamil Nadu

Institute Name	Availability (%)	Performance (%)	Quality (%)	OEE (%)	TEEP (%)
Government Stanley Medical College Hospital	84.4	86.4	100	72.9	24.3
Government Royapettah Hospital	166.1	2.5	100	4.2	1.0
Coimbatore Medical College Hospital	10.5	49.5	100	5.2	1.7
Madurai Medical College Hospital	8.7	113.6	100	9.9	2.9
Government Tirunelveli Medical College and Hospital	20.0	62.5	100	12.5	4.2

Government Medical College Hospital, Thanjavur	86.0	21.1	100	25.0	6.3
Government Mohan Kumaramangalam Medical College and Hospital, Salem	81.3	35.9	100	29.2	9.7
Government Villupuram Medical College Hospital	82.4	6.7	100	5.6	1.0

Table 28 provides an in-depth institute-wise analysis of time and motion observations for brachytherapy equipment utilization indicators across secondary and tertiary healthcare facilities in Tamil Nadu.

Rajiv Gandhi Government General Hospital (RGGGH):

Availability: High at 92.0%, indicating that Brachytherapy equipment is largely available for its scheduled operational times.

Performance: However, the performance is notably low at 10.3%, suggesting that the actual usage of the equipment for treatments is far below its potential capacity.

Quality: Perfect quality score of 100%, ensuring all Brachytherapy procedures are conducted effectively and meet the required therapeutic standards.

OEE: The OEE is low at 9.5%, significantly impacted by the very low performance, despite the high availability.

TEEP: At 2.8%, TEEP indicates minimal utilization of equipment over the entire calendar year.

Government Medical College, Omandurar:

Availability: Moderate at 66.8%, suggesting that the equipment is operational for a significant portion of its scheduled time.

Performance: Higher than RGGGH at 20.0%, but still indicative of underutilization of the equipment's treatment capacity.

Quality: Maintains a perfect quality score of 100%.

OEE: The OEE is slightly better than RGGGH at 13.3%, but still low, reflecting the balance between moderate availability and low performance.

TEEP: At 2.8%, similar to RGGGH, indicating limited overall year-round utilization of the Brachytherapy equipment.

Government Royapettah Hospital:

Availability: Moderate at 55.0%, indicating that Brachytherapy equipment is available for over half of its scheduled operational times. This suggests room for improvement in equipment scheduling or availability.

Performance: Low at 15.2%, showing that the actual utilization of the equipment for treatments is significantly below its potential capacity.

Quality: Perfect quality score of 100%, ensuring all Brachytherapy procedures meet the required therapeutic standards.

OEE: The OEE is low at 8.3%, reflecting the impact of moderate availability and low performance on the overall effectiveness.

TEEP: At 2.8%, indicating limited utilization of the equipment over the entire calendar year, suggesting underutilization of Brachytherapy capabilities.

Coimbatore Medical College Hospital:

Availability: Very low at 4.7%, suggesting that the Brachytherapy equipment is rarely available for its intended use. This could be due to extended equipment downtime or limited patient demand.

Performance: Surprisingly high at 88.9%, indicating that when the equipment is available, it is used near its full treatment capacity.

Quality: Maintains a perfect quality score of 100%, indicating effective therapeutic procedures.

OEE: Despite the high performance, the OEE is very low at 4.2%, primarily due to the extremely limited availability of the equipment.

TEEP: At 1.4%, one of the lowest, reflecting the minimal overall year-round utilization of the Brachytherapy equipment.

Madurai Medical College Hospital:

Availability: Low at 13.8%, indicating that the Brachytherapy equipment is operational for a small fraction of its scheduled time. This could be due to limited patient demand or equipment availability issues.

Performance: Also low at 30.3%, suggesting that when the equipment is available, it's used below its potential capacity. This might reflect scheduling inefficiencies or operational challenges.

Quality: Maintains a perfect quality score of 100%, indicating effective therapeutic procedures when conducted.

OEE: The OEE is low at 4.2%, reflecting the combined impact of limited availability and performance.

TEEP: At 1.4%, indicating minimal overall year-round utilization of the Brachytherapy equipment, pointing to a significant underutilization.

Government Medical College Hospital, Thanjavur:

Availability: Moderately low at 53.5%, suggesting that the equipment is operational for just over half of its scheduled time.

Performance: Similar to Madurai Medical College Hospital, performance is low at 31.2%, indicating underutilization of the equipment's treatment capacity.

Quality: Like Madurai Medical College Hospital, it has a perfect quality score of 100%.

OEE: Moderate at 16.7%, higher than Madurai Medical College Hospital, but still indicating room for improvement in operational efficiency.

TEEP: At 4.2%, somewhat higher than Madurai Medical College Hospital, but still suggesting limited utilization throughout the year.

Table 28: Institute-wise utilization performance indicators of Brachytherapy equipment in secondary and tertiary healthcare facilities of Tamil Nadu

Institute Name	Availability (%)	Performance (%)	Quality (%)	OEE (%)	TEEP (%)
Rajiv Gandhi Government General Hospital (RGGGH)	92.0	10.3	100	9.5	2.8
Government Medical College, Omandurar	66.8	20.0	100	13.3	2.8
Government Royapettah Hospital	55.0	15.2	100	8.3	2.8
Coimbatore Medical College Hospital	4.7	88.9	100	4.2	1.4
Madurai Medical College Hospital	13.8	30.3	100	4.2	1.4
Government Medical College Hospital, Thanjavur	53.5	31.2	100	16.7	4.2

Equipment Utilization Rate:

CT Scan:

Rajiv Gandhi Government General Hospital (RGGGH):

Figure S1 and S2 depicts the year-wise trend of CT scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Rajiv Gandhi Government General Hospital (RGGGH).

Figure S1 shows the number of patients undergoing CT scans each year from 2017 to 2022. There is a general upward trend in the number of CT scans over the six-year period, with a peak in 2021. The Annual Percent Change (APC) for this period is calculated at 1.37, indicating a slight growth rate in utilization. The year 2020 shows a noticeable dip in the number of CT scans, which could be attributed to the impact of the COVID-19 pandemic.

Figure S2 shows the utilization rate of CT scan services per 100,000 OPD visits from 2017 to 2022. The trend shows a significant increase, with the utilization rate growing from 3,762.5 in 2017 to 7,954.5 in 2022. The APC for this timeframe is 17.94, and the trend is statistically significant ($p<0.05$). The steady increase suggests a growing reliance on CT scans relative to the number of OPD visits, possibly indicating wider availability, increased demand, or changes in diagnostic practices.

Government Stanley Medical College Hospital:

Figure S3 and S4 depicts the year-wise trend of CT scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Stanley Medical College Hospital.

Figure S3 shows a general upward trend in the number of CT scans over the six-year period, with a peak in 2022. The APC for this period is calculated at 1.93, indicating a slight growth rate in utilization. The year 2020 shows a noticeable dip in the number of CT scans, which could be attributed to the impact of the COVID-19 pandemic.

Figure S4 shows the utilization rate of CT scan services per 100,000 OPD visits from 2017 to 2022. The trend shows a significant increase, with the utilization rate growing from 2198.1 in 2017 to 4200.6 in 2022. The APC for this time period is 12.71, and the trend is statistically significant ($p<0.05$). The steady increase suggests a growing reliance on CT scans relative to the number of OPD visits, possibly indicating wider availability, increased demand, or changes in diagnostic practices.

Government Medical College Omandurar:

Figure S5A and S5B depicts the year-wise trend of CT scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Medical College Omandurar.

CT scan is being operated from the year 2021 and hence, only two years data was available for this facility. Joinpoint regression to identify the APC was not performed due to this limitation. However, there has been a declining trend reported in terms of both absolute numbers and rate per 100,000 OPD visits at the facility. Hence, further exploration towards the reasons for decline in the utilization can be explored.

Government Royapettah Hospital:

Figure S6 and S7 depicts the year-wise trend of CT scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Royapettah Hospital.

Figure S6 shows an alternate upward and downward trend in the number of CT scans over the six-year period, with a peak in 2021. The APC for this period is calculated at 5.64, indicating a good growth rate in utilization. However, the trend was not statistically significant.

Figure S7 shows the utilization rate of CT scan services per 100,000 OPD visits from 2017 to 2022. The rate showed a consistent increasing trend with a dip in the year 2022 (similar to Government Medical College, Omandurar). The APC showed a substantial growth of about 10.99%. However, this trend was also not statistically significant.

Coimbatore Medical College Hospital:

Figure S8 and S9 depicts the year-wise trend of CT scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Coimbatore Medical College Hospital.

Figure S8 shows a consistent increasing trend in the number of CT scans over the ten-year period, with a peak in 2021. However, there is a recent dip in the utilization in the year 2022. The APC for this period is calculated at 11.19, indicating a substantial and statistically significant growth rate in utilization ($p<0.05$). Figure S9 shows the utilization rate of CT scan services per 100,000 OPD visits from 2013 to 2022. The rate showed a consistent increasing trend with a dip in the year 2022 (similar to Government Medical College, Omandurar and Government Royapettah Hospital). The APC showed a substantial growth of about 20.46% and this trend was also statistically significant ($p<0.05$).

Madurai Medical College Hospital:

Figure S10 and S11 depicts the year-wise trend of CT scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Madurai Medical College Hospital.

Figure S10 shows that there was a slight decline (-3.46%) in the number of CT scans over the initial four-year period (2015-2018). However, there was a drastic change in the trend in 2019 (presence of joinpoint – year where the trend significantly changes), providing APC of 18.42% between 2019 and 2022. Over the entire period from 2015 to 2022, the Average Annual Percent Change (AAPC) is 8.49%, which is also statistically significant.

Figure S11 shows the utilization rate of CT scan services per 100,000 OPD visits from 2015 to 2022. From 2015 to 2018, there was a slight decrease in the trend under study, with an APC of -1.04%. This indicates that the measure was decreasing by an average of 1.04% each year during this period. This part of the trend did not show significant growth or decline.

Between 2018 and 2022, the trend shifted dramatically, with a significant increase at an APC of 34.23% ($p<0.05$). It suggests that there was an average annual increase of 34.23% in the trend during these years, representing a substantial growth phase.

Over the entire period from 2015 to 2022, the AAPC is 17.79%, which is also statistically significant. The AAPC provides a summary measure of the trend over the entire period, taking into account any joinpoints (years where the trend significantly changes). This indicates that, on average, there was an annual increase of 17.79% over the seven-year period.

Government Hospital, Melur:

Figure S12A and S12B depicts the year-wise trend of CT scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Hospital, Melur.

CT scan is being operated from the year 2020 and hence, only three years data was available for this facility. Joinpoint regression to identify the APC was not performed due to this limitation. However, though the absolute numbers showed a steady increasing trend, the utilization rate per 100,000 OPD visits did not show any clear trend in the utilization of CT scan services. Hence, further exploration in the utilization can be explored for this facility.

Government Tirunelveli Medical College and Hospital:

Figure S13 and S14 depicts the year-wise trend of CT scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Tirunelveli Medical College and Hospital.

Figure S13 shows a steady increasing trend in number of patients undergoing CT scan except a dip in 2020 due to COVID-19 pandemic. The APC was 11%, indicating 11% annual increase in the CT scan utilization and this trend was statistically significant ($p<0.05$).

However, Figure S14 showed a steady increasing trend with a spike in 2020, showing that the utilization rate was substantially higher during COVID-19 pandemic in this facility. The APC was 17.1% and this trend was statistically significant ($p<0.05$).

KAP Vishwanathan Government Medical College and Hospital, Trichy:

Figure S15 and S16 depicts the year-wise trend of CT scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at KAP Vishwanathan Government Medical College and Hospital, Trichy.

Both absolute numbers and rate shows a steady increasing trend in utilization of CT scan services. However, there has been a recent dip in the year 2022. The APC for absolute numbers was 17.81%, while for utilization rate, it was 25.11%. This shows a substantial growth in the utilization of CT scan services in this facility.

Government Hospital, Srirangam:

Figure S17 and S18 depicts the year-wise trend of CT scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Hospital, Srirangam.

Similar to Trichy Medical College, this facility also had a steady increasing trend in both absolute numbers and utilization and had a recent dip in the year 2022. The highest increase in utilization in terms of both absolute numbers and rate was seen in the year 2021.

The APC for absolute numbers was 22.57%, while for utilization rate, it was 29.64%. Both the APCs were statistically significant ($p<0.05$).

Government Medical College Hospital, Thanjavur:

Figure S19 and S20 depicts the year-wise trend of CT scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Medical College Hospital, Thanjavur. Both absolute numbers and rate shows a steady increasing trend in utilization of CT scan services with slight dip in the year 2019. However, the utilization rate per 100,000 OPD visits showed a recent dip in the year 2022 also. The APC for absolute numbers was 11.54%, while for utilization rate, it was 18.28%. This shows a substantial growth in the utilization of CT scan services in this facility and both the APCs were statistically significant ($p<0.05$).

Government Hospital, Pattukottai:

Figure S21A and S21B depicts the year-wise trend of CT scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Medical College Hospital, Thanjavur. The data was available for only two years as the equipment has come into operation from the year 2021. There is an increase in the utilization frequency and rate in 2022 compared to 2021. However, joinpoint regression could be performed due to limitation of the data.

Government Mohan Kumaramangalam Medical College and Hospital, Salem:

Figure S22 and S23 depicts the year-wise trend of CT scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Mohan Kumaramangalam Medical College and Hospital, Salem.

Both absolute numbers and rate shows a steady increasing trend in utilization of CT scan services with a sudden peak in 2020 and 2021. This sudden peak indicates that several patients visiting this facility had undergone CT scan as a part of COVID-19 severity screening or indirectly reflect the high burden of COVID-19 in this particular district, necessitating the requirement of CT scan for severity screening. However, both the absolute numbers and utilization rate per 100,000 OPD visits showed a recent dip in the year 2022.

The APC for absolute numbers was 13.68%, which was substantial, but was not statistically significant. The APC for utilization rate per 100,000 OPD visits was 21.58% and this was statistically significant ($p<0.05$). This shows a substantial growth in the utilization of CT scan services in this facility and both the APCs were statistically significant ($p<0.05$).

Government Headquarters Hospital, Mettur:

Figure S24 and S25 depicts the year-wise trend of CT scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Headquarters Hospital, Mettur.

Both absolute numbers and rate shows a steady increasing trend in utilization of CT scan services with a drastic peak in 2021. This sudden peak again reiterates the finding obtained in the Salem Medical College that several patients had undergone CT scan as a part of COVID-19 severity screening or indirectly reflect the high burden of COVID-19 in this particular district.

Similar to Salem Medical College, both the absolute numbers and utilization rate per 100,000 OPD visits showed a recent dip in the year 2022.

The AAPC for absolute numbers was 71.85%, which shows such a huge growth in the number of patients utilizing the CT scan services in this facility. The APC for utilization rate per 100,000 OPD visits was also similar to the absolute numbers i.e., 77.11% and this was statistically significant ($p<0.05$).

Government Sivagangai Medical College and Hospital:

Figure S26 and S27 depicts the year-wise trend of CT scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Sivagangai Medical College and Hospital.

Similar to facilities in Salem, Sivagangai also had showed a steady increasing trend in utilization of CT scan services with a drastic peak in 2021. This sudden peak again reiterates the surge in demand of CT scan in central and southern districts of Tamil Nadu. Both the absolute numbers and utilization rate per 100,000 OPD visits showed a recent dip in the year 2022.

The AAPC for absolute numbers was 17.84%, which shows such a huge growth in the number of patients utilizing the CT scan services in this facility and it was statistically significant ($p<0.05$). The APC for utilization rate per 100,000 OPD visits was also similar to the absolute numbers i.e., 18.8% and this was statistically significant ($p<0.05$).

Government Hospital, Karaikudi:

Figure S28 and S29 depicts the year-wise trend of CT scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Hospital**,** Karaikudi.

There was a steady increasing trend with peak in the utilization at 2021 and dip in 2022, like the rest of the facilities. The APC for absolute number of patients undergoing CT scan was 306.03% and for utilization rate per 100,000 OPD visits was 370.33%, both of which was statistically significant ($p<0.05$).

Government Villupuram Medical College and Hospital:

Figure S30 and S31 depicts the year-wise trend of CT scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Villupuram Medical College and Hospital.

There was a consistent increasing trend in absolute number of patients undergoing CT scan with slight dip in 2020 followed by steady increase in 2021 and 2022 again. However, the utilization rate showed consistent increasing from 2017 to 2022. The APC for absolute numbers was 11.54%, which shows such a huge growth in the number of patients utilizing the CT scan services in this facility and it was statistically significant ($p<0.05$). The APC for utilization rate per 100,000 OPD visits was also similar to the absolute numbers i.e., 16.28% and this was statistically significant ($p<0.05$).

Government Hospital, Tindivanam:

Figure S32 and S33 depicts the year-wise trend of CT scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Hospital, Tindivanam.

There was a consistent increasing trend in absolute number of patients undergoing CT scan, while the utilization rate had slight dip in 2022. The APC for absolute numbers was 82.89%, which shows such a substantial growth in the number of patients utilizing the CT scan services in this facility. The APC for utilization rate per 100,000 OPD visits was also like the absolute numbers i.e., 106.94%.

Government Theni Medical College and Hospital:

Figure S34 and S35 depicts the year-wise trend of CT scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Theni Medical College and Hospital.

Similar to facilities in Salem, Sivagangai, Theni Medical College also had showed a steady increasing trend in utilization of CT scan services with a drastic peak in 2021. This sudden peak again reiterates the surge in demand of CT scan in central and southern districts of Tamil Nadu. Both the absolute numbers and utilization rate per 100,000 OPD visits showed a recent dip in the year 2022. The AAPC for absolute numbers was 13.67%, with joinpoint at 2017 (statistically significant change in trend). The period between 2017 to 2022 showed a substantial increasing trend of 19.81% in terms of absolute numbers and 28.26% in terms of utilization rate. Both these figures were statistically significant ($p<0.05$). The AAPC for utilization rate per 100,000 OPD visits was 14.17%, which shows such a huge growth in the number of patients utilizing the CT scan services in this facility and it was statistically significant ($p<0.05$).

Government Hospital, Periyakulam:

Figure S36A and S36B depicts the year-wise trend of CT scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Hospital, Periyakulam.

The data was available for only three years (from 2020 to 2022) and there was alternate increasing and decreasing trend throughout this period without any particular direction. The finding was applicable for both absolute numbers and utilization rate per 100,000 OPD visits. The joinpoint regression was not done due to the limitation of data in terms of number of years.

Government Medical College, Nilgiris:

Figure S37 and S38 depicts the year-wise trend of CT scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Medical College, Nilgiris.

This facility showed a steady increasing trend in utilization of CT scan services with a drastic peak in 2021. This sudden peak again reiterates the surge in demand of CT scan in central and southern districts of Tamil Nadu. Both the absolute numbers and utilization rate per 100,000 OPD visits showed a recent dip in the year 2022. The APC was 52.34% for number of patients undergoing CT scan per year. The APC was 59.33% in terms of utilization rate and it was statistically significant ($p<0.05$).

Lawley Government Hospital, Coonoor:

Figure S39 and S40 depicts the year-wise trend of CT scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Lawley Government Hospital, Coonoor.

This facility showed a steady declining trend in utilization of CT scan services with a drastic peak in 2021. This sudden peak again reiterates the surge in demand of CT scan in central and southern districts of Tamil Nadu. Both the absolute numbers and utilization rate per 100,000 OPD visits again showed a recent dip in the year 2022. The APC was -1.91% for number of patients undergoing CT scan per year. The APC was 3.67% in terms of utilization rate. However, both these figures were not statistically significant.

Government Thiruvarur Medical College:

Figure S41 and S42 depicts the year-wise trend of CT scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Thiruvarur Medical College.

This facility showed a steady increasing trend in number of patients utilizing the CT scan services with a drastic peak in 2021. This sudden peak again reiterates the surge in demand of CT scan in central and southern districts of Tamil Nadu. Both the absolute numbers and utilization rate per 100,000 OPD visits again showed a recent dip in the year 2022. The APC was 12.01% for number of patients undergoing CT scan per year, while the APC was 5.67% in terms of utilization rate. Both these figures are statistically significant ($p<0.05$).

Five-Year Trend in Utilization of CT Scan services across selected Government Medical Colleges in Tamil Nadu:

Figure 4A-4E depicts the medical college-wise trend of CT scan utilization in terms of absolute numbers from 2018 to 2022.

Over the past five years, Madras Medical College (Rajiv Gandhi Government General Hospital) had the highest number of patients visiting the facility to utilize CT scan services. Government Medical College Hospital Madurai had the second highest number of patients visiting the facility for CT scan services.

Government Medical Colleges in Salem, Coimbatore and Stanley Medical College Hospital are the other facilities with the highest frequency of utilization for CT scan services. Government Medical College, Nilgiris had the least number of patients visiting the facility for CT scan services followed by Government Medical Colleges in Sivagangai, Omandurar (Chennai), Theni and Tiruvarur.

Figure 5A-5E depicts the medical college-wise trend of CT scan utilization in terms of utilization per 100,000 OPD visits from 2018 to 2022. The utilization rate paints a different picture as Government Medical College, Thanjavur had the highest utilization rate per 100,000 OPD visits throughout the last five years followed by Government Medical Colleges in Salem, Sivagangai, Tiruvarur. Government Medical College, Nilgiris had the lowest utilization rate.

However, the facilties having highest utilization in terms of absolute numbers had the next lowest utilization rate like Government Stanley Medical College Hospital and Government Medical College Hospital, Madurai.

Figure 4A: Utilization of CT Scan services (in terms of absolute numbers) across Government Medical Colleges in Tamil Nadu in the year 2022

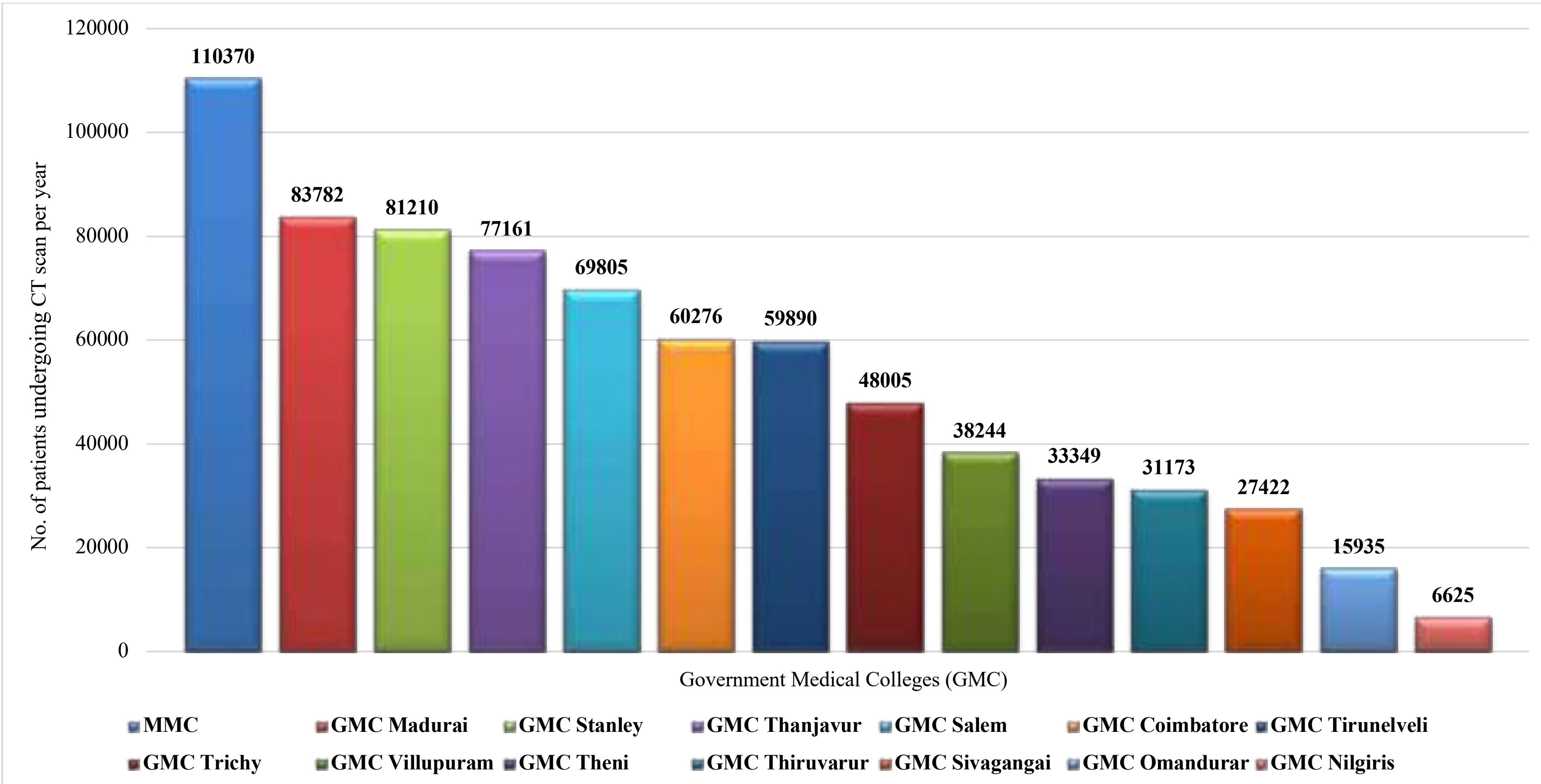


Figure 4B: Utilization of CT Scan services (in terms of absolute numbers) across Government Medical Colleges in Tamil Nadu in the year 2021

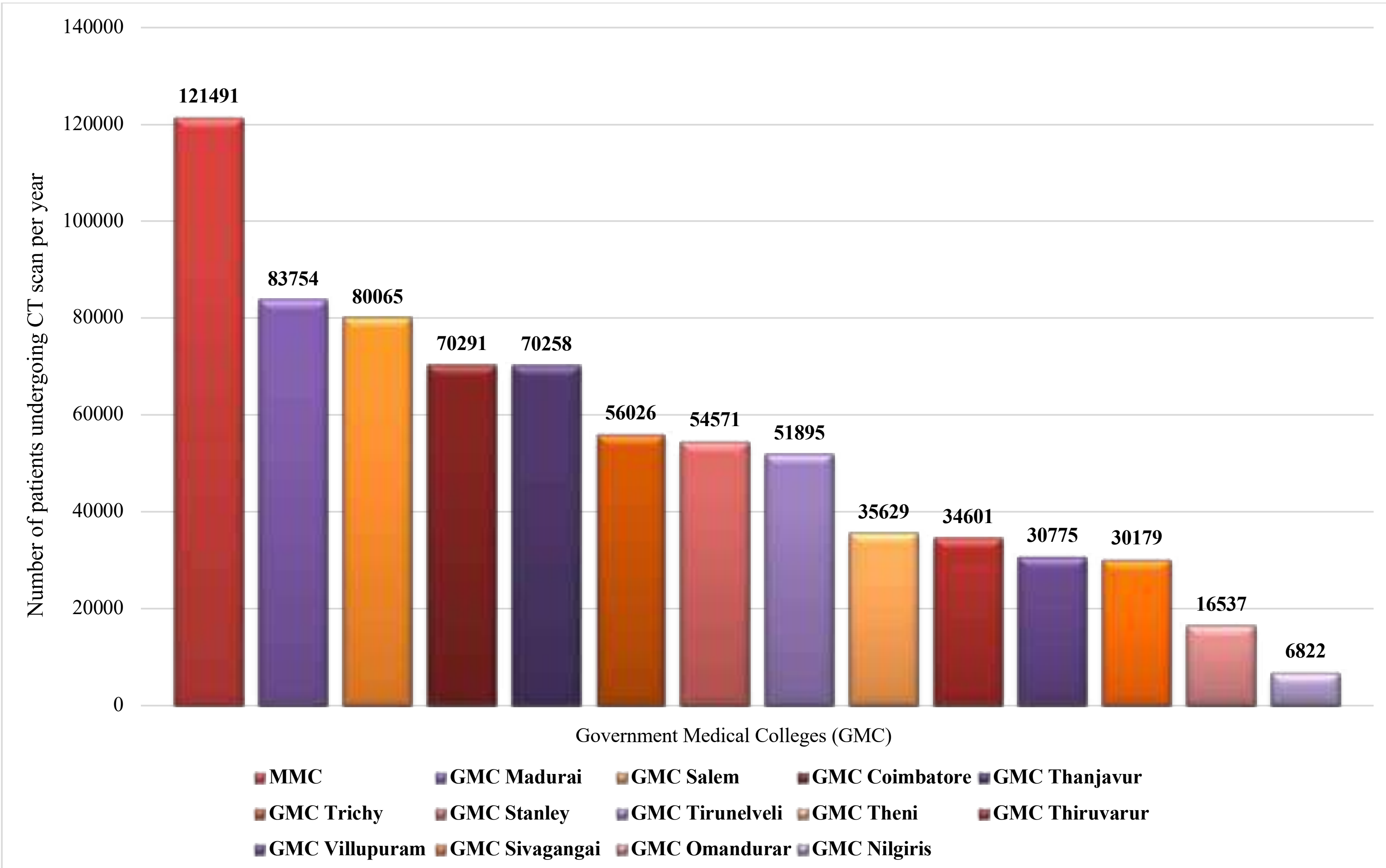


Figure 4C: Utilization of CT Scan services (in terms of absolute numbers) across Government Medical Colleges in Tamil Nadu in the year 2020

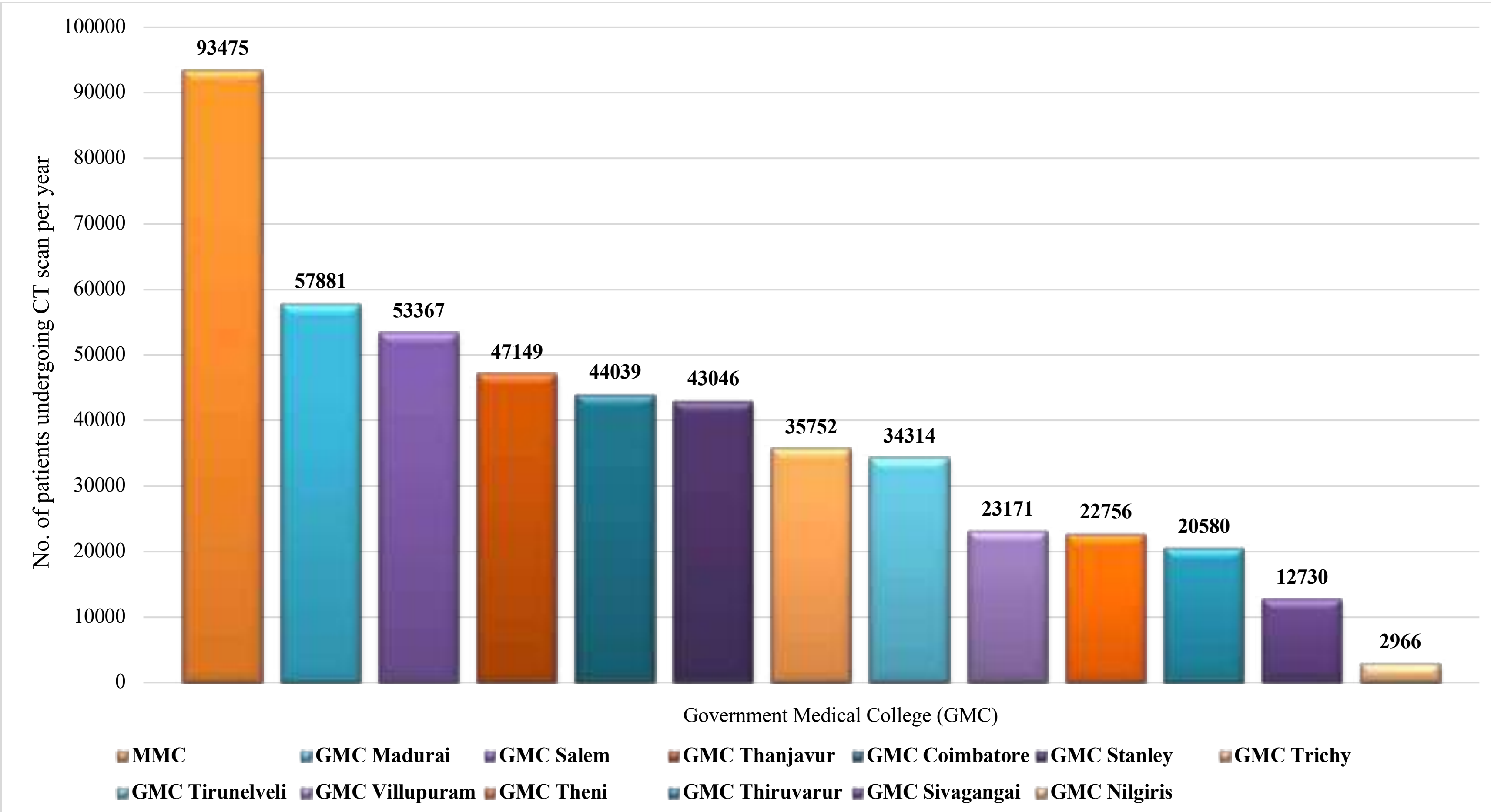


Figure 4D: Utilization of CT Scan services (in terms of absolute numbers) across Government Medical Colleges in Tamil Nadu in the year 2019

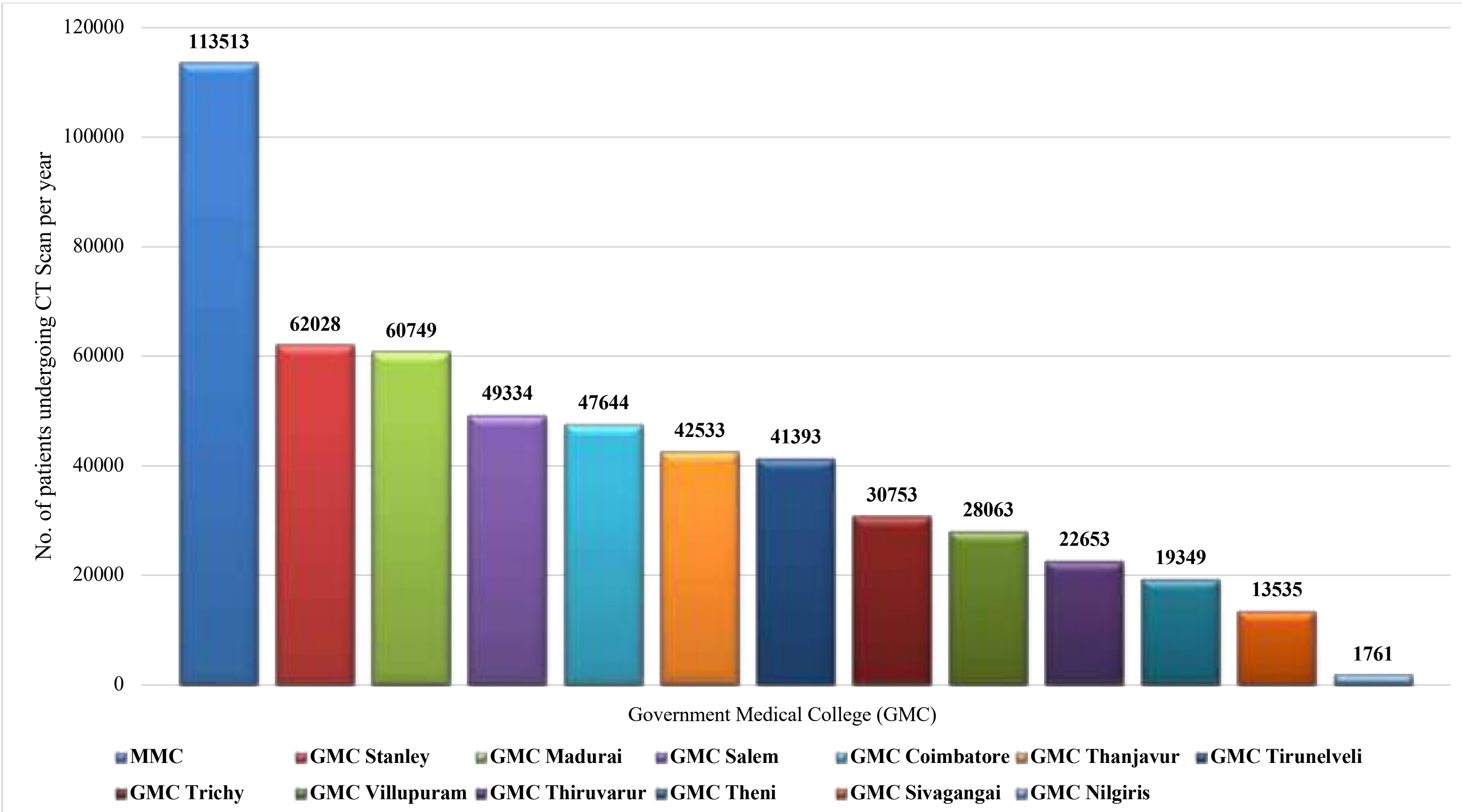


Figure 4E: Utilization of CT Scan services (in terms of absolute numbers) across Government Medical Colleges in Tamil Nadu in the year 2018

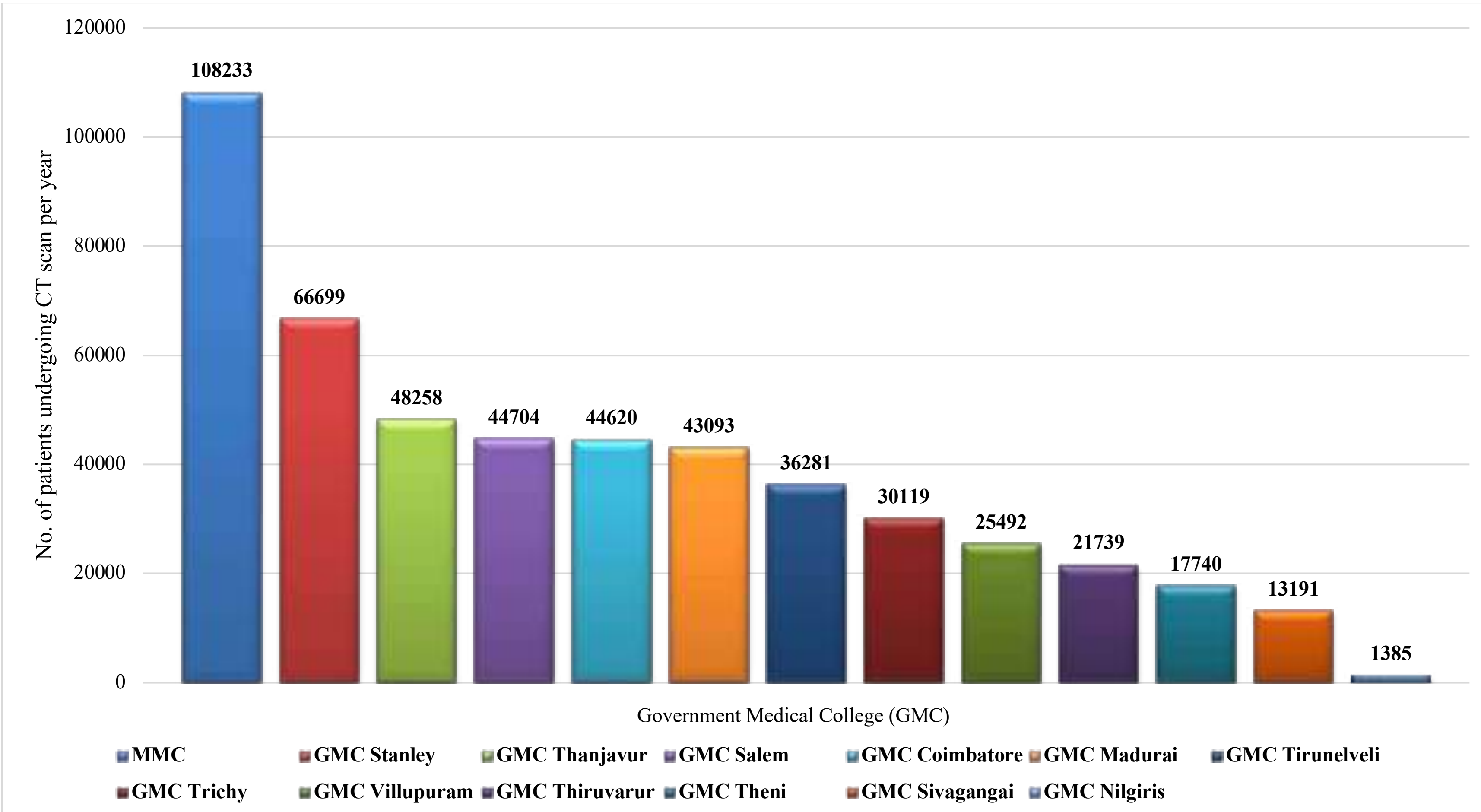


Figure 5A: Utilization of CT Scan services (in terms of rate per 100,000 OPD visits) across Government Medical Colleges in Tamil Nadu in the year 2022

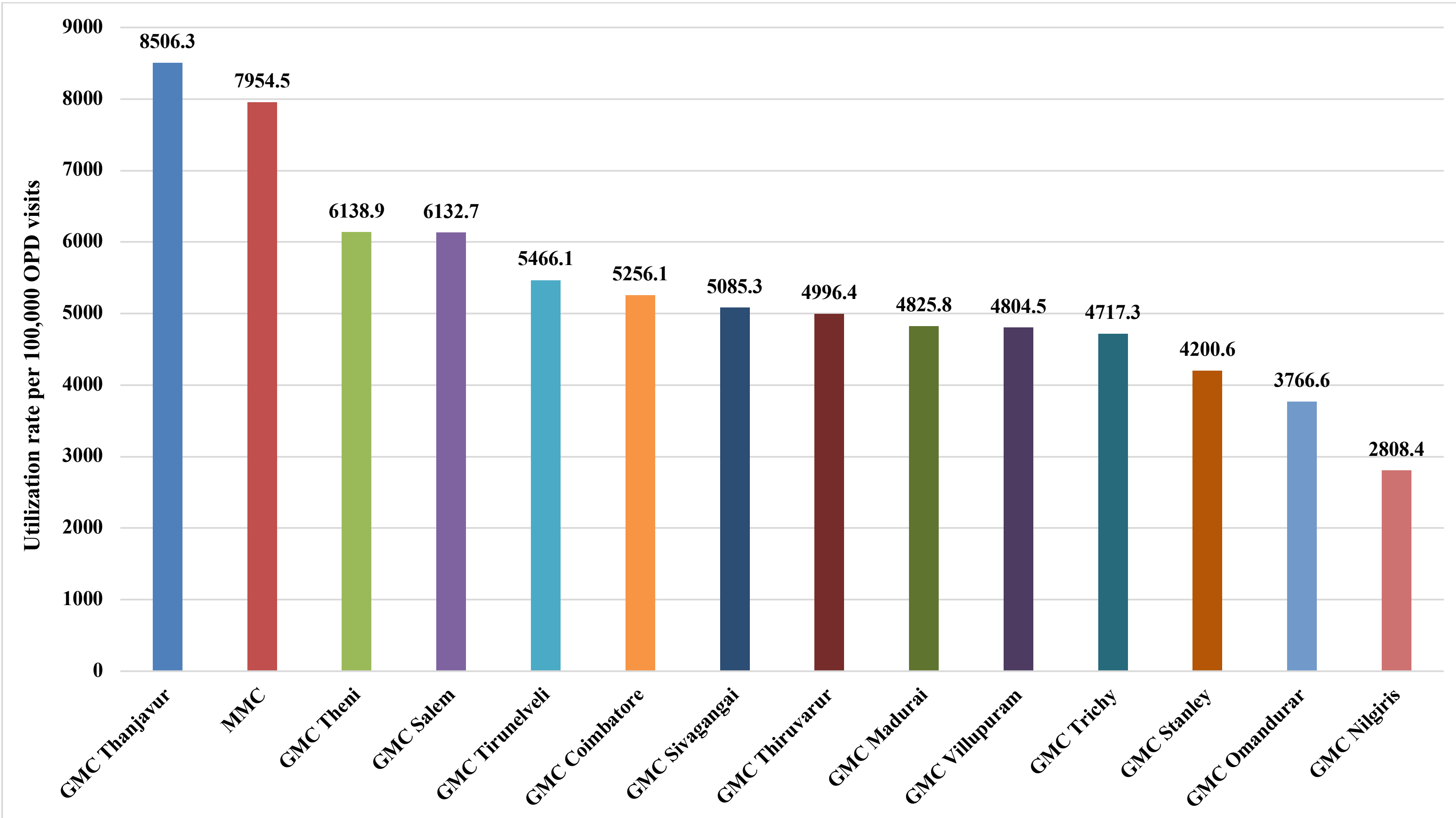


Figure 5B: Utilization of CT Scan services (in terms of rate per 100,000 OPD visits) across Government Medical Colleges in Tamil Nadu in the year 2021

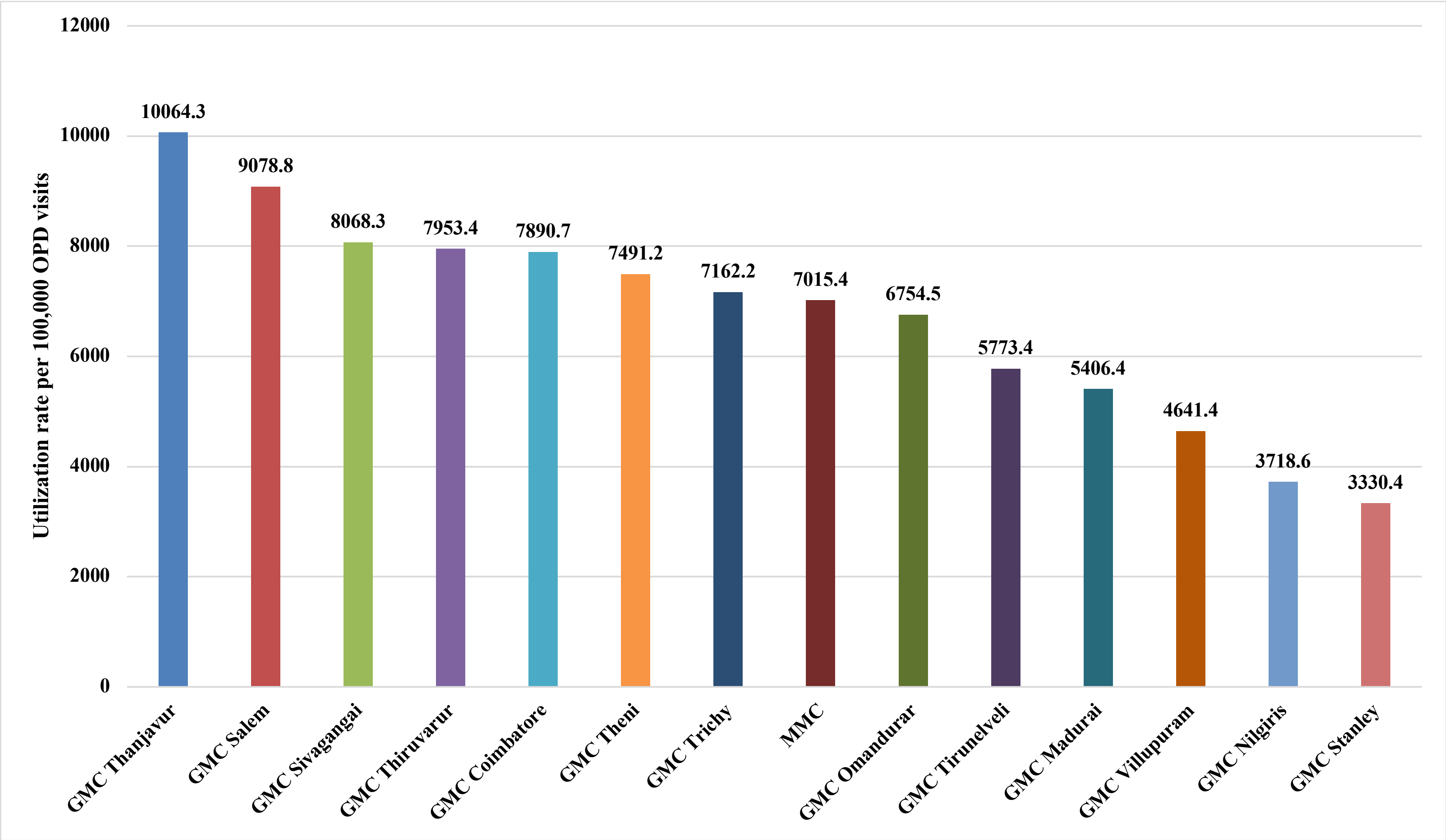


Figure 5C: Utilization of CT Scan services (in terms of rate per 100,000 OPD visits) across Government Medical Colleges in Tamil Nadu in the year 2020

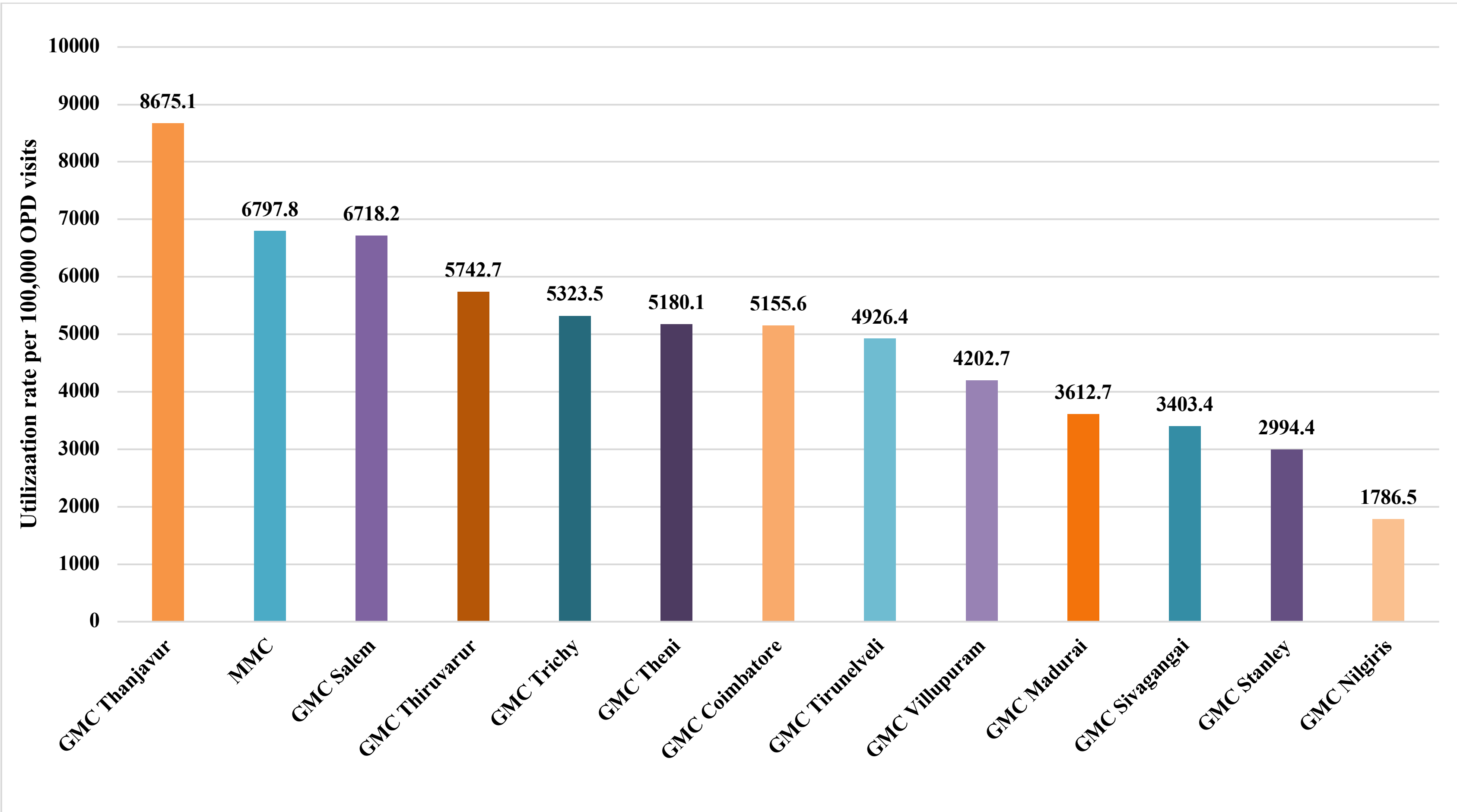


Figure 5D: Utilization of CT Scan services (in terms of rate per 100,000 OPD visits) across Government Medical Colleges in Tamil Nadu in the year 2019

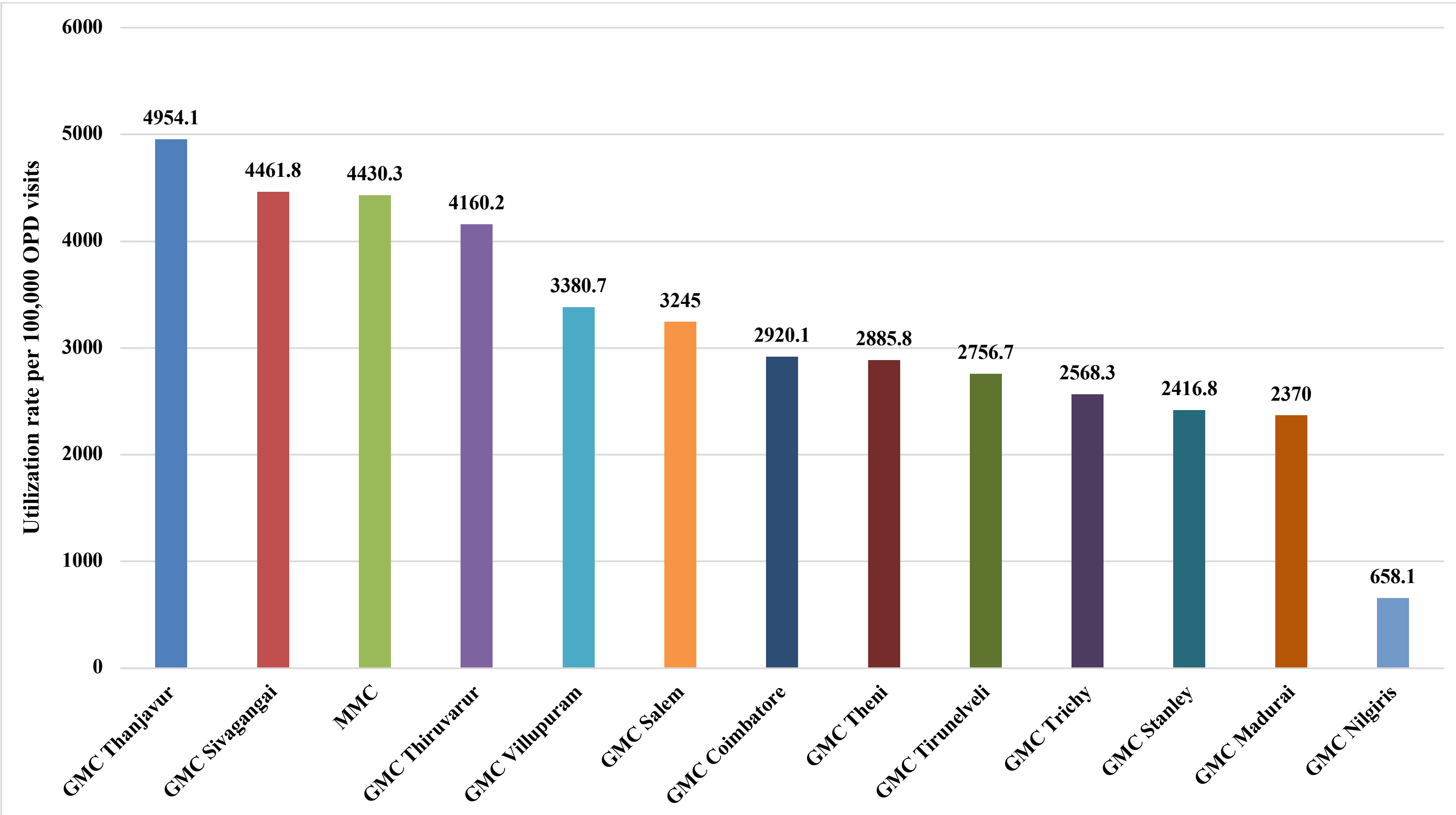
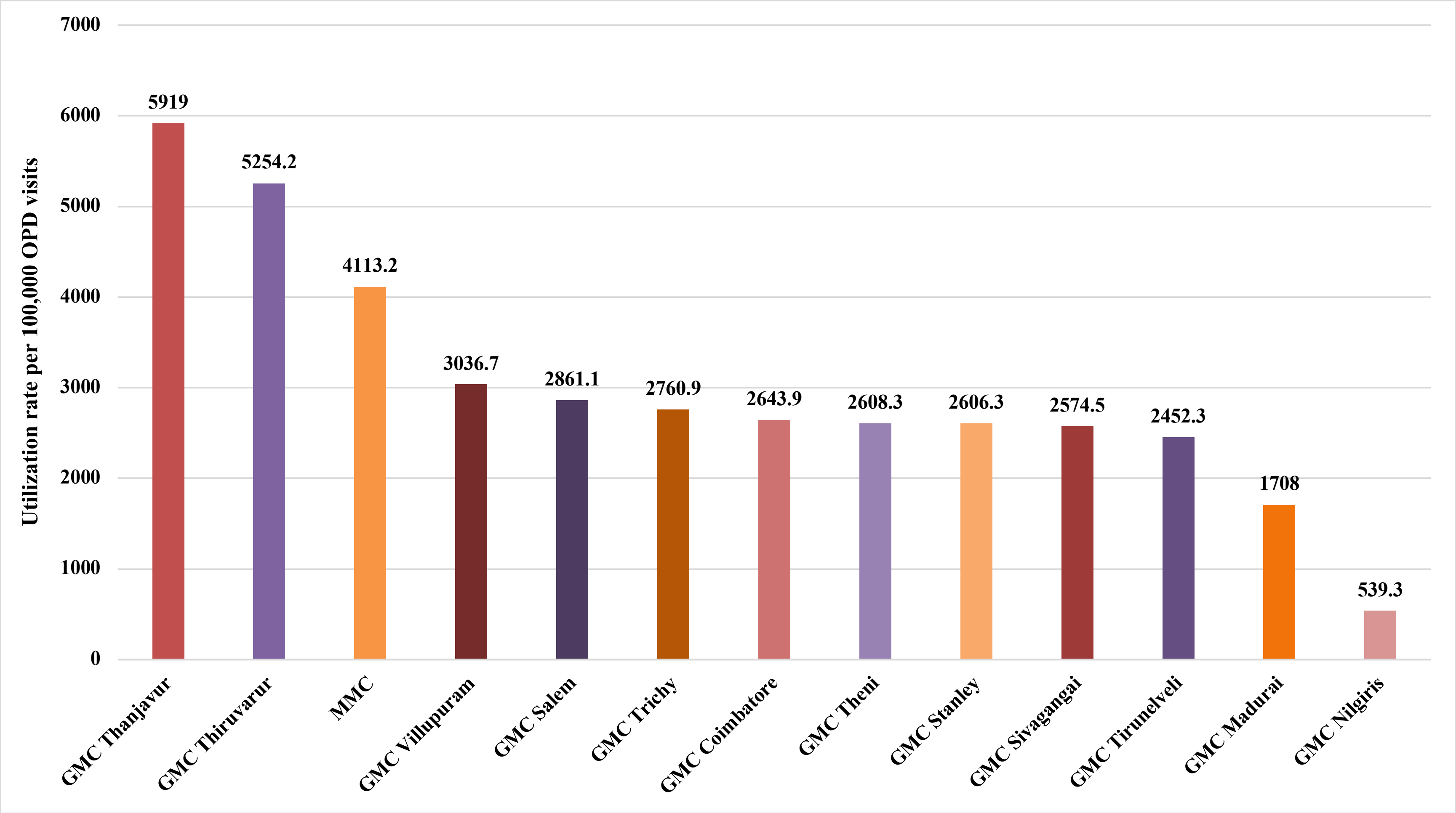


Figure 5E: Utilization of CT Scan services (in terms of rate per 100,000 OPD visits) across Government Medical Colleges in Tamil Nadu in the year 2018



Five-Year Trend in Utilization of CT Scan services across selected Government Hospitals in Tamil Nadu:

Figure 6A-6E depicts the Government Hospital-wise trend of CT scan utilization in terms of absolute numbers from 2018 to 2022.

Over the past five years, Government Hospital, Royapettah had the highest number of patients visiting the facility to utilize CT scan services. Government Hospital, Srirangam and Mettur had the next highest number of patients visiting the facility for CT scan services. However, there was recent spike in the number of patients undergoing CT scan in Government Hospital, Pattukottai. Government Hospitals in Coonoor (least over the past five years), Mellur and Karaikudi have consistently reported lesser number of patients visiting the facility for CT scan services.

Figure 7A-7E depicts the medical college-wise trend of CT scan utilization in terms of utilization per 100,000 OPD visits from 2018 to 2022. The utilization rate paints a different picture as Government Hospital, Srirangam had the highest utilization rate per 100,000 OPD visits throughout the last five years followed by Government Hospital, Royapettah. Government Hospital, Coonoor had the lowest utilization rate. However, the facilties having lowest utilization in terms of absolute numbers also had the lowest utilization rate.

Figure 6A: Utilization of CT Scan services (in terms of absolute numbers) across Government Hospitals in Tamil Nadu in the year 2022

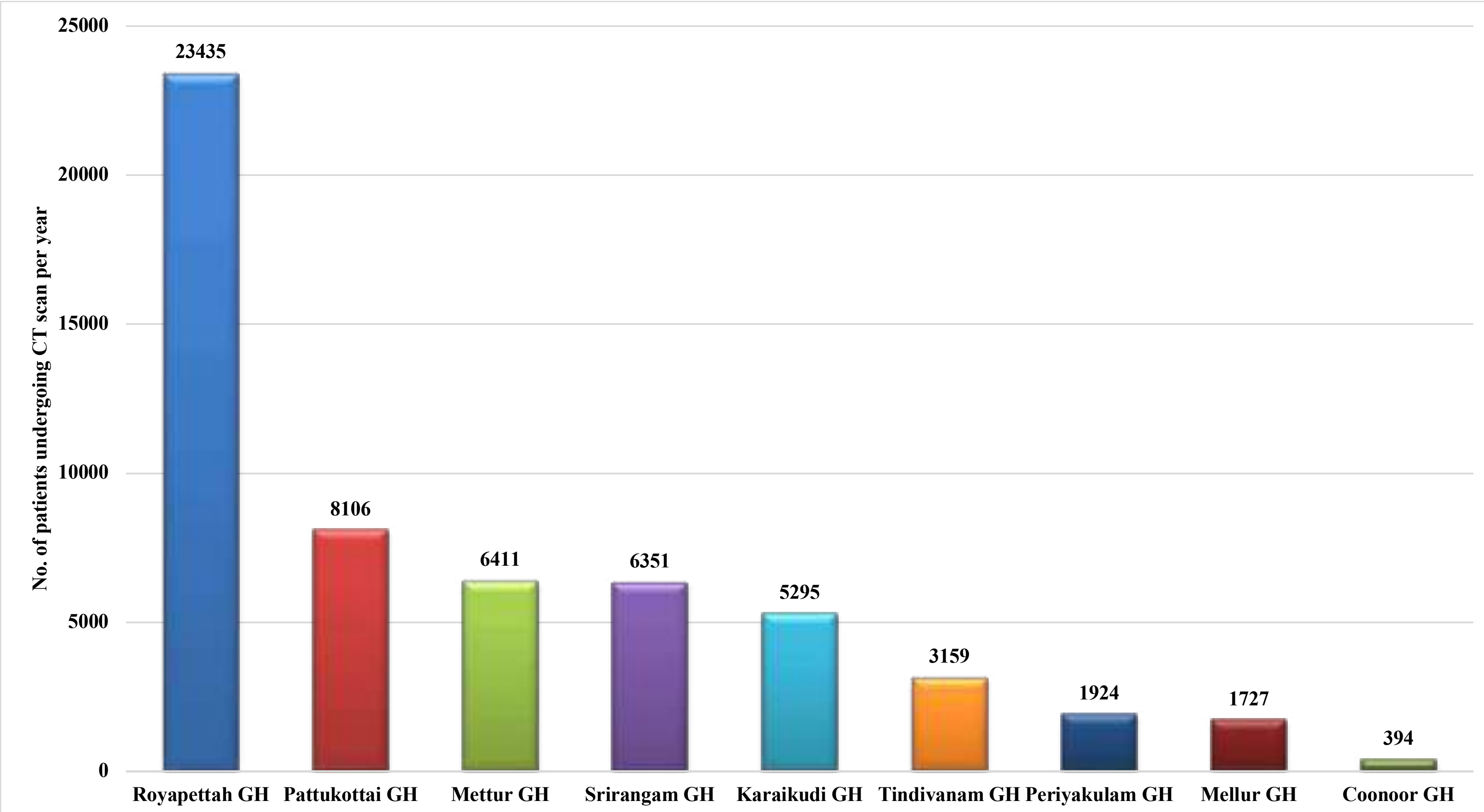


Figure 6B: Utilization of CT Scan services (in terms of absolute numbers) across Government Hospitals in Tamil Nadu in the year 2021

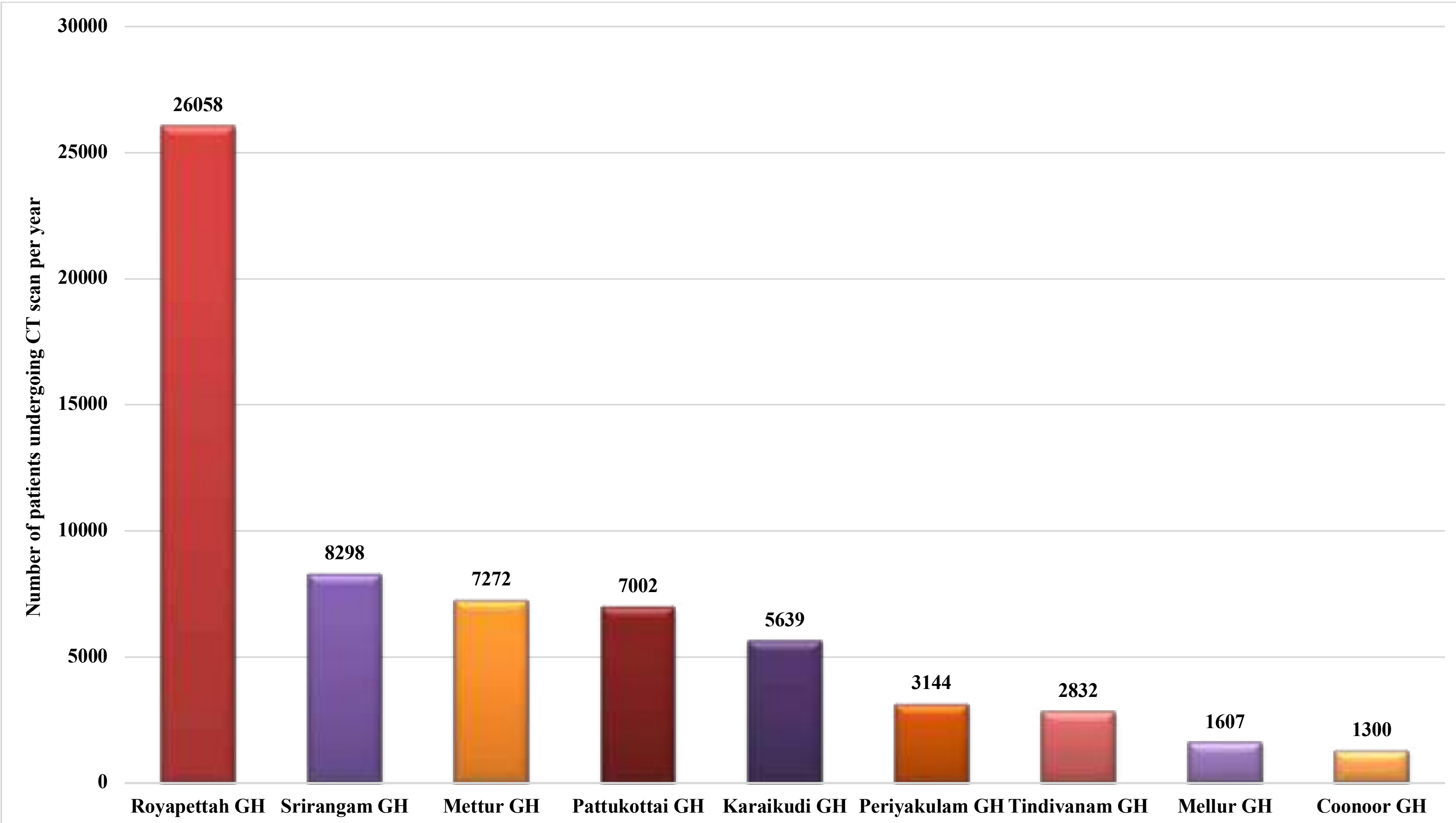


Figure 6C: Utilization of CT Scan services (in terms of absolute numbers) across Government Hospitals in Tamil Nadu in the year 2020

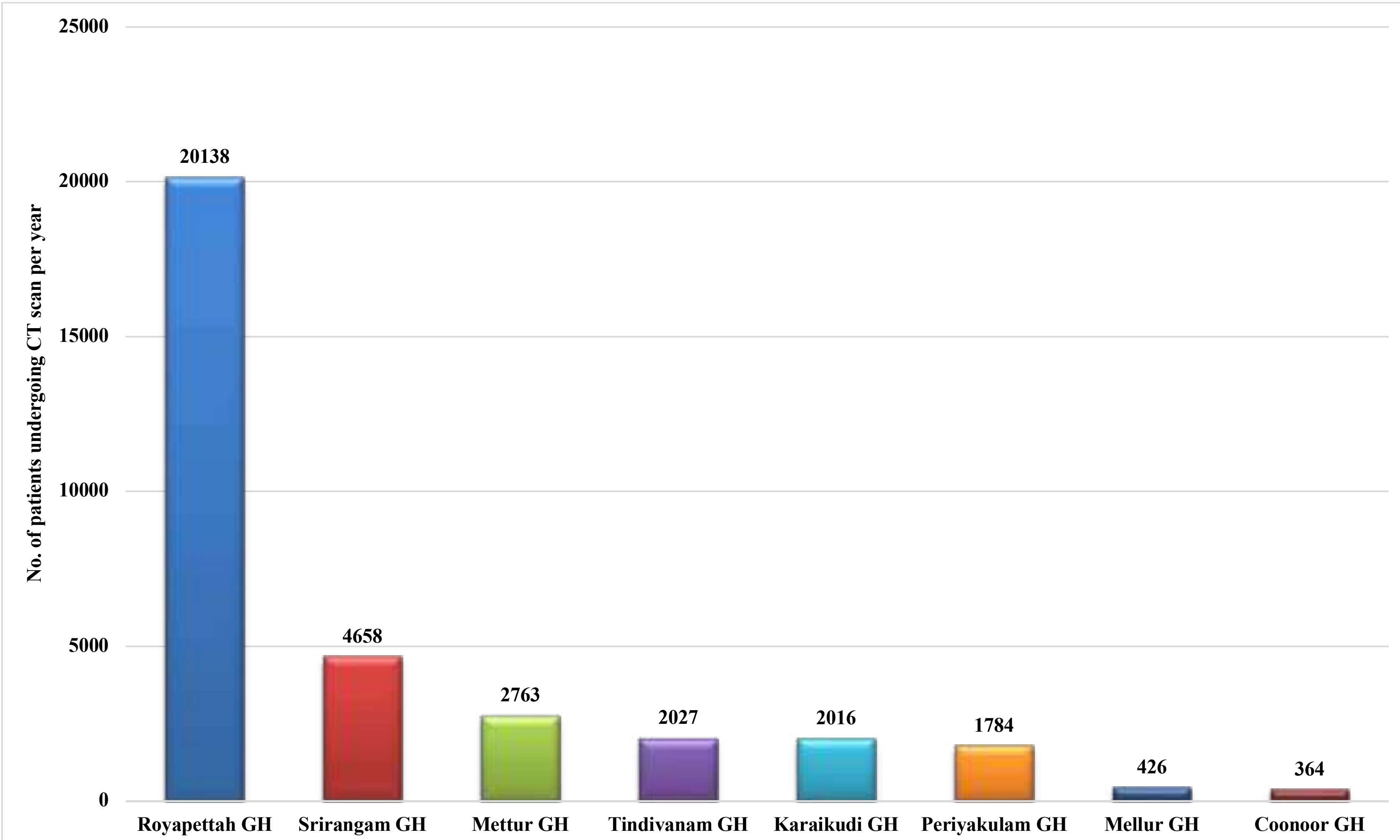


Figure 6D: Utilization of CT Scan services (in terms of absolute numbers) across Government Hospitals in Tamil Nadu in the year 2019

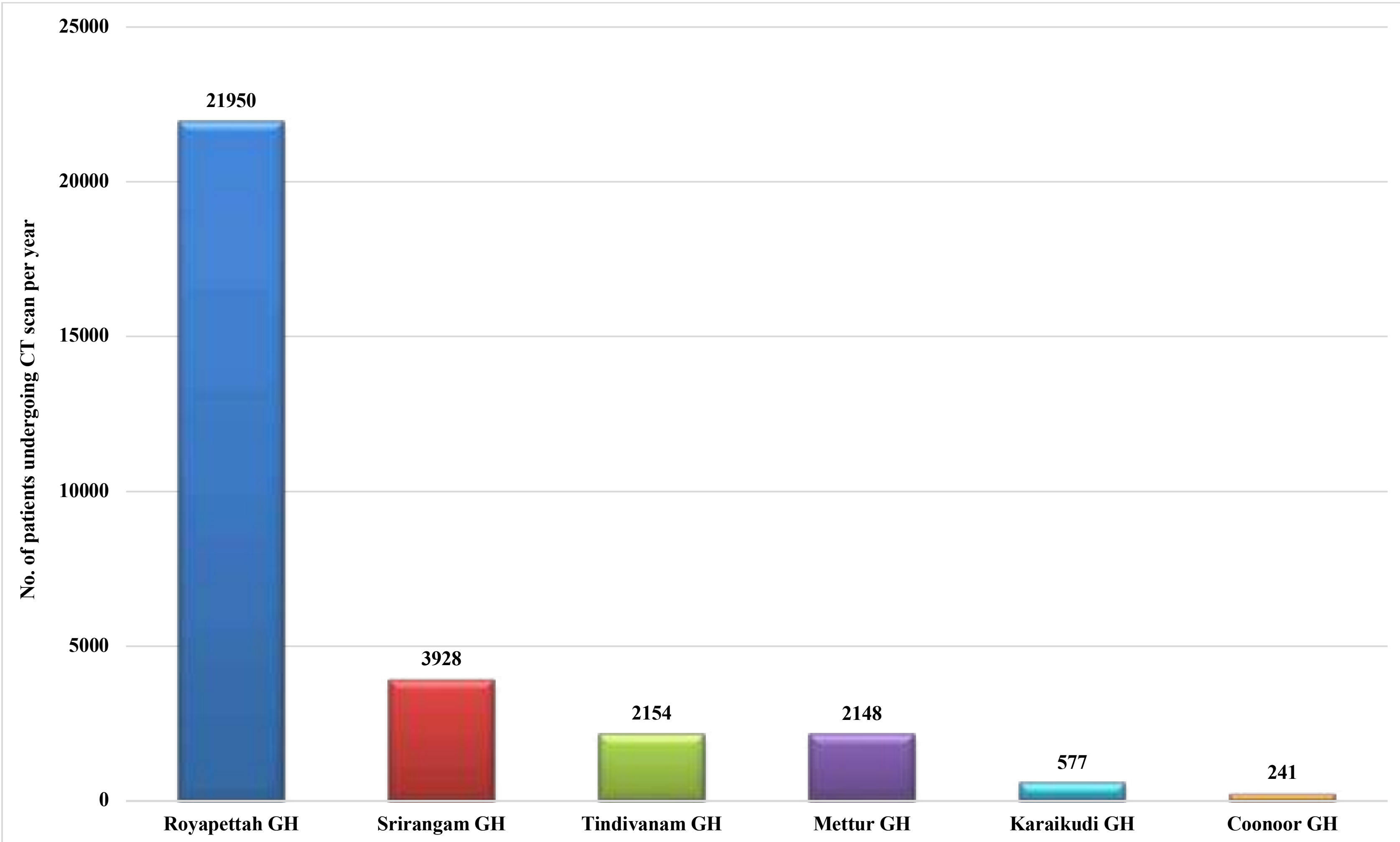


Figure 6E: Utilization of CT Scan services (in terms of absolute numbers) across Government Hospitals in Tamil Nadu in the year 2018

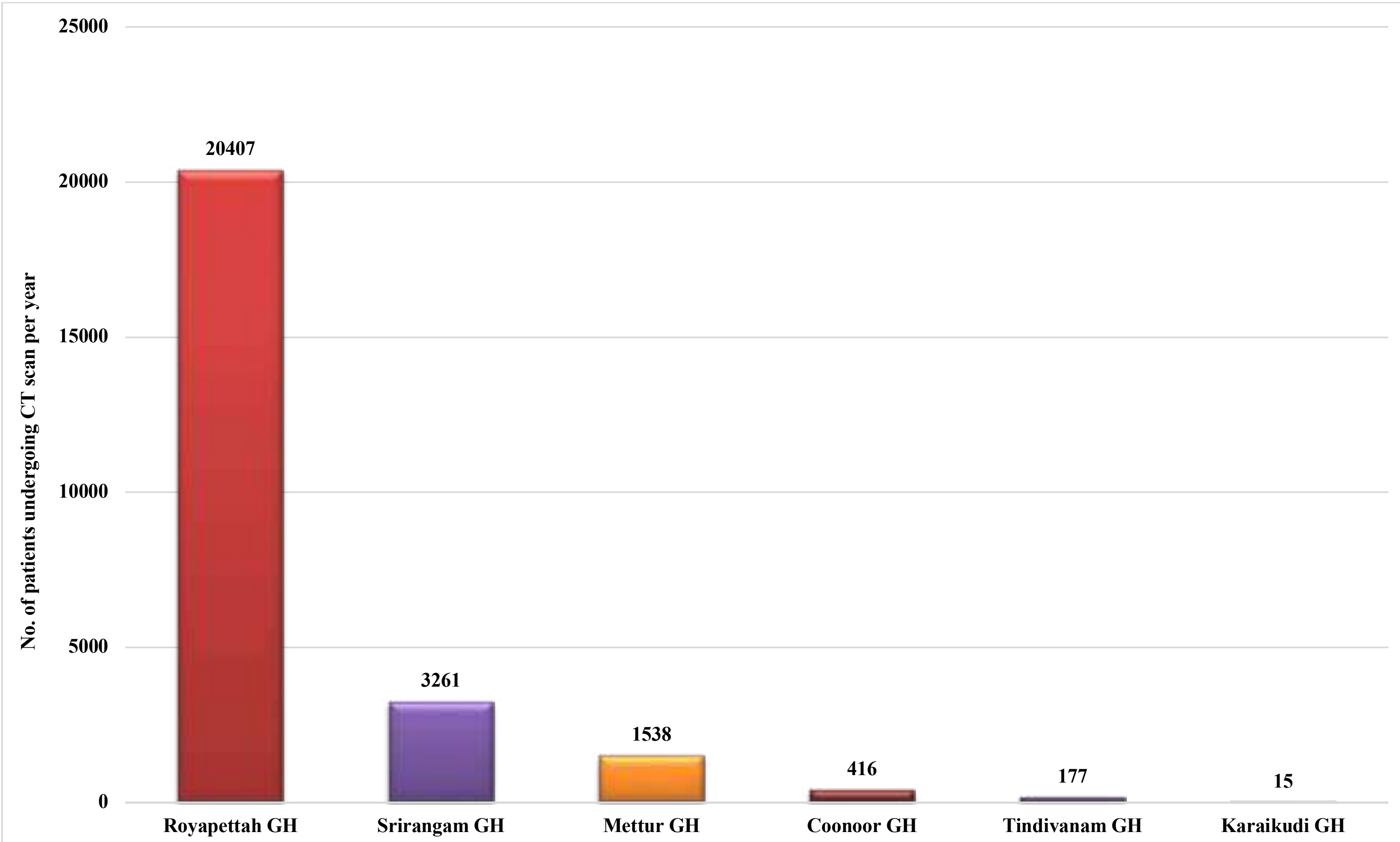


Figure 7A: Utilization of CT Scan services (in terms of rate per 100,000 OPD visits) across Government Hospitals in Tamil Nadu in the year 2022

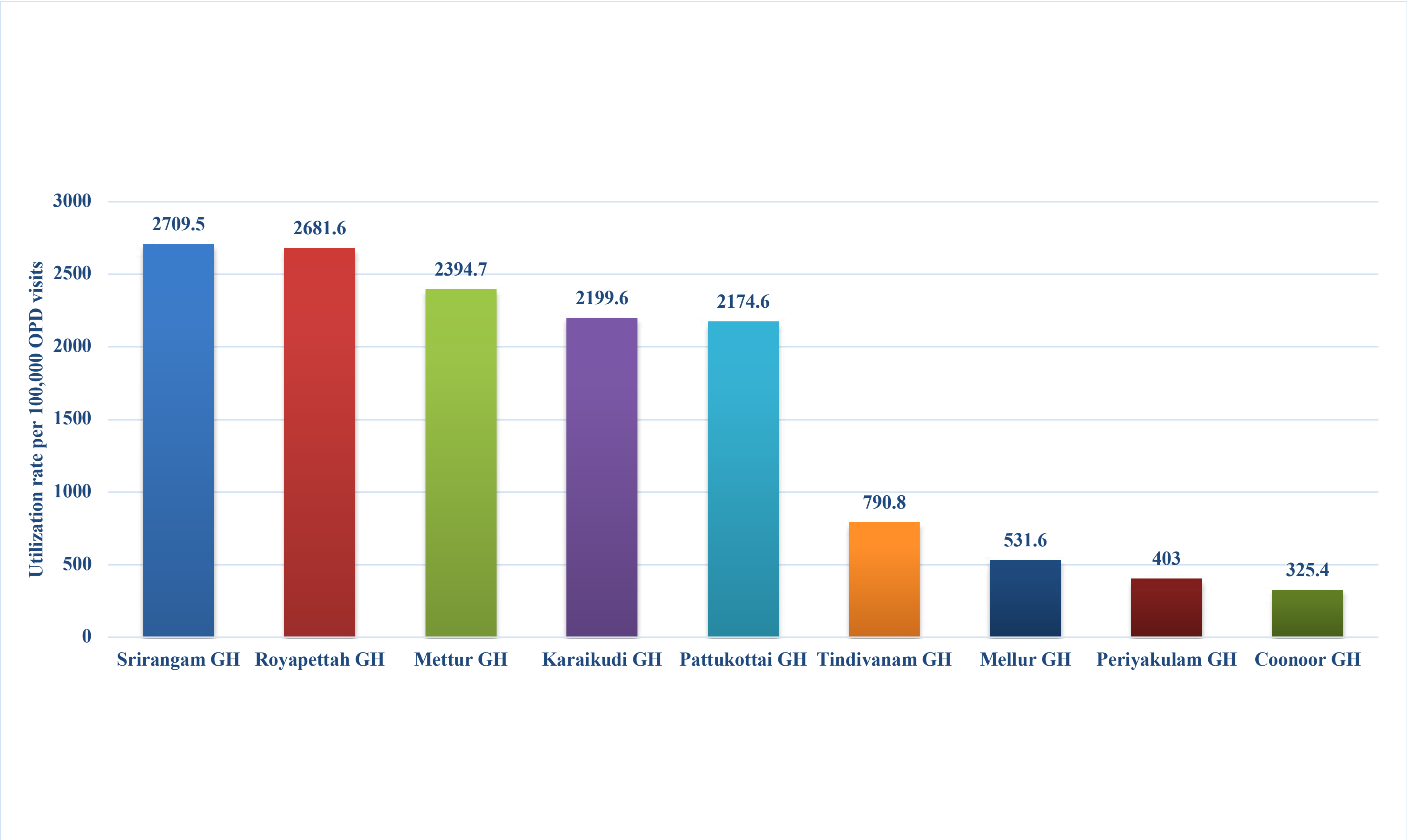


Figure 7B: Utilization of CT Scan services (in terms of rate per 100,000 OPD visits) across Government Hospitals in Tamil Nadu in the year 2021

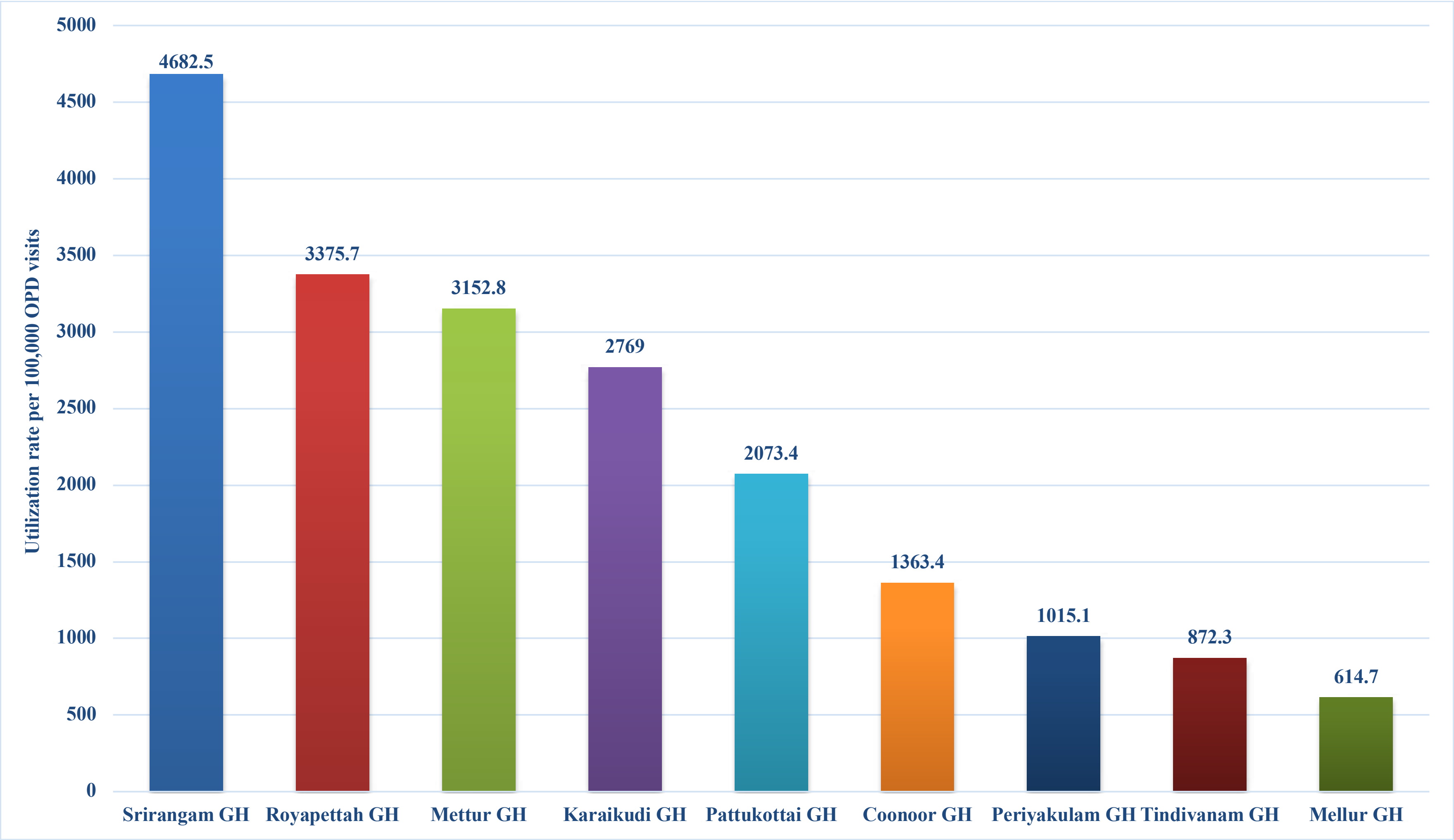


Figure 7C: Utilization of CT Scan services (in terms of rate per 100,000 OPD visits) across Government Hospitals in Tamil Nadu in the year 2020

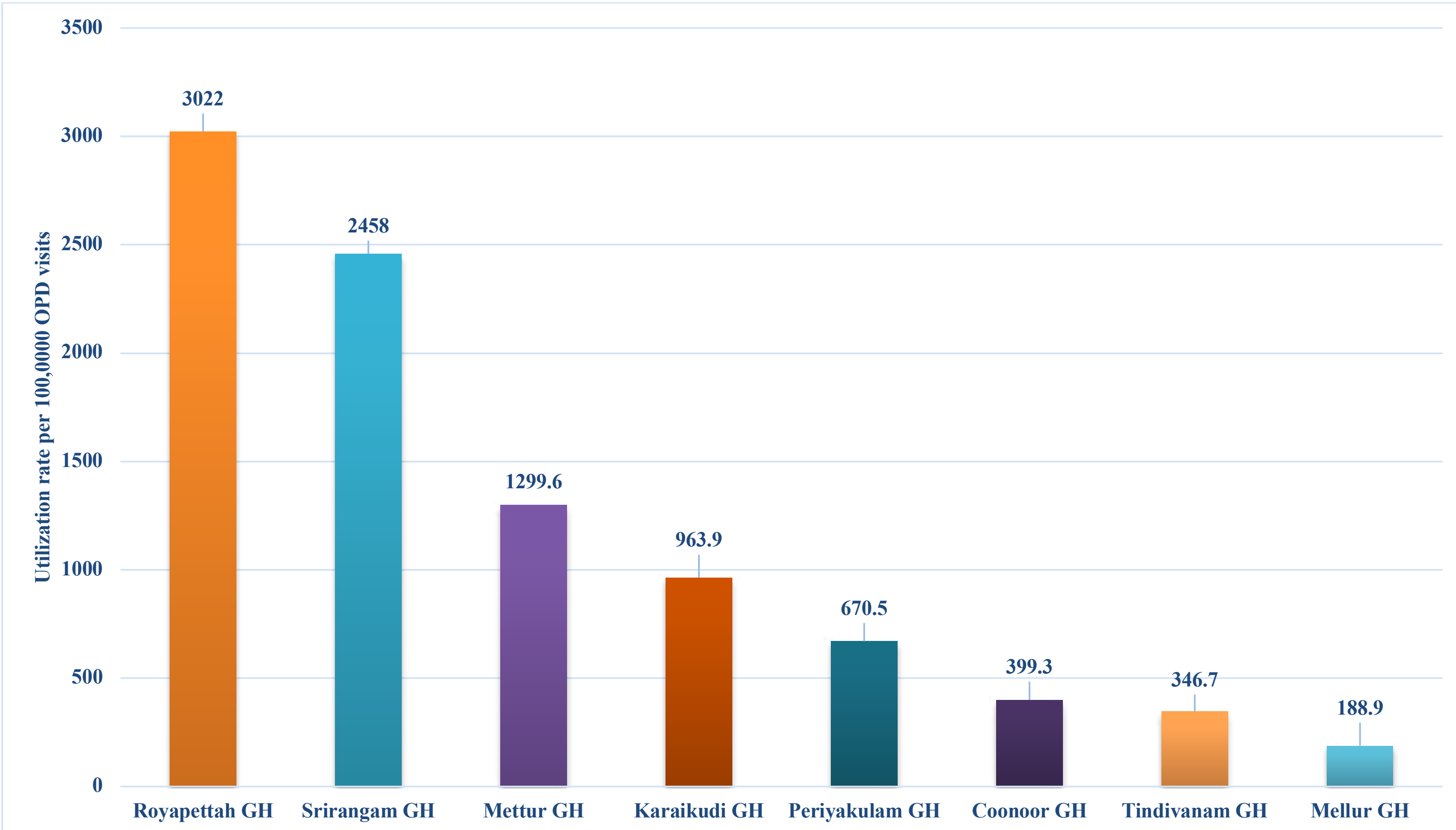


Figure 7D: Utilization of CT Scan services (in terms of rate per 100,000 OPD visits) across Government Hospitals in Tamil Nadu in the year 2019

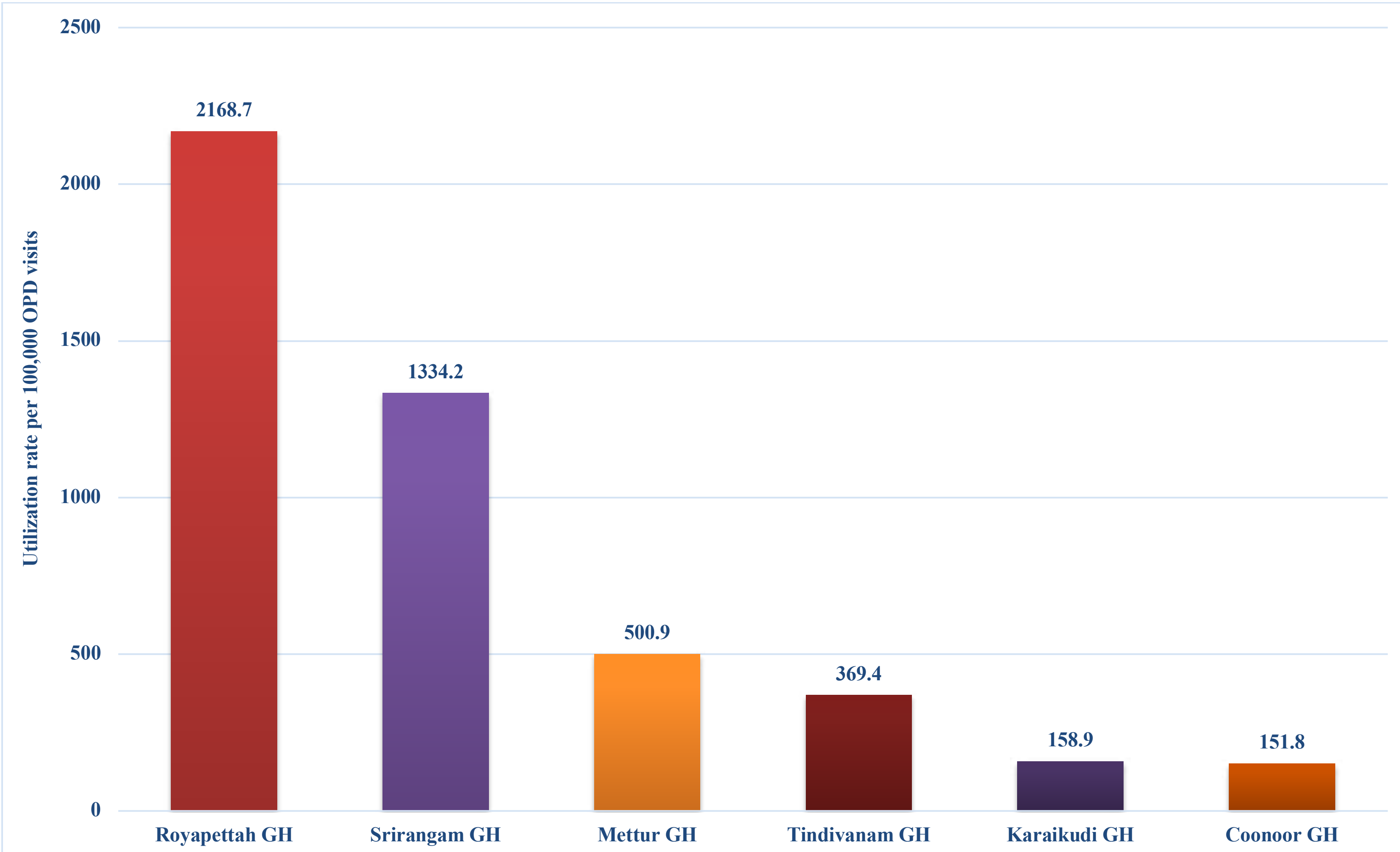
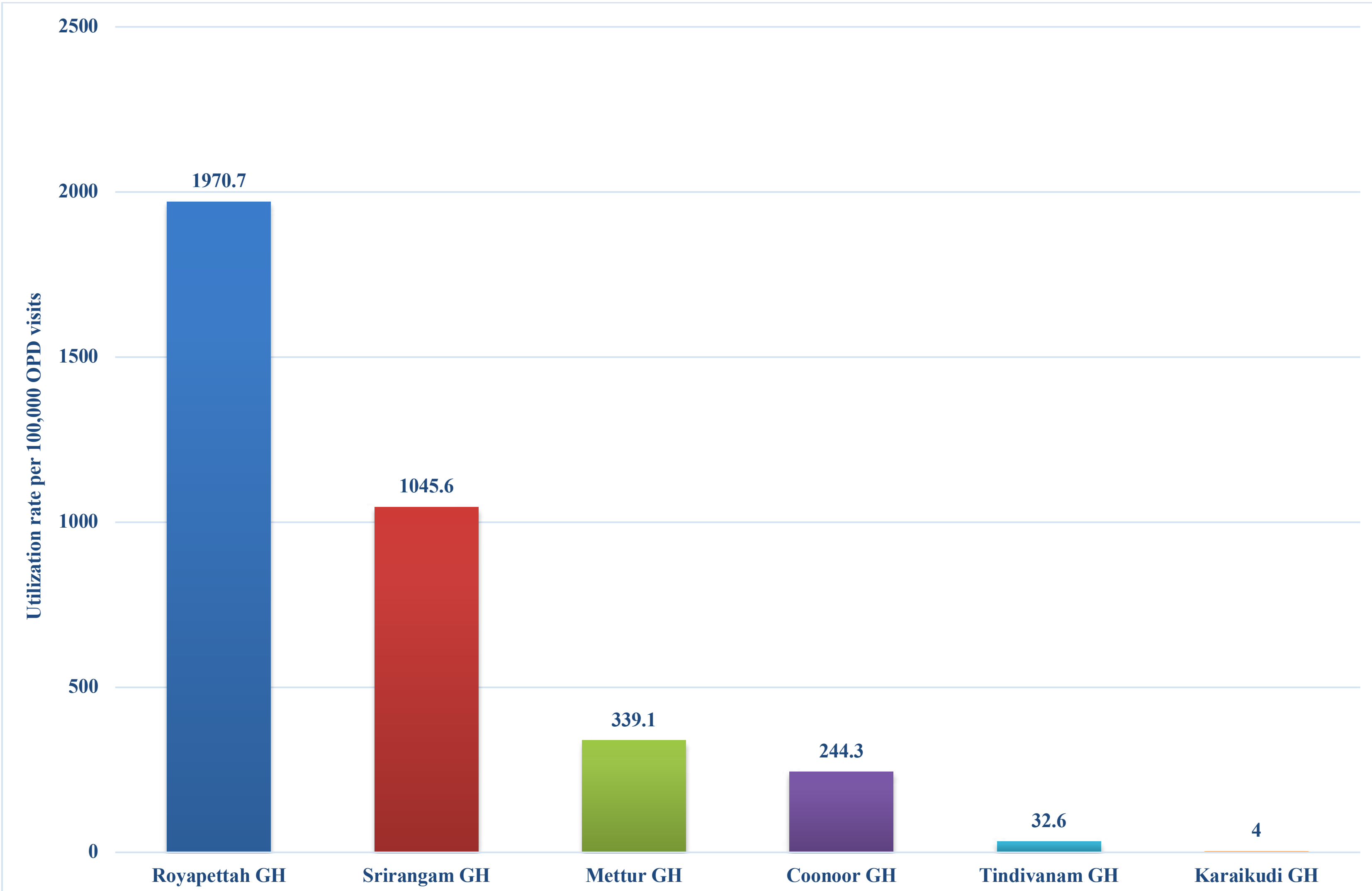


Figure 7E: Utilization of CT Scan services (in terms of rate per 100,000 OPD visits) across Government Hospitals in Tamil Nadu in the year 2018



Equipment Utilization - MRI Scan:

Rajiv Gandhi Government General Hospital (RGGGH):

Figure S43 and S44 depicts the year-wise trend of MRI scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Rajiv Gandhi Government General Hospital (RGGGH).

Figure S43 shows the number of patients undergoing MRI scans each year from 2017 to 2022. There is a steady declining trend in MRI utilization till 2020 (maximum dip in utilization seen in 2020) after which there has an upward trend in utilization. The maximum decline in the year 2020 could be attributed to the impact of the COVID-19 pandemic. However, the overall APC for this period is calculated at -0.20%, indicating a slight declining rate in utilization. The trend was not statistically significant ($p>0.05$).

Figure S44 shows the utilization rate of MRI scan services per 100,000 OPD visits from 2017 to 2022. The trend shows a significant increase, with the utilization rate growing from 541.2 in 2017 to 1352.7 in 2022. The APC for this timeframe is 16.13, but the trend was not statistically significant ($p>0.05$). The steady increase in utilization suggests a growing reliance on MRI scans relative to the number of OPD visits, possibly indicating wider availability, increased demand, or changes in diagnostic practices.

Government Stanley Medical College Hospital:

Figure S45 and S46 depicts the year-wise trend of MRI scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Stanley Medical College Hospital.

Figure S45 shows that there is no upward or downward trend from 2017 to 2019 in number of patients undergoing MRI scan. However, at 2020, similar to RGGGH, there was a noticeable decline in the utilization due to COVID-19 pandemic. After 2020, there has been a rapid increase in the number of patients undergoing MRI scan in this facility. The overall APC was 6.09% and it was statistically significant ($p<0.05$).

Figure S46 shows that there was a consistent increasing trend in terms of utilization rate of MRI scan services per 100,000 OPD visits from 2017 to 2022. The trend shows a significant increase, with the utilization rate growing from 269.9 in 2017 to 603.9 in 2022. The APC for this timeframe is 17.34, and this trend was statistically significant ($p<0.05$).

Government Medical College, Omandurar: Utilization data was not available for this facility and hence, the trend analysis could not be performed.

Government Royapettah Hospital:

Figure S47 and S48 depicts the year-wise trend of MRI scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Royapettah Hospital. Figure S47 shows that there was a consistent increasing trend in the number of patients undergoing MRI scan services in their facility. However, at 2020, similar to other facilities in Chennai, there was a noticeable decline in the utilization due to COVID-19 pandemic. After 2020, there has again been a rapid increase in the number of patients undergoing MRI scan in this facility.

The overall APC was 5.24% and it was statistically significant ($p<0.05$). Figure S48 shows that there was a consistent increasing trend throughout the last five years in terms of utilization rate of MRI scan services per 100,000 OPD visits. The trend shows a significant increase, with the utilization rate growing from 288.9 in 2017 to 466.9 in 2022. The APC for this timeframe is 10.57%, and this trend was statistically significant ($p<0.05$).

Coimbatore Medical College Hospital:

Figure S49 and S50 depicts the year-wise trend of MRI scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Coimbatore Medical College Hospital. Figure 32A shows that there was a consistent increasing trend except, at 2020 (noticeable decline due to COVID-19 pandemic). After 2020, there has again been a rapid increase in the number of patients undergoing MRI scan in this facility.

The overall APC was 5.07% and it was statistically significant ($p<0.05$). Figure 32B shows that there was a consistent increasing trend throughout the last ten years in terms of utilization rate of MRI scan services per 100,000 OPD visits. The trend shows a significant increase, with the utilization rate growing from 190.4 in 2013 to 611.1 in 2021. However, in 2022, there has been a slight dip in the utilization to 586.3 per 100,000 OPD visits. The APC for this timeframe is 13.84%, and this trend was statistically significant ($p<0.05$).

Madurai Medical College Hospital:

Figure S51 and S52 depicts the year-wise trend of MRI scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Madurai Medical College Hospital.

Figure S51 shows that there was no clear direction of trend (as there was alternate increasing and declining trend) during the initial years from 2015 to 2020. At 2020, there was a joinpoint (i.e, statistically significant change in trend), a noticeable decline in the utilization happened due to COVID-19 pandemic similar to the facilities in Chennai and Coimbatore. After 2020, there has again been a rapid increase in the number of patients undergoing MRI scan in this facility. The overall AAPC was 9.78%, but it was not statistically significant ($p>0.05$).

Figure S52 shows that there was a consistent increasing trend throughout the last ten years in terms of utilization rate of MRI scan services per 100,000 OPD visits. The trend shows a significant increase, with the utilization rate growing from 199.8 in 2013 to 636.7 in 2022. The AAPC for this timeframe is 19.43%, and this trend was statistically significant ($p<0.05$).

Government Tirunelveli Medical College and Hospital:

Figure S53 and S54 depicts the year-wise trend of MRI scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Tirunelveli Medical College and Hospital.

Figure S53 shows that there was no clear direction of trend (as there was alternate increasing and declining trend) with maximum dip seen in 2018 and 2020. At 2020, there was a joinpoint (i.e, statistically significant change in trend), a noticeable decline in the utilization happened due to COVID-19 pandemic similar to the facilities in Chennai, Coimbatore and Madurai.

After 2020, there has again been a rapid increase in the number of patients undergoing MRI scan in this facility. The APC for period between 2020 and 2022 was 30.90%, showing a substantial increase in the utilization of MRI scan services in 2021 and 2022. The overall AAPC was 9.52%, but it was not statistically significant ($p>0.05$).

Figure S54 shows that there was a consistent increasing trend with a sudden dip in the year 2018 in terms of utilization rate of MRI scan services per 100,000 OPD visits. The trend shows a substantial increase, with the utilization rate growing from 277.1 in 2014 to 760.2 in 2022. The AAPC for this timeframe is 13.72%, but this trend was not statistically significant ($p>0.05$).

KAP Vishwanathan Government Medical College and Hospital, Trichy:

Figure S55 and S56 depicts the year-wise trend of MRI scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at KAP Vishwanathan Government Medical College and Hospital, Trichy. Figure S55 shows that there was no clear direction of trend (as there was alternate increasing and declining trend) with maximum dip seen in 2018 and 2020, similar to Tirunelveli Medical College. After 2020, there has again been a rapid increase in the number of patients undergoing MRI scan in this facility. The overall AAPC was 9.32%, but it was not statistically significant (p>0.05). Figure S56 shows that there was a consistent increasing trend after 2018 in terms of utilization rate of MRI scan services per 100,000 OPD visits. The trend shows a substantial increase, with the utilization rate growing from 267.2 in 2018 to 662.5 in 2022. The APC from 2017 to 2022 is 15.83%, but this trend was not statistically significant (p>0.05).

Government Medical College Hospital, Thanjavur:

Figure S57 and S58 depicts the year-wise trend of MRI scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Medical College Hospital, Thanjavur. Figure S57 shows that there was alternate increasing and declining trend with dip seen in 2018 and huge drop in utilization in 2020 (2801 in 2019 to 30 in 2020). After 2020, utilization was slightly increased to 979 in 2021 and then raised substantially to 5585 in 2022. The timeline of such a drastic change in trend aligns with the first and second wave of COVID-19 pandemic. The possible reason for such finding could be that the MRI equipment might be non-functional or non-operational during this period and then started after the second wave of COVID-19 pandemic. The APC was -8.30%, but it was not statistically significant (p>0.05).

Figure S58 also shows similar trend in terms of utilization rate per 100,000 OPD visits. The trend shows a substantial increase, with the utilization rate growing from 138.3 in 2013 to 615.7 in 2022. However, the APC from 2013 to 2022 showed a decline rate of about -2.52%, attributed to the drastic drop in utilization in 2020 and 2021. But this trend was not statistically significant (p>0.05).

Government Mohan Kumaramangalam Medical College and Hospital, Salem:

Figure S59 and S60 depicts the year-wise trend of MRI scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Mohan Kumaramangalam Medical College and Hospital, Salem. Figure S59 shows that there was consistent increasing trend with dip seen in 2020 owing to the COVID-19 pandemic. The APC was 4.64%, but it was not statistically significant (p>0.05). Figure S60 also shows similar trend in terms of utilization rate per 100,000 OPD visits. The trend shows a substantial increase, with the utilization rate growing from 231.3 in 2013 to 713.2 in 2022. The APC was 11.90% and trend was statistically significant (p<0.05).

Government Sivagangai Medical College and Hospital:

Figure S61 and S62 depicts the year-wise trend of MRI scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Sivagangai Medical College and Hospital. Figure S61 showed that there was consistent increasing trend with dip seen in 2020 owing to the COVID-19 pandemic. The overall AAPC for number of patients utilizing MRI scan was 33.02%, but it was not statistically significant (p>0.05). Figure S62 also shows similar trend in terms of utilization rate per 100,000 OPD visits. The trend shows a substantial increase, with the utilization rate growing from 128.4 in 2013 to 1215.1 in 2021. The overall AAPC was 34.89% and this trend was not statistically significant (p>0.05).

Government Villupuram Medical College and Hospital:

Figure S63 and S64 depicts the year-wise trend of MRI scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Villupuram Medical College and Hospital.

Figure 39A shows that there was consistent increasing trend with dip seen in 2020 owing to the COVID-19 pandemic. The APC was 10.42%, and it was statistically significant ($p<0.05$). Figure 39B also shows similar trend in terms of utilization rate per 100,000 OPD visits. The trend shows a substantial increase, with the utilization rate growing from 205.0 in 2017 to 460.9 in 2022. The overall APC was 15.80% and this trend was statistically significant ($p<0.05$).

Government Theni Medical College and Hospital:

Figure S65 and S66 depicts the year-wise trend of MRI scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Theni Medical College and Hospital.

Figure 40A showed that there was consistent increasing trend with dip seen in 2020 owing to the COVID-19 pandemic. The overall APC for number of patients utilizing MRI scan was 20.80%, but it was not statistically significant ($p>0.05$). Figure 40B also shows similar trend in terms of utilization rate per 100,000 OPD visits. The trend shows a substantial increase, with the utilization rate growing from 476.4 in 2017 to 2446.6 in 2022. The overall AAPC was 27.21% and this trend was not statistically significant ($p>0.05$).

Government Medical College, Nilgiris:

Figure S67 and S68 depicts the year-wise trend of MRI scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Medical College, Nilgiris.

Figure S67 shows that there was consistent increasing trend with dip seen in 2020 owing to the COVID-19 pandemic. The APC was 28.94%, but it was not statistically significant ($p>0.05$). Figure S68 also shows similar trend in terms of utilization rate per 100,000 OPD visits. The trend shows a substantial increase, with the utilization rate growing from 185.8 in 2016 to 1333.2 in 2022. The overall AAPC was 33.21% and this trend was not statistically significant ($p>0.05$).

Government Thiruvarur Medical College:

Figure S69 and S70 depicts the year-wise trend of MRI scan utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Thiruvarur Medical College.

Figure S69 showed that there was consistent increasing trend with the overall APC for number of patients utilizing MRI scan was 62.03%, and it was statistically significant ($p<0.05$). Figure S70 also shows similar trend in terms of utilization rate per 100,000 OPD visits. The trend shows a substantial increase, with the utilization rate growing from 268.3 in 2019 to 1012.6 in 2022. The overall APC was 52.46% and this trend was statistically significant ($p<0.05$).

Five-Year Trend in Utilization of MRI Scan services across selected secondary and tertiary care facilities in Tamil Nadu:

Figure 8A-8E depicts the institute-wise trend of MRI scan utilization in terms of absolute numbers from 2018 to 2022.

Over the past five years, Rajiv Gandhi General Government Hospital (RGGGH) had the highest number of patients visiting the facility to utilize MRI scan services compared to other facilities. Government Stanley Medical College and Hospital and Government Theni Medical College and Hospital had the next highest number of patients visiting the facility for MRI scan services. Government Medical College, Nilgiris and Government Medical College, Thiruvarur and Government Villupuram Medical College Hospital have consistently reported lesser number of patients visiting the facility for MRI scan services compared to other facilities.

Figure 9A-9E depicts the institute-wise trend of MRI scan utilization in terms of utilization per 100,000 OPD visits from 2018 to 2022.

The utilization rate paints a different picture as Government Theni Medical College had the highest utilization rate per 100,000 OPD visits throughout the last five years. Government Medical College, Nilgiris and Government Medical College, Thiruvarur had the next highest utilization rate (though their absolute numbers are lesser than rest of the facilities). This shows that the utilization rate is higher in these facilities relative to the OPD load of the facility.

Figure 8A: Utilization of MRI Scan services (in terms of absolute numbers) across secondary and tertiary care facilities in Tamil Nadu in the year 2022

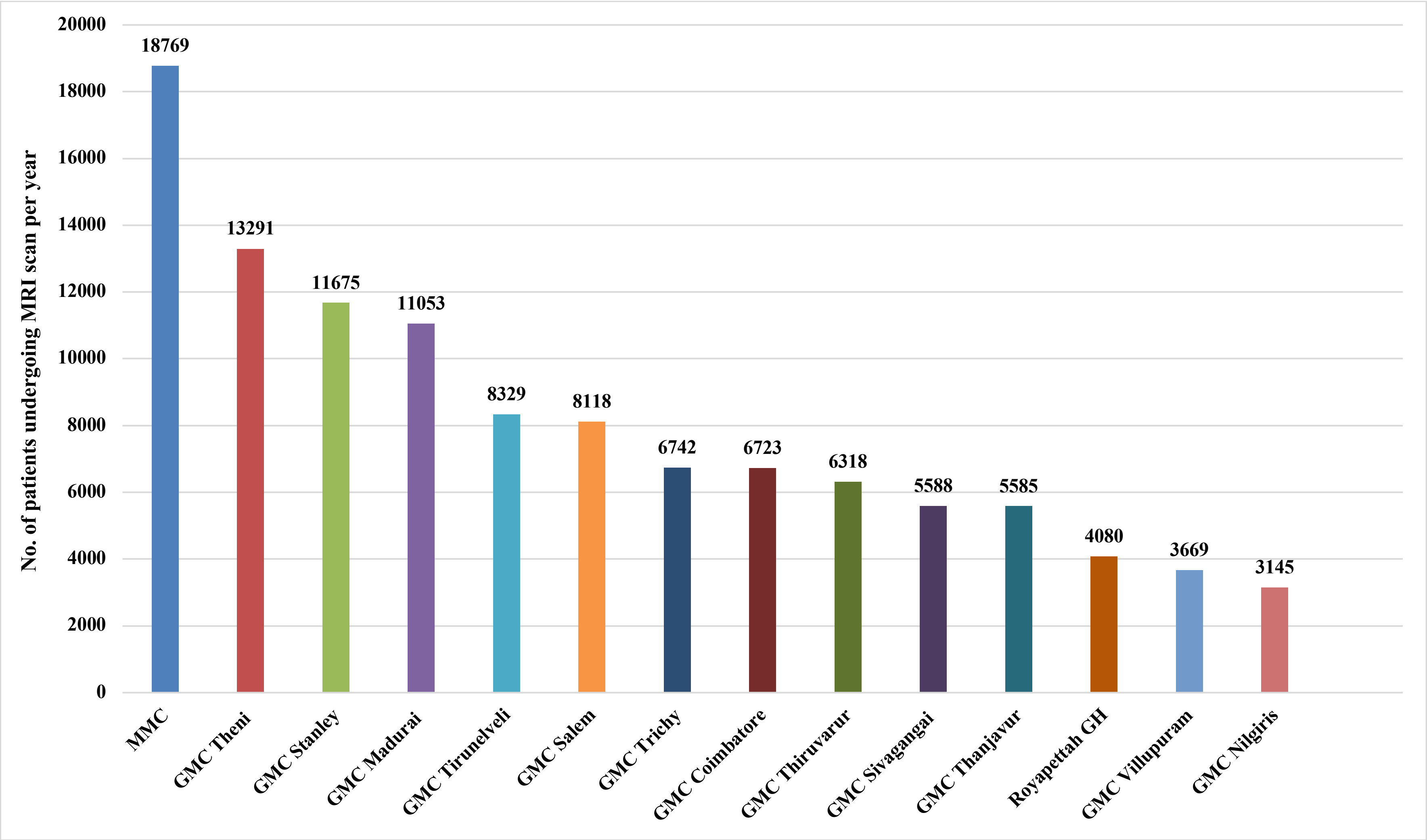


Figure 8B: Utilization of MRI Scan services (in terms of absolute numbers) across secondary and tertiary care facilities in Tamil Nadu in the year 2021

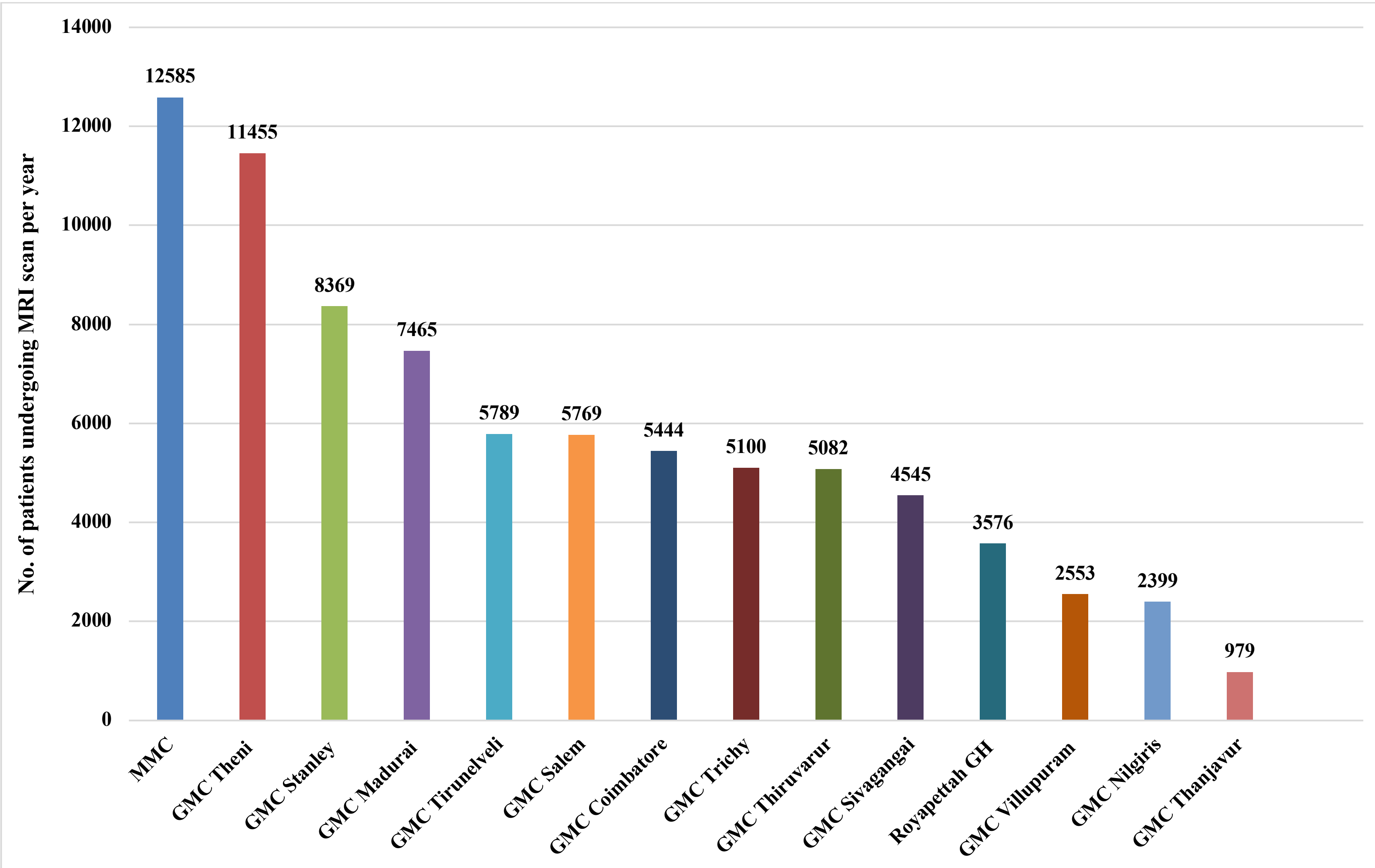


Figure 8C: Utilization of MRI Scan services (in terms of absolute numbers) across secondary and tertiary care facilities in Tamil Nadu in the year 2020

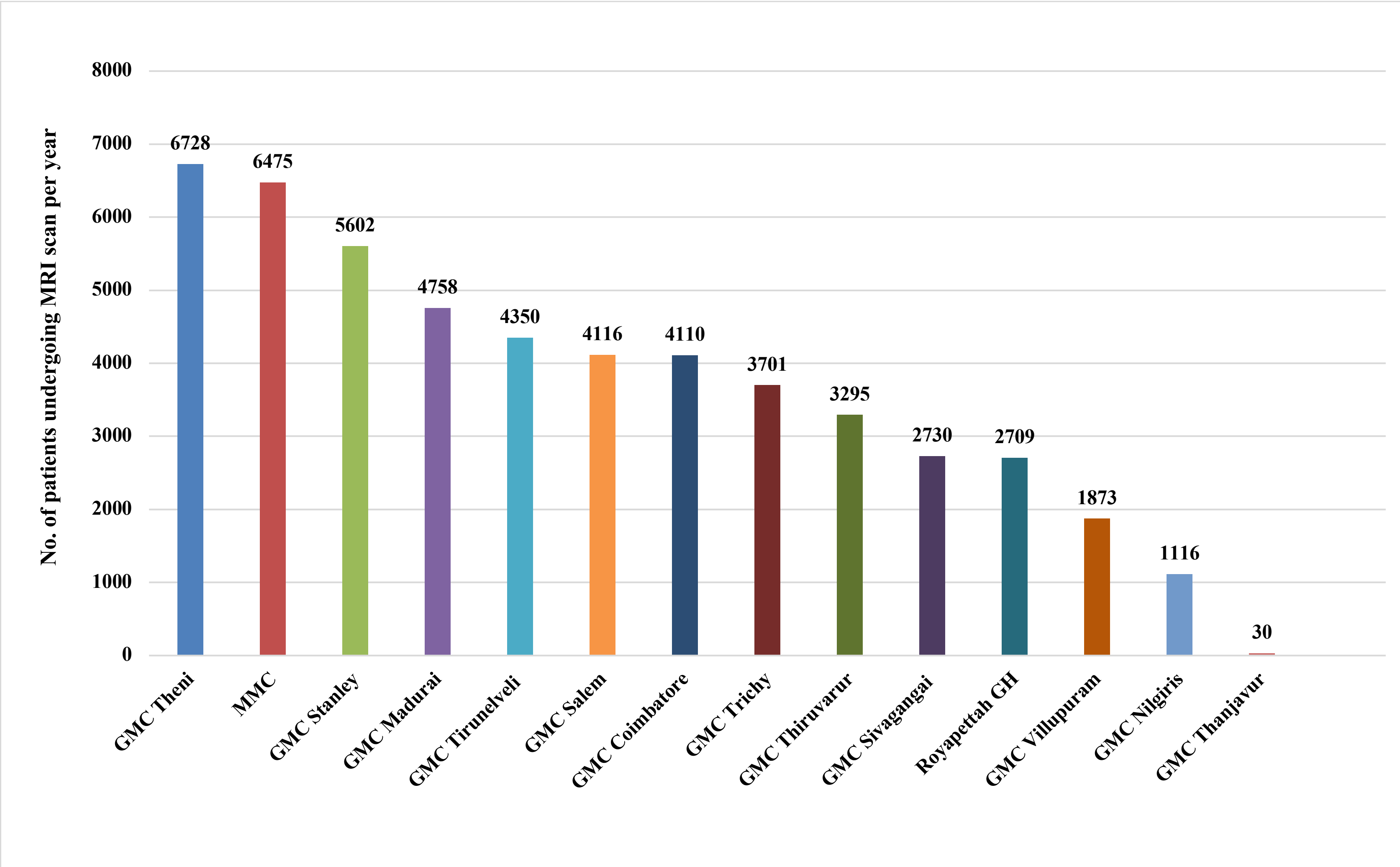


Figure 8D: Utilization of MRI Scan services (in terms of absolute numbers) across secondary and tertiary care facilities in Tamil Nadu in the year 2019

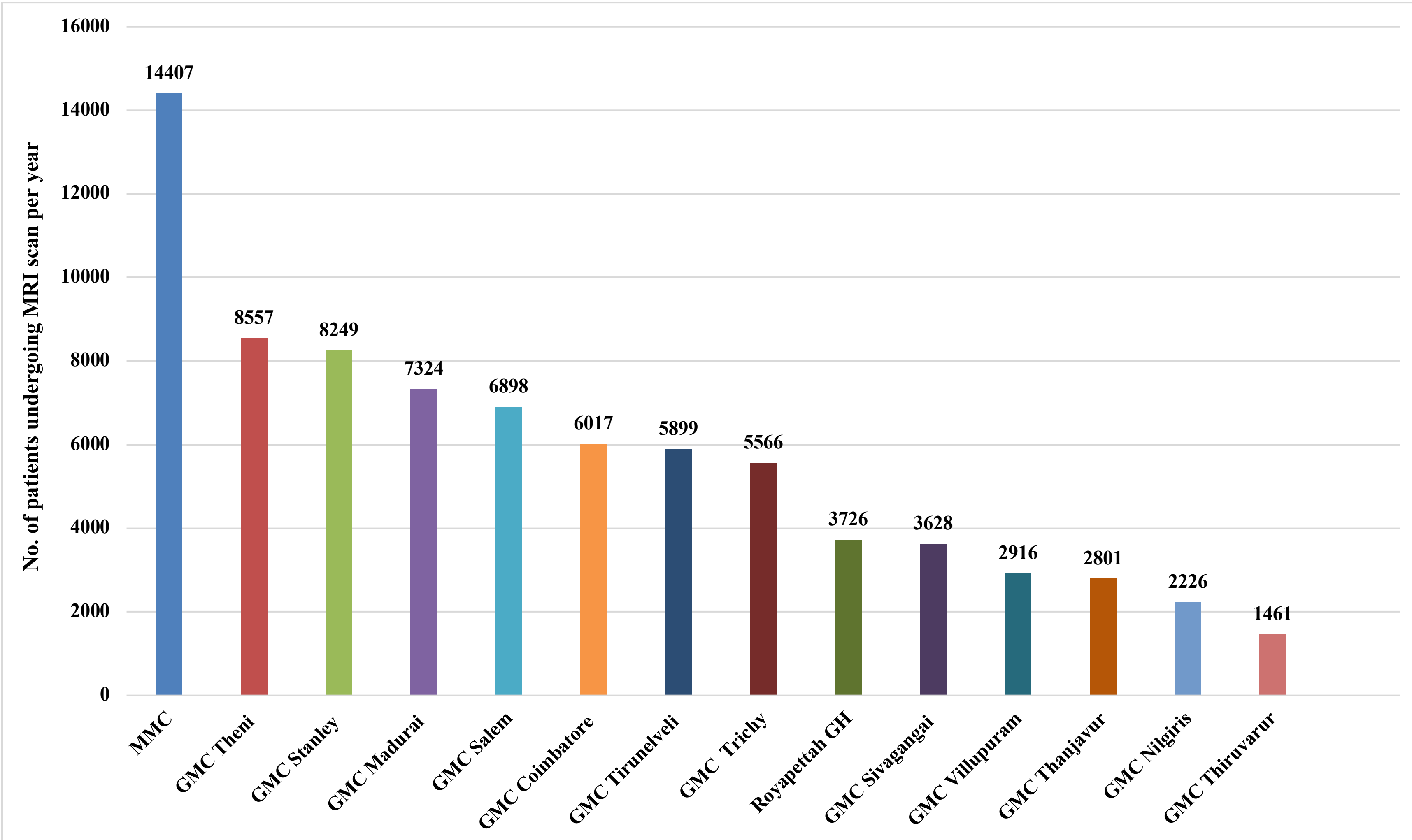


Figure 8E: Utilization of MRI Scan services (in terms of absolute numbers) across secondary and tertiary care facilities in Tamil Nadu in the year 2018

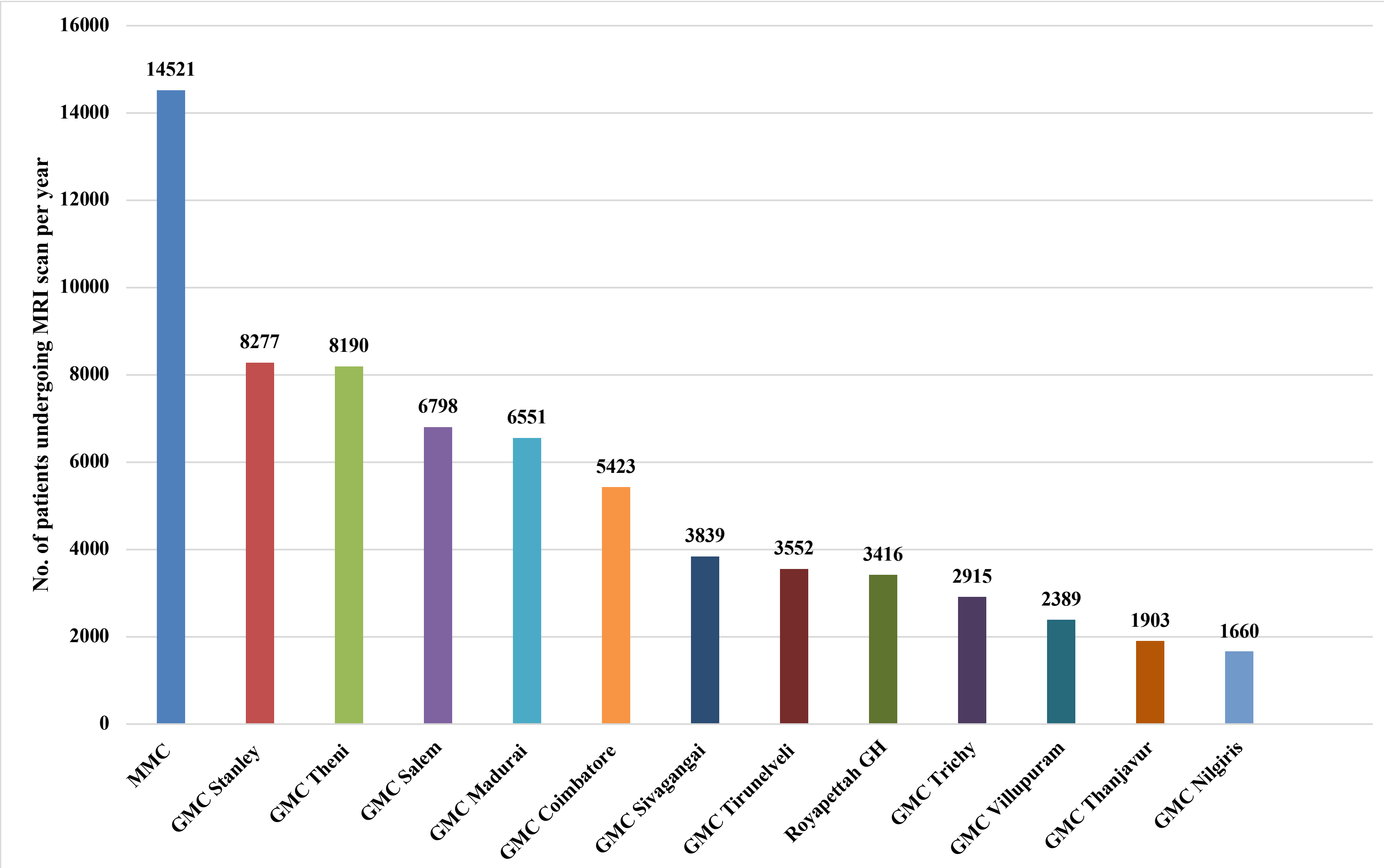


Figure 9A: Utilization of MRI Scan services (in terms of utilization rate per 100,000 OPD visits) across secondary and tertiary care facilities in Tamil Nadu in the year 2022

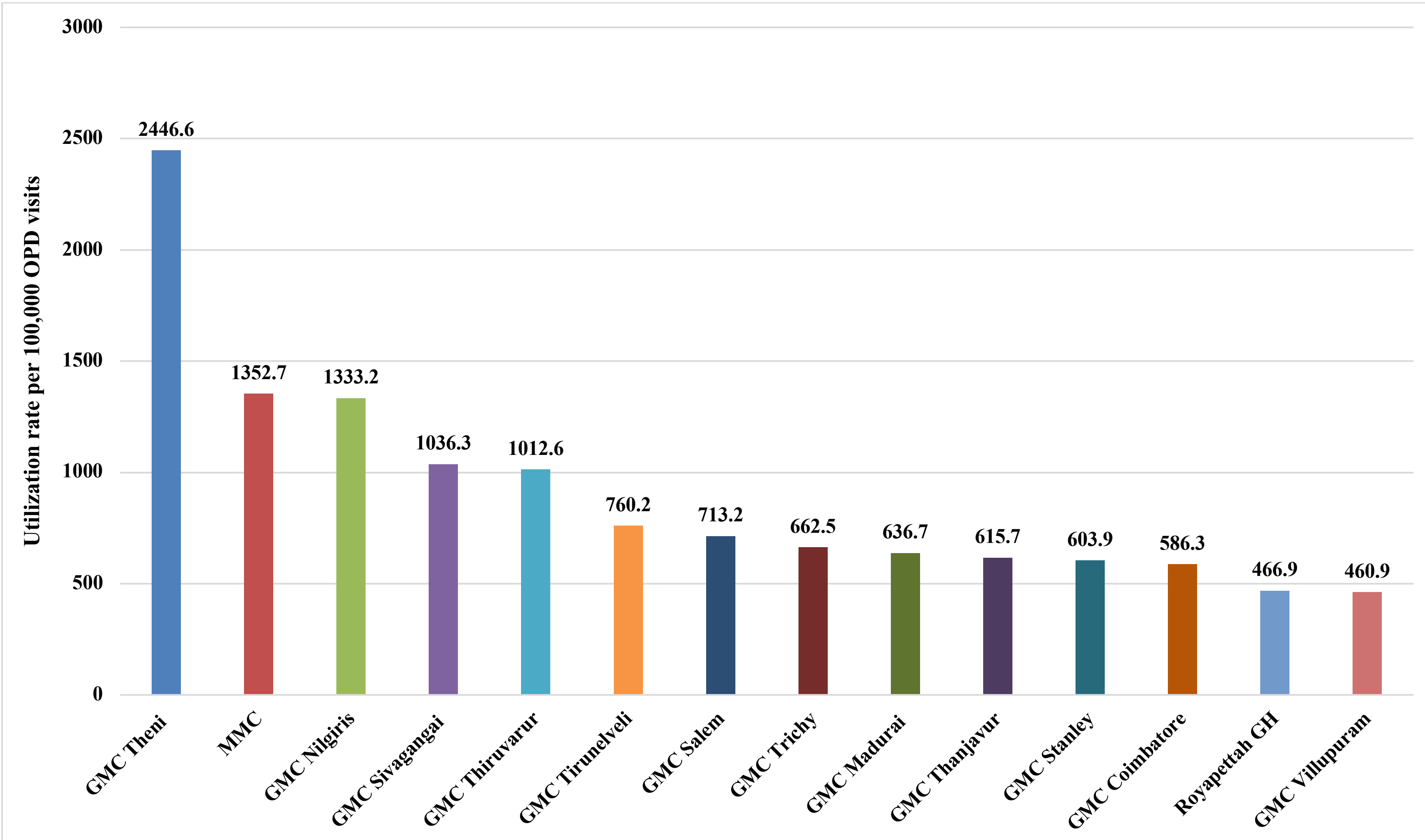


Figure 9B: Utilization of MRI Scan services (in terms of utilization rate per 100,000 OPD visits) across secondary and tertiary care facilities in Tamil Nadu in the year 2021

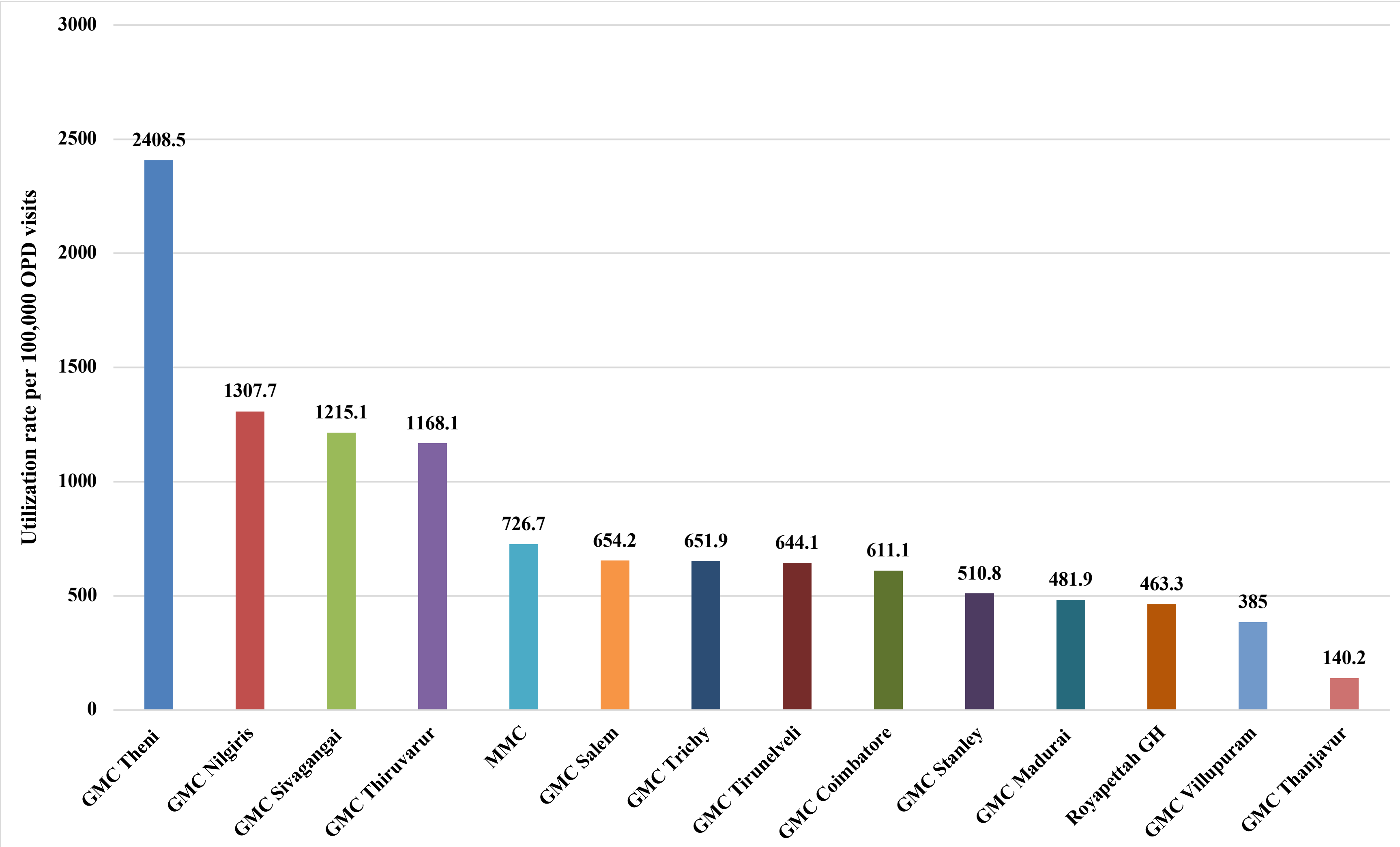


Figure 9C: Utilization of MRI Scan services (in terms of utilization rate per 100,000 OPD visits) across secondary and tertiary care facilities in Tamil Nadu in the year 2020

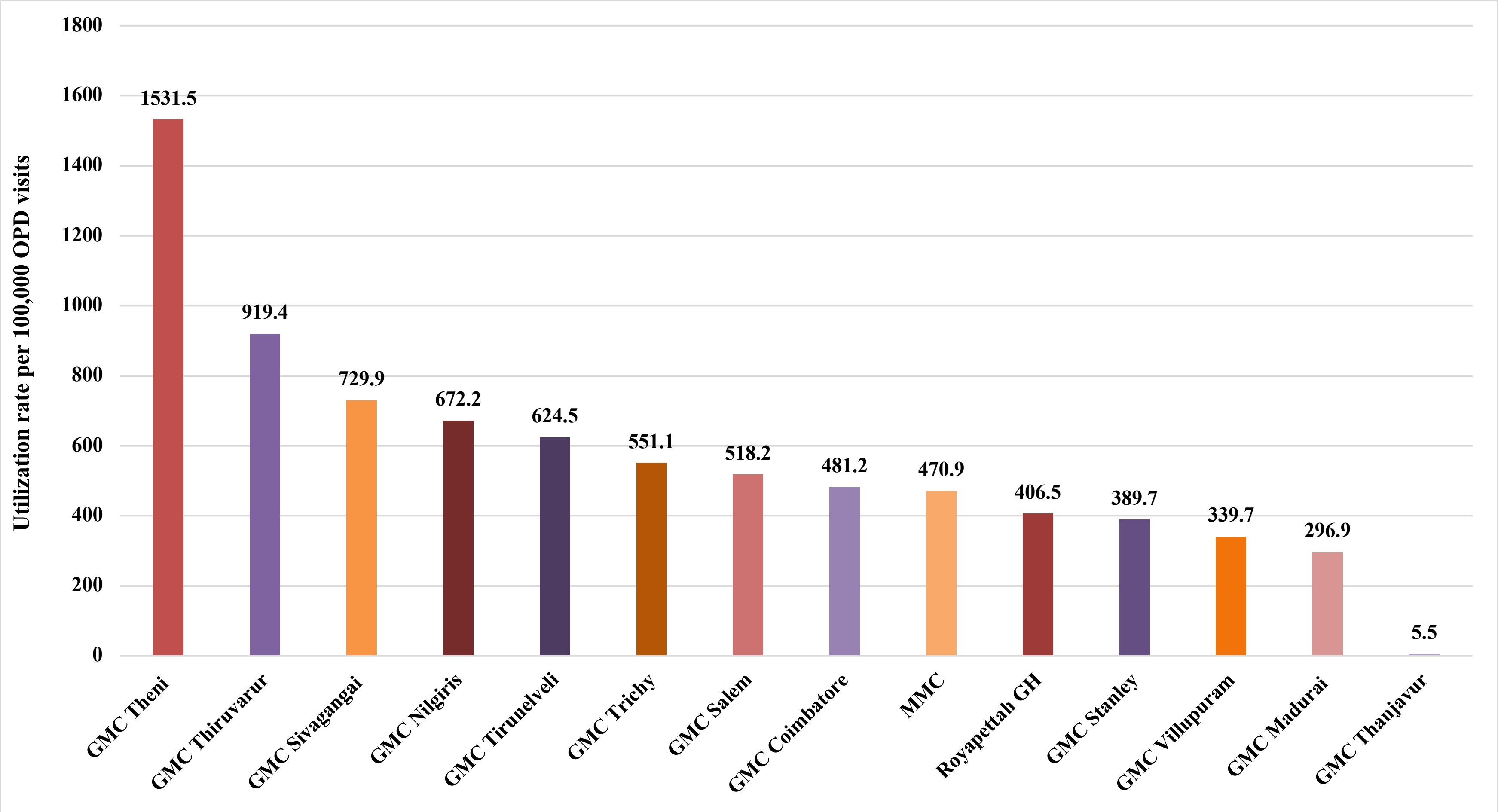


Figure 9D: Utilization of MRI Scan services (in terms of utilization rate per 100,000 OPD visits) across secondary and tertiary care facilities in Tamil Nadu in the year 2019

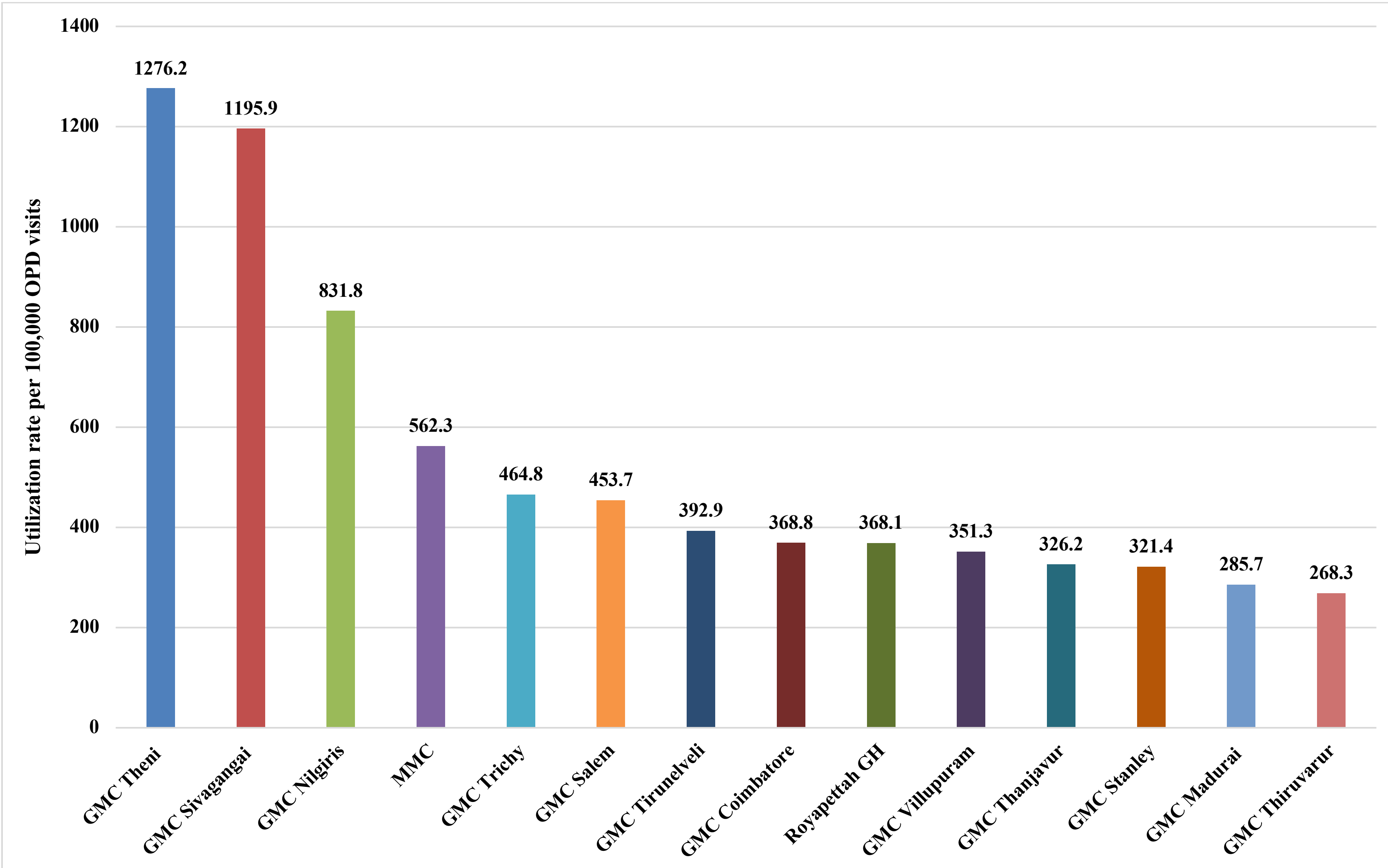
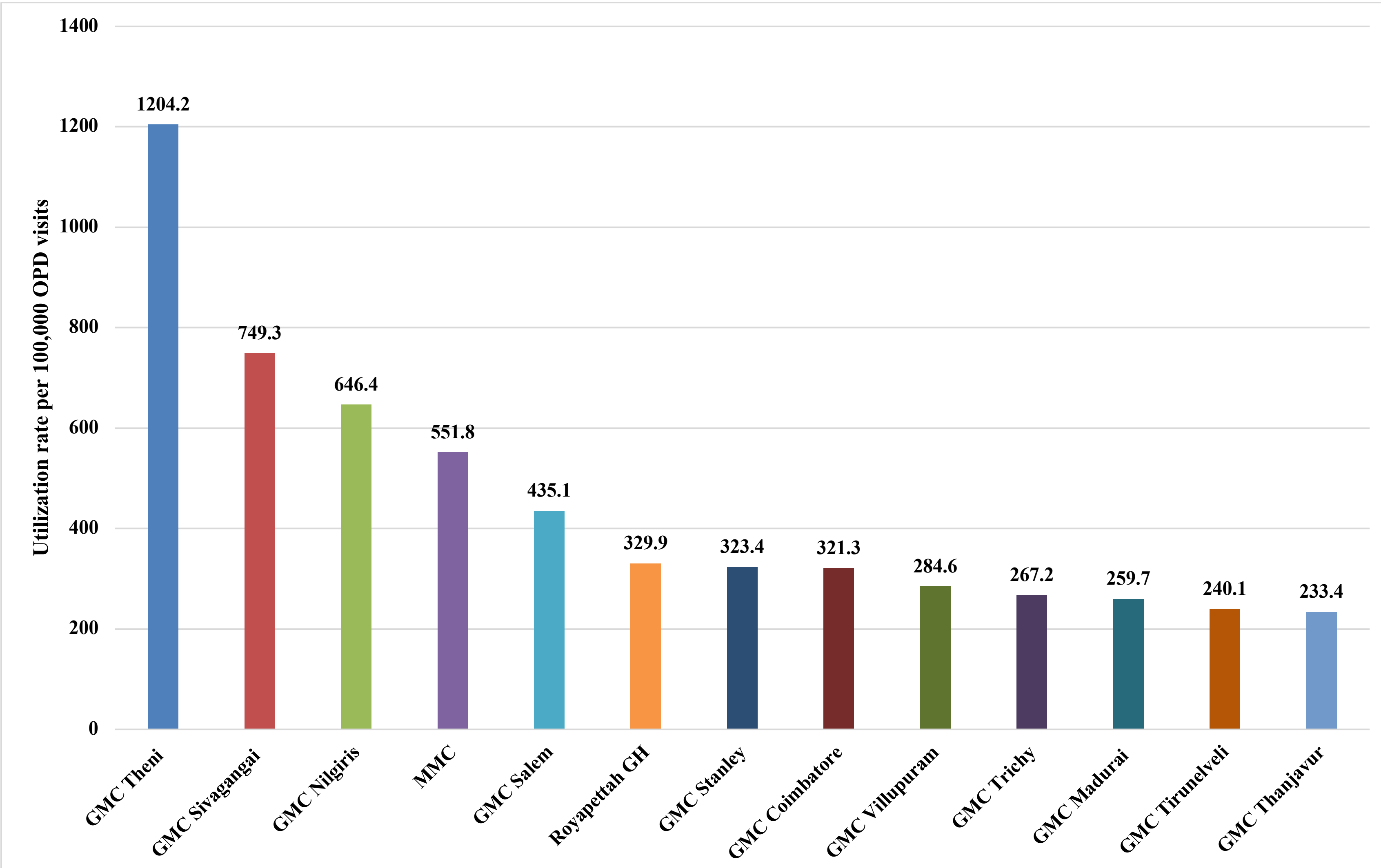


Figure 9E: Utilization of MRI Scan services (in terms of utilization rate per 100,000 OPD visits) across secondary and tertiary care facilities in Tamil Nadu in the year 2018



Equipment Utilization - Lithotripsy:

Rajiv Gandhi Government General Hospital (RGGGH):

Figure S71 and S72 depicts the year-wise trend of Lithotripsy utilization in terms of absolute numbers and rate per 100,000 OPD visits at Rajiv Gandhi Government General Hospital.

Figure S71 shows that there was consistent declining trend with maximum dip seen in 2020 owing to the COVID-19 pandemic. The APC was -6.91%, but it was not statistically significant ($p>0.05$). Figure S72 shows that the utilization was in a plateau phase from 2015 to 2019 (APC = -6.47%) with dip in 2020 (presence of joinpoint – statistically significant change in trend) due to COVID-19 pandemic. There was substantial increase in the Lithotripsy utilization in 2021 and 2022 with an APC of 50.09%, and it was statistically significant ($p<0.05$). The overall AAPC was 7.07% and this trend was not statistically significant ($p>0.05$).

Coimbatore Medical College Hospital:

Figure S73 and S74 depicts the year-wise trend of Lithotripsy utilization in terms of absolute numbers and rate per 100,000 OPD visits at Coimbatore Medical College Hospital.

Figure S73 shows that there was consistent increasing trend from year of inception (2016) till 2019 (before the COVID-19 pandemic). The APC from 2016 to 2019 was 109.90%, indicating a substantial increase in utilization during this period and it was statistically significant ($p<0.05$). However, from 2020, there was been a substantial decline in utilization. The APC from 2020 to 2022 is -52.73%, indicating the significant decline in the utilization over the recent years ($p<0.05$). The overall AAPC was -0.39% and it was not statistically significant ($p>0.05$).

Figure S74 also shows a similar trend in terms of utilization rate with consistent increasing trend from 2016 to 2019 with APC of 81.33%. The APC from 2020 to 2022 was -66.21% indicating the substantial decline during this period. The overall AAPC was 3.58% and this trend was not statistically significant ($p>0.05$). In addition, the equipment is currently not functional during the time of data collection.

Madurai Medical College Hospital:

Figure S75 and S76 depicts the year-wise trend of Lithotripsy utilization in terms of absolute numbers and rate per 100,000 OPD visits at Madurai Medical College Hospital.

Figure S75 shows that there was an increasing trend from 2013 till 2019 (before the COVID-19 pandemic). The APC from 2013 to 2019 was 11.77%, indicating a substantial increase in utilization during this period and it was statistically significant ($p<0.05$). However, from 2020, there was been a substantial decline in utilization. The APC from 2019 to 2022 is -26.38%, indicating the significant decline in the utilization over the recent years ($p<0.05$). The overall AAPC was -7.15% and it was not statistically significant ($p>0.05$).

Figure S76 also shows a similar trend in terms of utilization rate with consistent increasing trend from 2013 to 2019 with APC of 8.96% and it was statistically significant ($p<0.05$). The APC from 2019 to 2022 was -22.22% indicating the substantial decline during this period. The overall AAPC was -2.62% and this trend was not statistically significant ($p>0.05$). In addition, the equipment is currently not functional during the time of data collection.

Government Tirunelveli Medical College and Hospital:

Figure S77 and S78 depicts the year-wise trend of Lithotripsy utilization in terms of absolute numbers and rate per 100,000 OPD visits at Government Tirunelveli Medical College and Hospital.

Figure S77 shows that there was an increasing trend from 2016 till 2019 (before the COVID-19 pandemic). Then, there was a dip in utilization during 2020. However, after 2020, there was again a substantial increase in utilization with peak utilization in the year 2022. The overall APC from 2016 to 2022 is 68.90%, indicating the substantial increase in the utilization over the recent years. However, this trend was not statistically significant ($p>0.05$). Figure S78 also shows a similar trend in terms of utilization rate with consistent increasing trend from 2013 to 2019 followed by dip in 2020 and then substantial rise in the utilization rate till 2022. The overall APC was 82.77% and this trend was not statistically significant ($p>0.05$).

Five-Year Trend in Utilization of Lithotripsy Scan services across tertiary care facilities in Tamil Nadu:

Figure 10A-10E depicts the institute-wise trend of Lithotripsy utilization in terms of absolute numbers from 2018 to 2022. Over the past five years, Rajiv Gandhi General Government Hospital (RGGGH) had the highest number of patients visiting the facility to utilize lithotripsy services compared to other facilities. Madurai Medical College and Hospital and Coimbatore Medical College and Hospital had the next highest number of patients visiting the facility for lithotripsy services except in the year 2022 (Government Tirunelveli Medical College and Hospital had a huge spike in utilization). **Figure 11A-11E** also shows similar trend in the number of cases across the four facilities.

Figure 10A: Utilization of Lithotripsy services (in terms of absolute numbers) across tertiary care facilities in Tamil Nadu in the year 2022

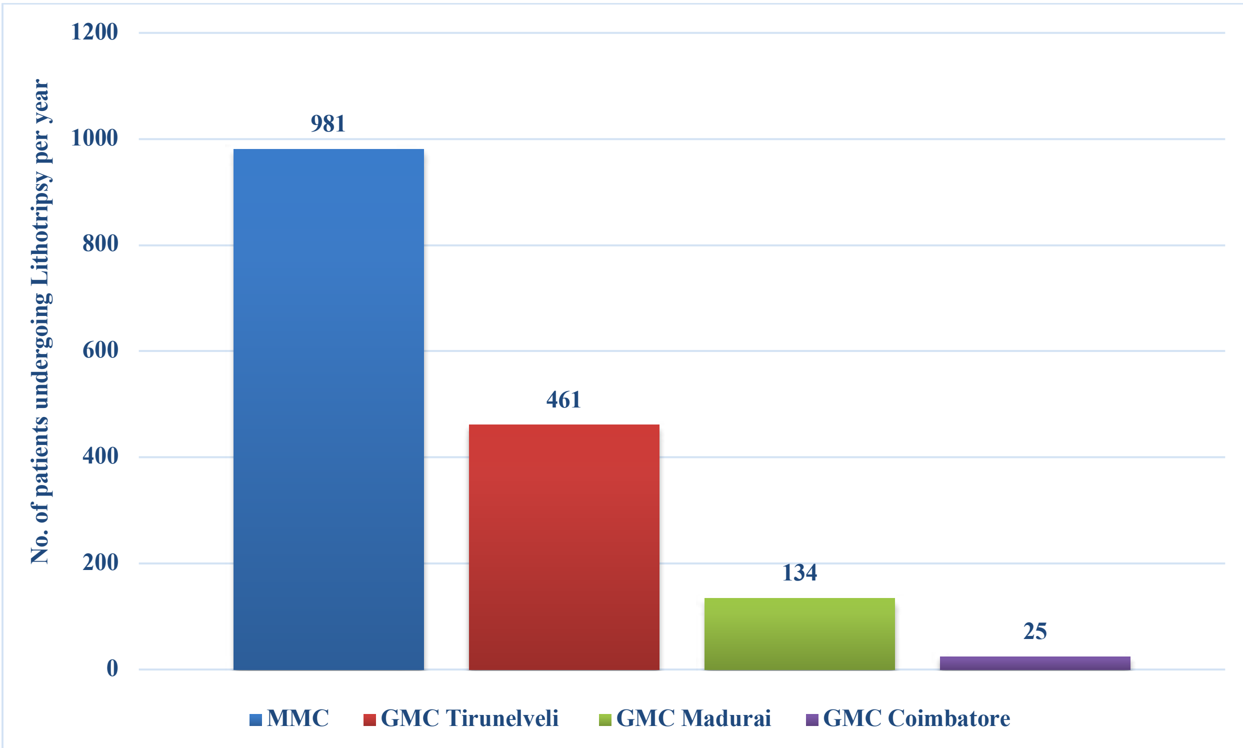


Figure 10B: Utilization of Lithotripsy services (in terms of absolute numbers) across tertiary care facilities in Tamil Nadu in the year 2021

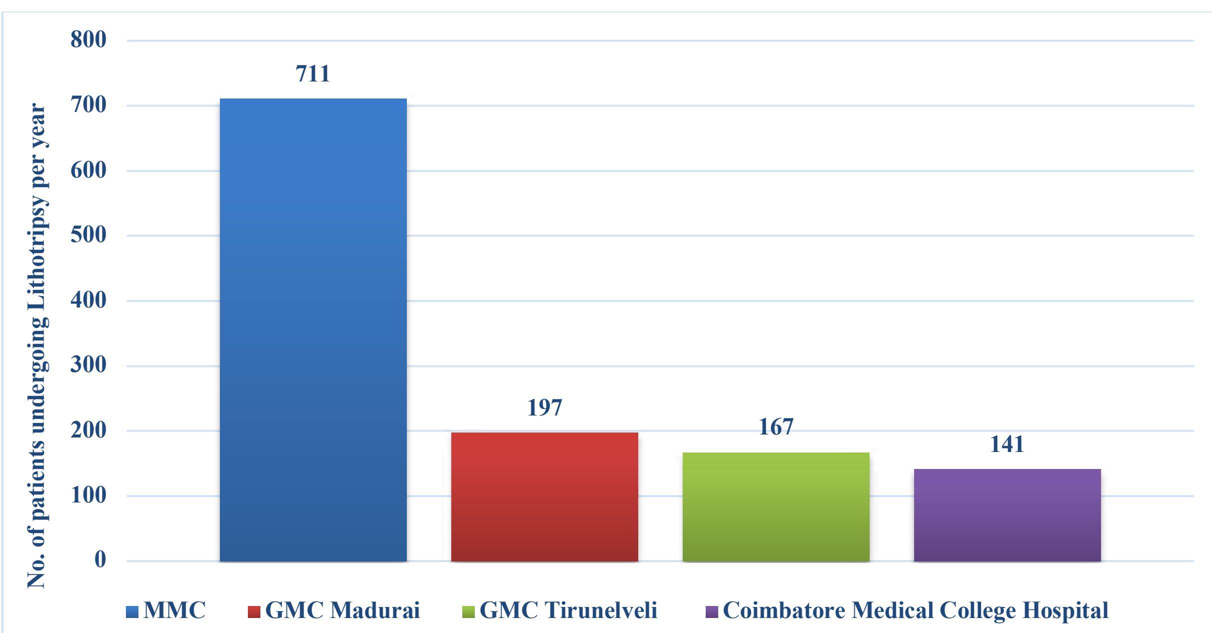


Figure 10C: Utilization of Lithotripsy services (in terms of absolute numbers) across tertiary care facilities in Tamil Nadu in the year 2020

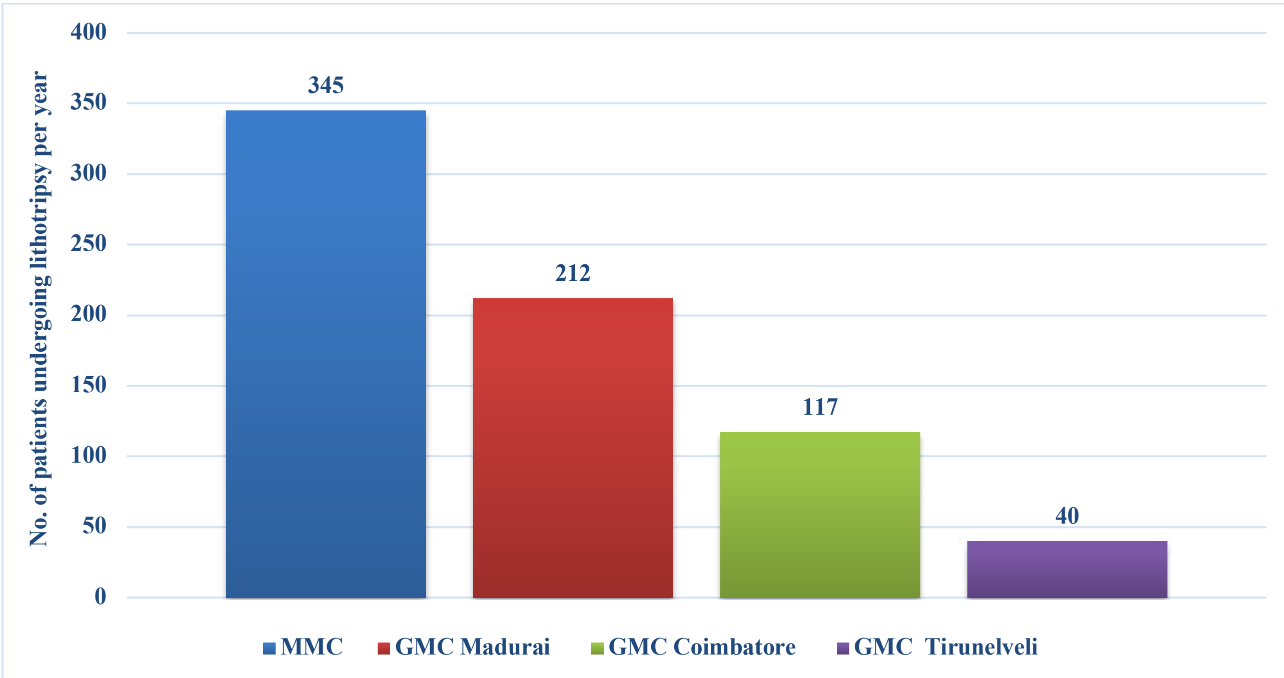


Figure 10D: Utilization of Lithotripsy services (in terms of absolute numbers) across tertiary care facilities in Tamil Nadu in the year 2019

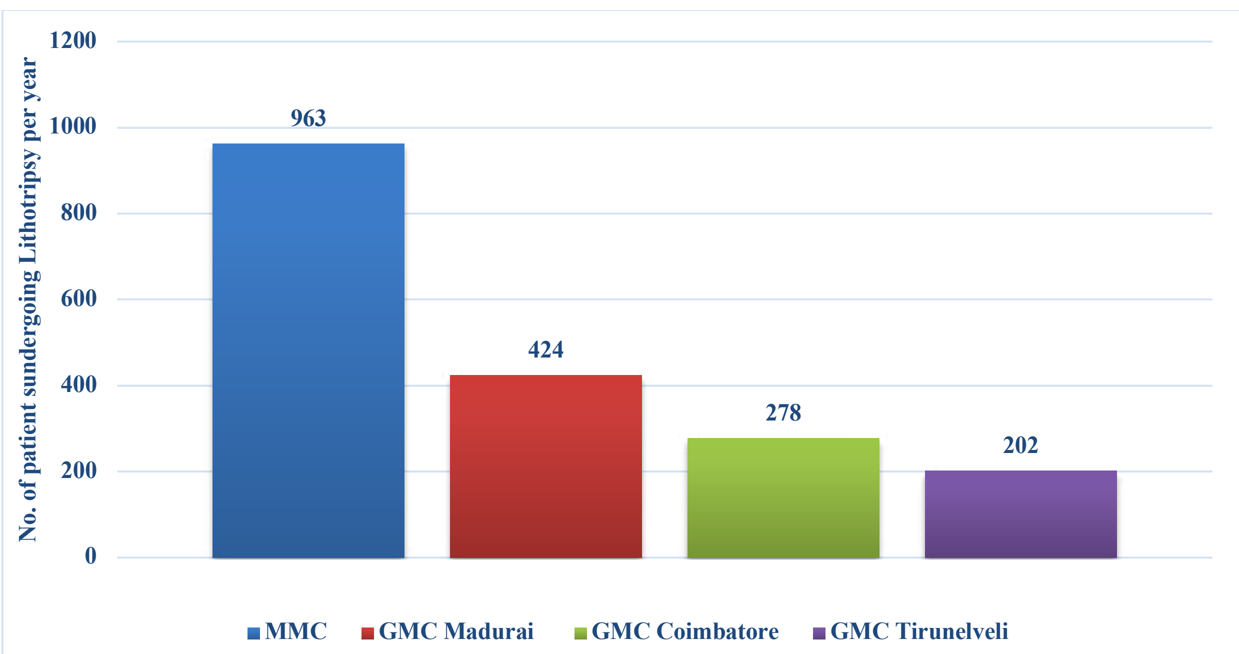


Figure 10E: Utilization of Lithotripsy services (in terms of absolute numbers) across tertiary care facilities in Tamil Nadu in the year 2018

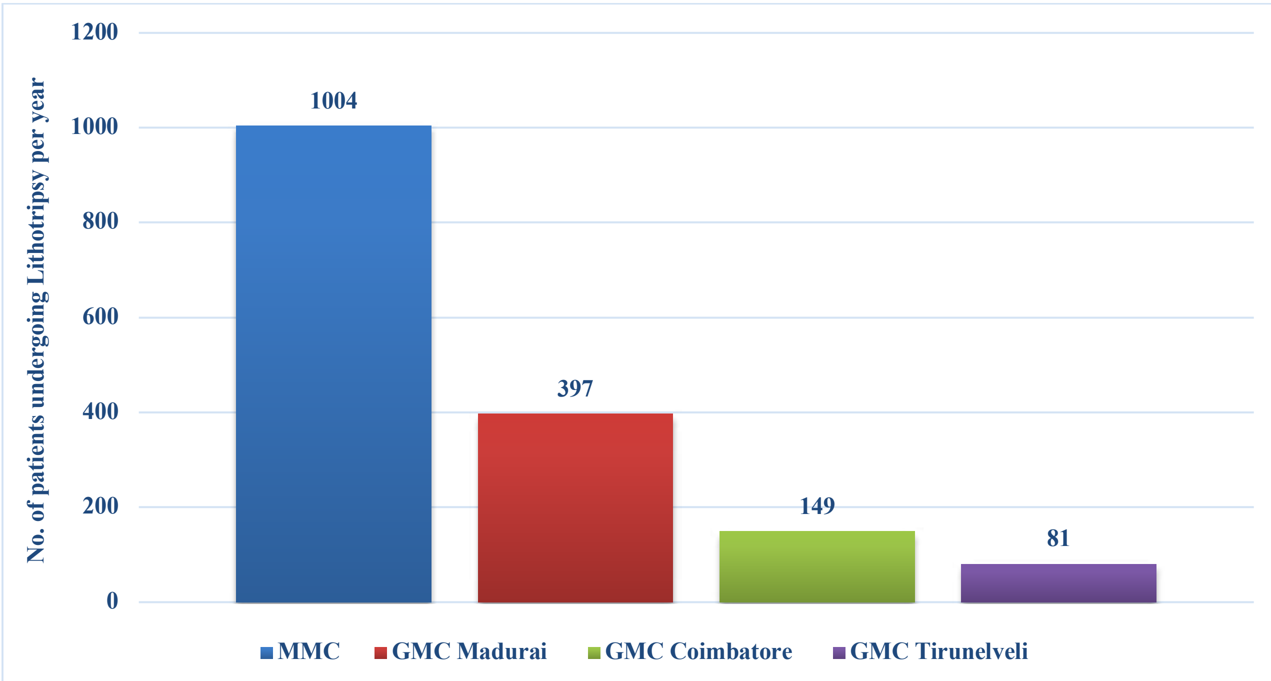


Figure 11A: Utilization of Lithotripsy services (in terms of utilization rate per 100,000 OPD visits) across tertiary care facilities in Tamil Nadu in the year 2022

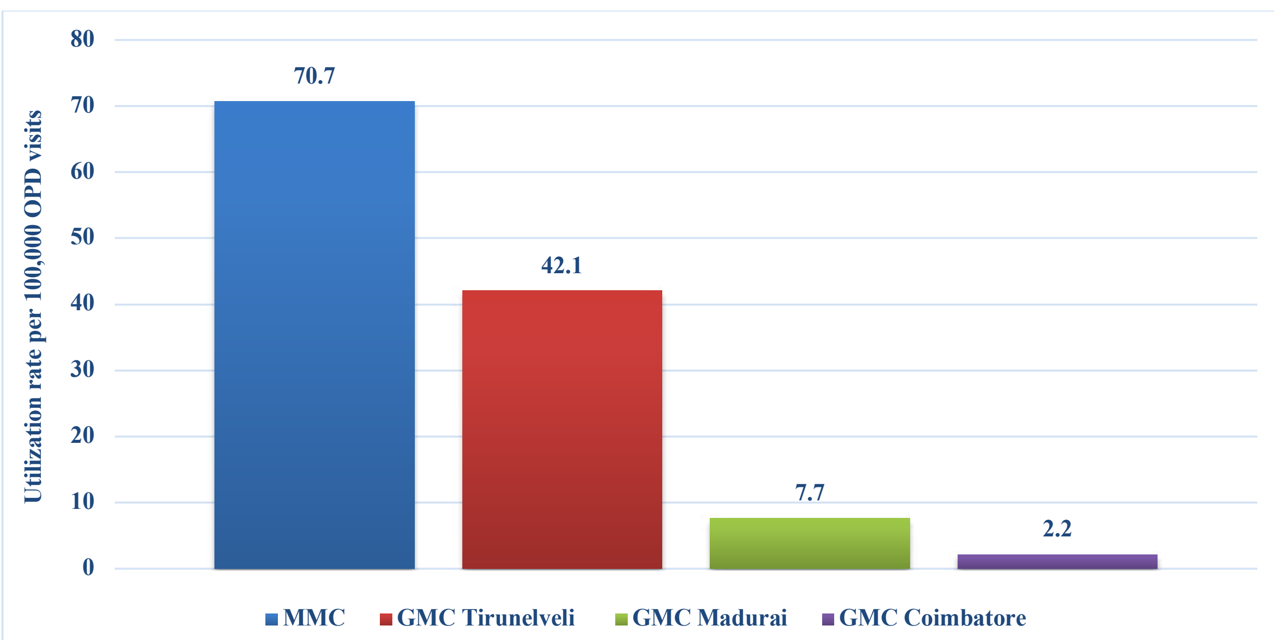


Figure 11B: Utilization of Lithotripsy services (in terms of utilization rate per 100,000 OPD visits) across tertiary care facilities in Tamil Nadu in the year 2021

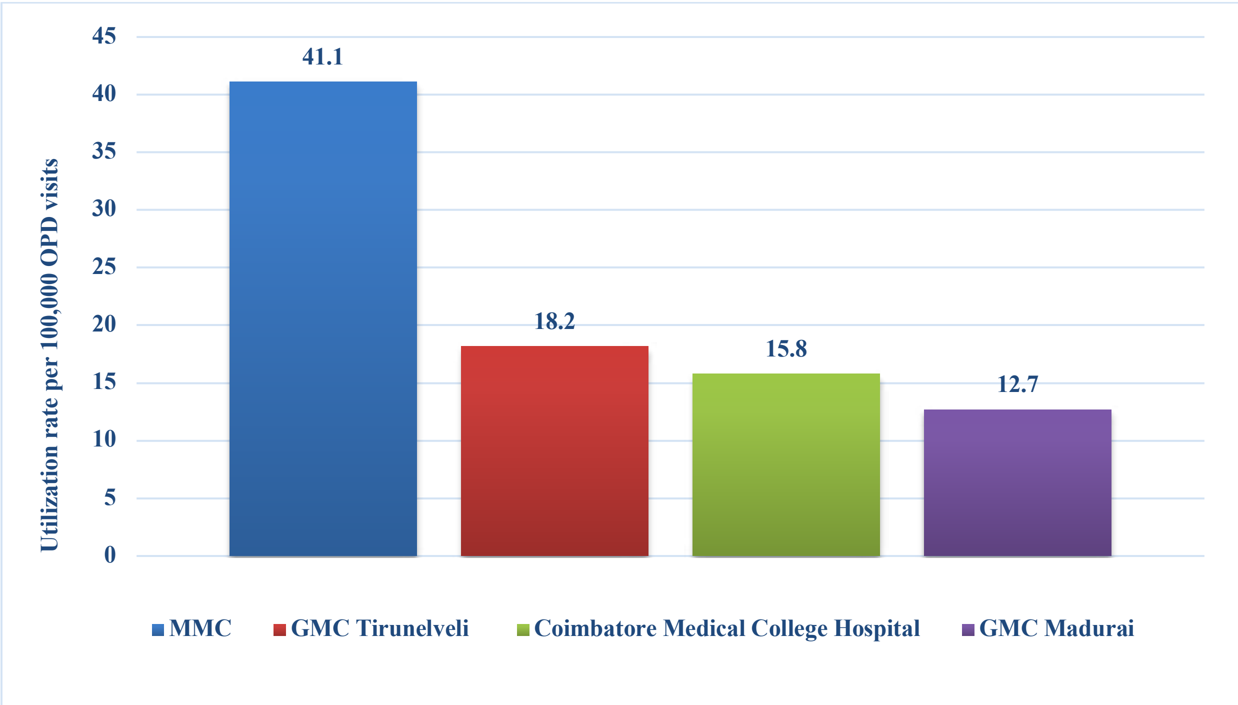


Figure 11C: Utilization of Lithotripsy services (in terms of utilization rate per 100,000 OPD visits) across tertiary care facilities in Tamil Nadu in the year 2020

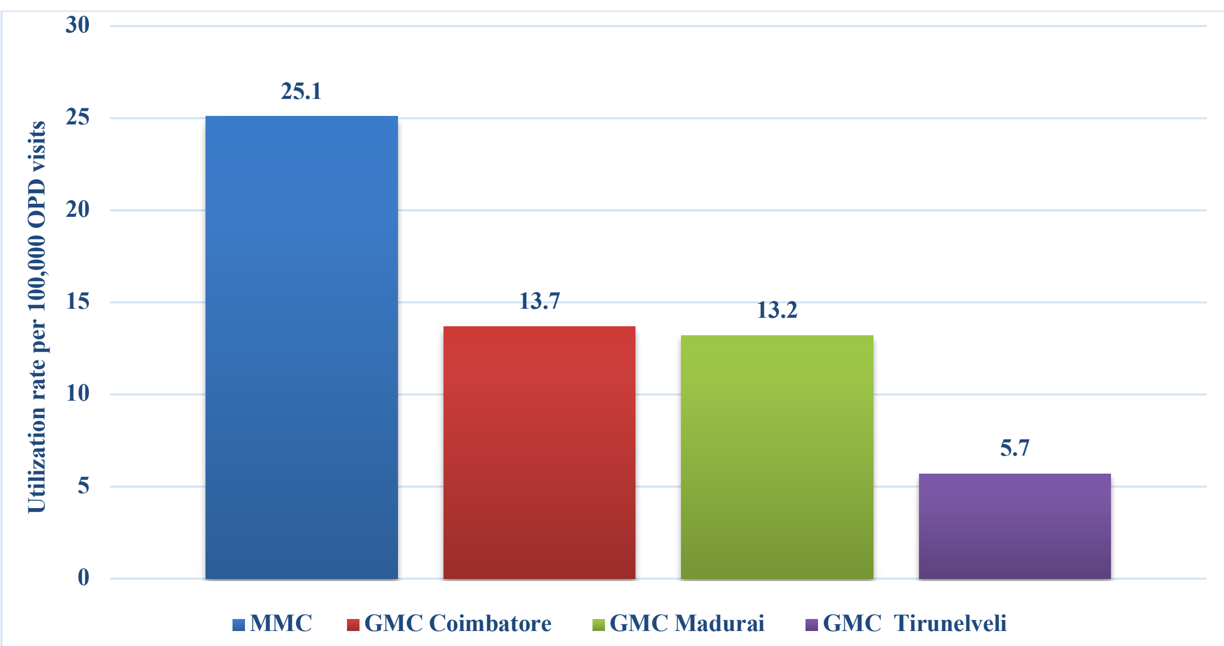


Figure 11D: Utilization of Lithotripsy services (in terms of utilization rate per 100,000 OPD visits) across tertiary care facilities in Tamil Nadu in the year 2019

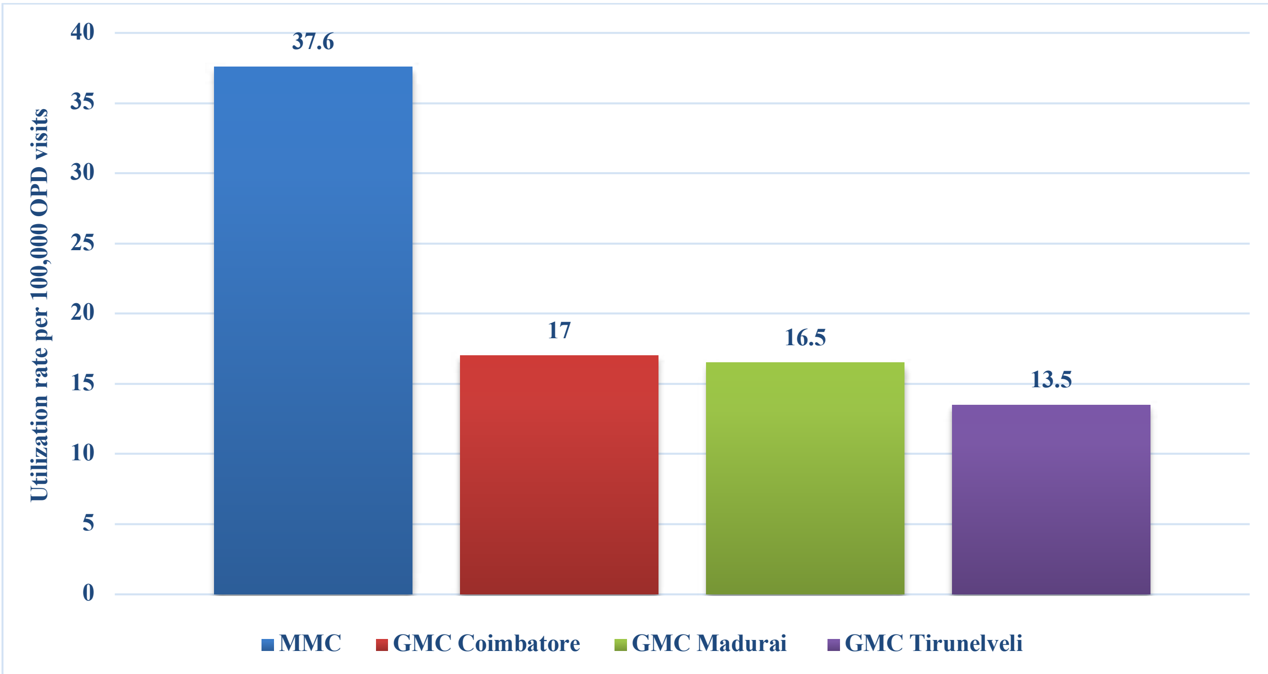
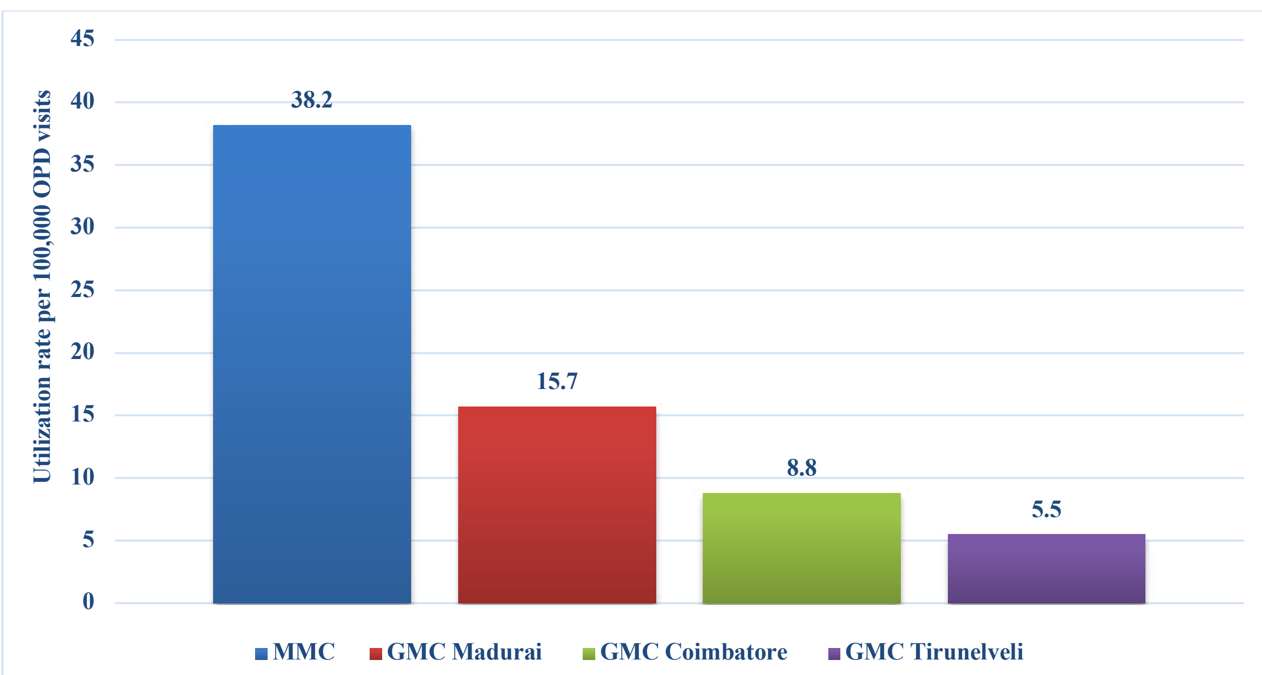


Figure 11E: Utilization of Lithotripsy services (in terms of utilization rate per 100,000 OPD visits) across tertiary care facilities in Tamil Nadu in the year 2018



Equipment utilization – LINAC:

Figure S79-S85 provides year-wise trend of utilization of LINAC services across various facilities in Tamil Nadu.

All the observed facilities in Chennai (Rajiv Gandhi Government General Hospital, Government Medical College, Omandurar and Government Royapettah Hospital), Madurai Medical College Hospital and Government Medical College, Thanjavur had increasing trend of utilization of LINAC services. Government Tirunelveli Medical College Hospital and Coimbatore Medical College Hospital had declining trend in utilization of LINAC services.

Joinpoint regression was not performed for any of the facilities having LINAC as almost all the facilities had LINAC for only the last 2-3 years.

Three-Year Trend in Utilization of LINAC services across various facilities in Tamil Nadu:

Figure 12A-12C depicts the institute-wise trend of LINAC utilization in terms of absolute numbers from 2020 to 2022. Over the past three years, Government Royapettah Hospital had the highest number of patients undergoing LINAC services. Coimbatore Medical College Hospital had the next highest utilization rate which got reduced substantially in the last year (2022). Government Tirunelveli Medical College and Hospital had the lowest number of patients undergoing LINAC services. **Figure 13A-13C** also shows similar trend in the number of cases across the seven facilities.

Figure 12A: Utilization of LINAC services (in terms of absolute numbers) across tertiary care facilities in Tamil Nadu in the year 2022

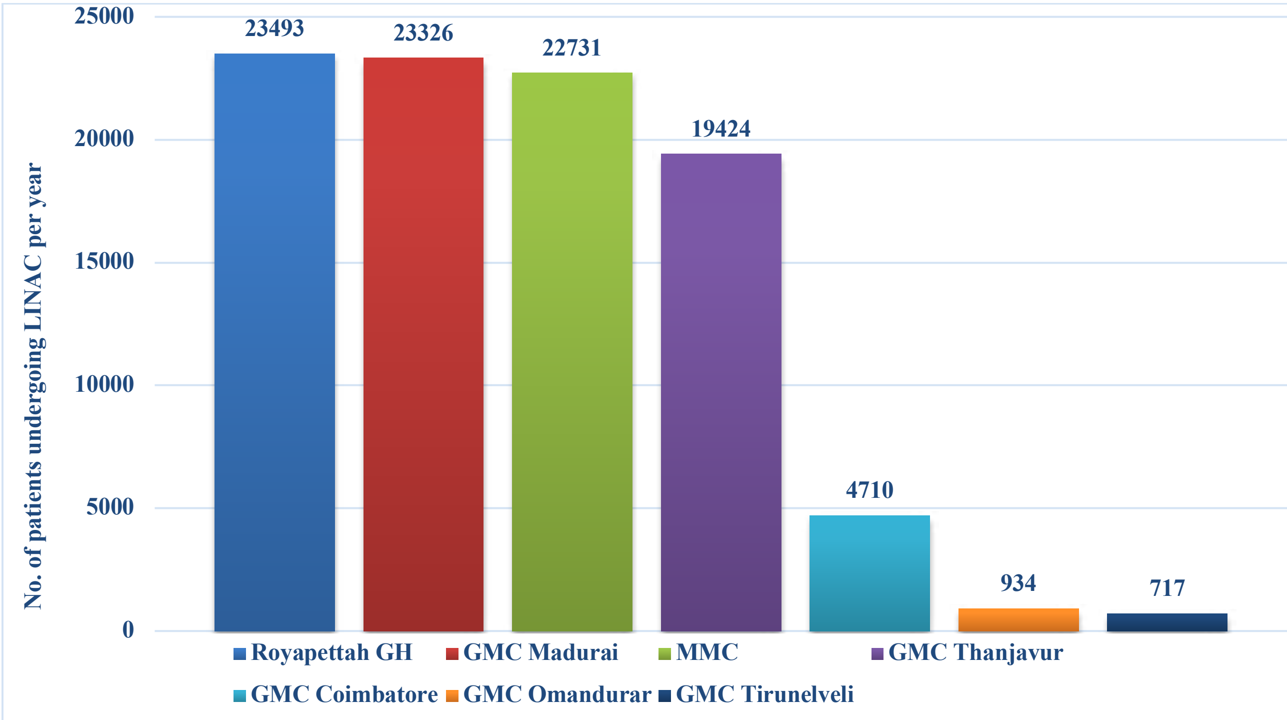


Figure 12B: Utilization of LINAC services (in terms of absolute numbers) across tertiary care facilities in Tamil Nadu in the year 2021

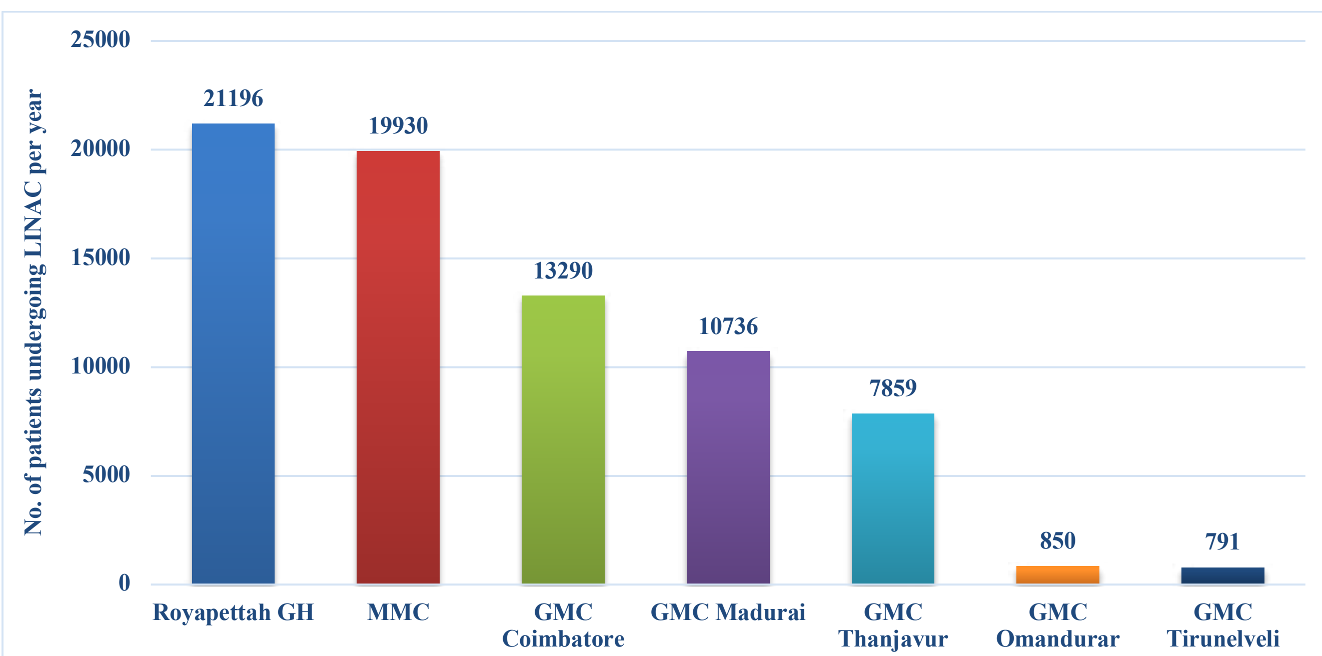


Figure 12C: Utilization of LINAC services (in terms of absolute numbers) across tertiary care facilities in Tamil Nadu in the year 2020

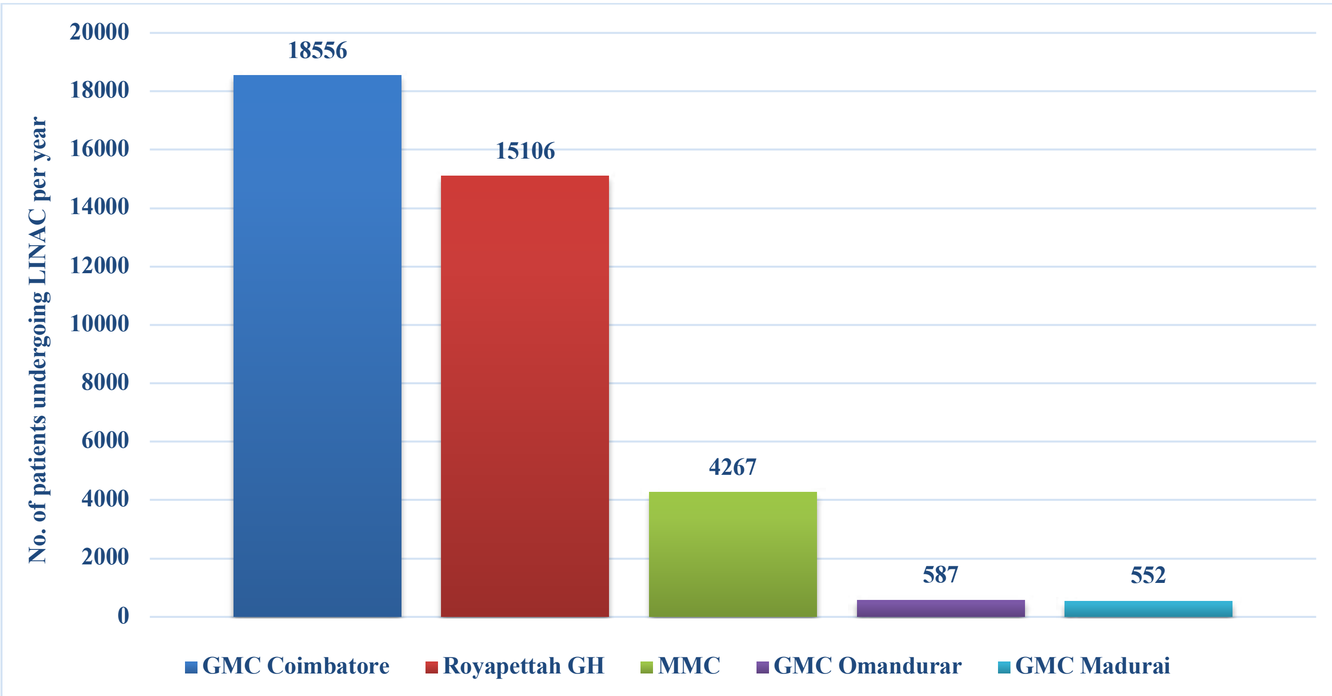


Figure 13A: Utilization of LINAC services (in terms of utilization rate per 100,000 OPD visits) across tertiary care facilities in Tamil Nadu in the year 2022

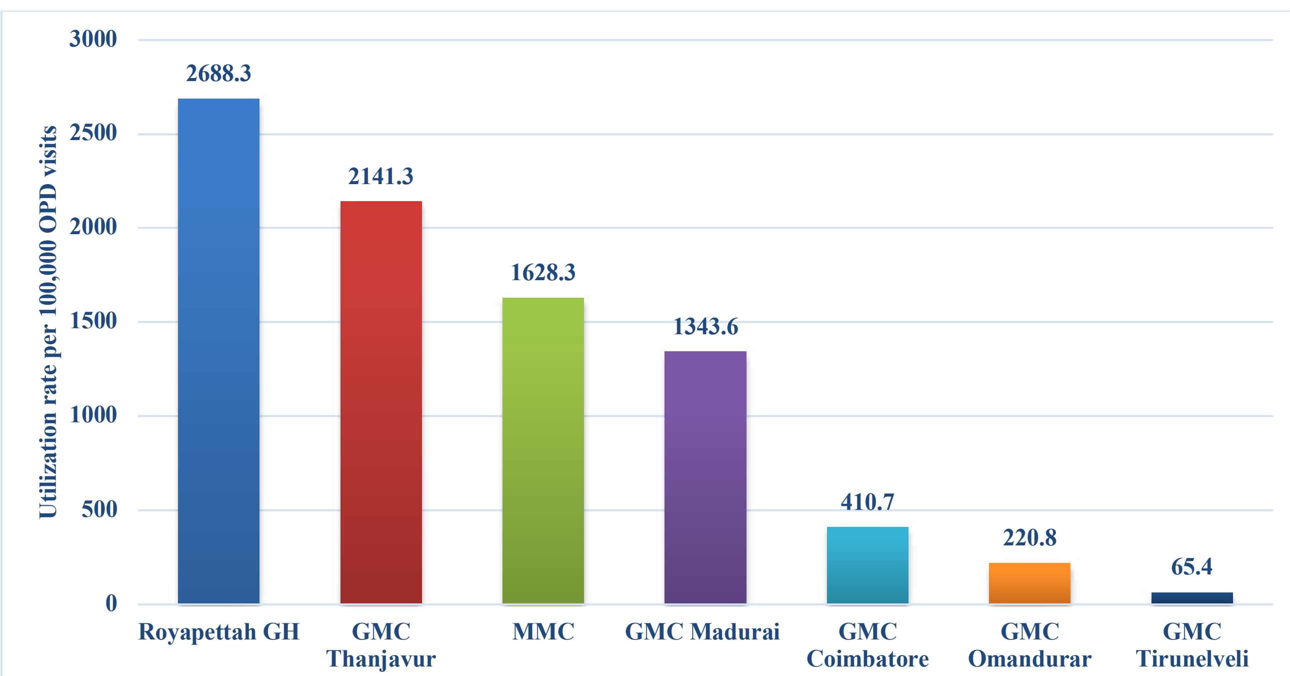


Figure 13B: Utilization of LINAC services (in terms of utilization rate per 100,000 OPD visits) across tertiary care facilities in Tamil Nadu in the year 2021

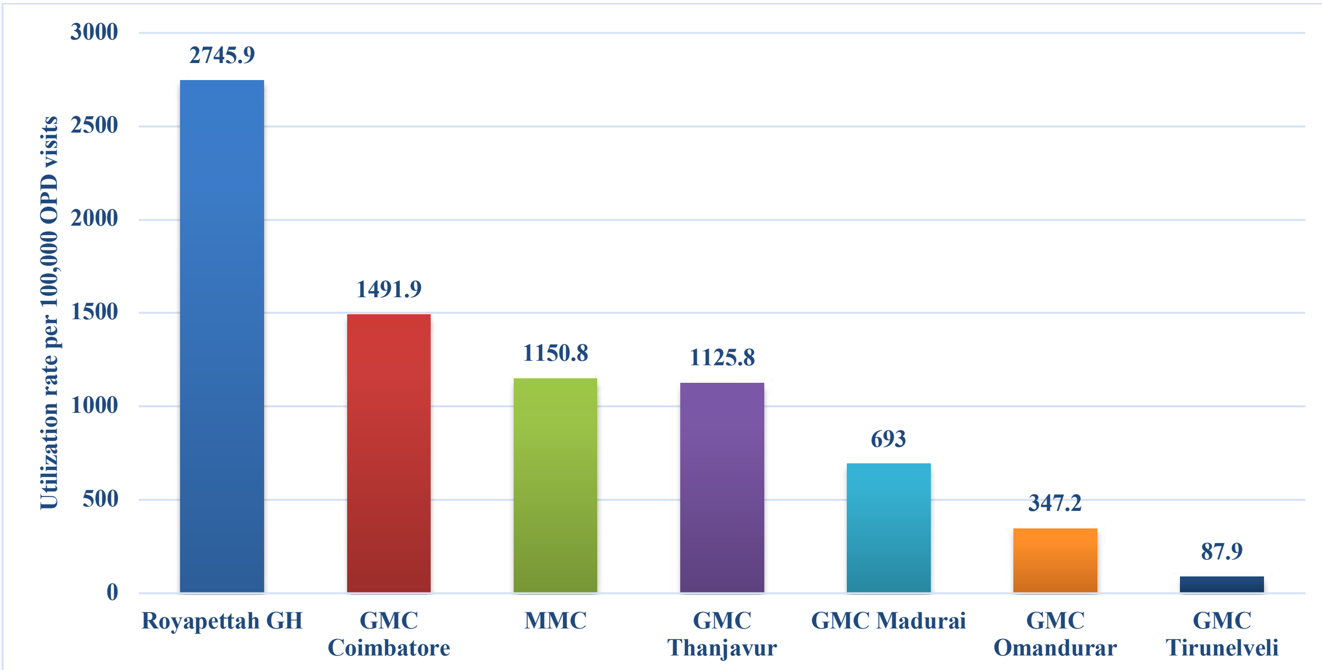
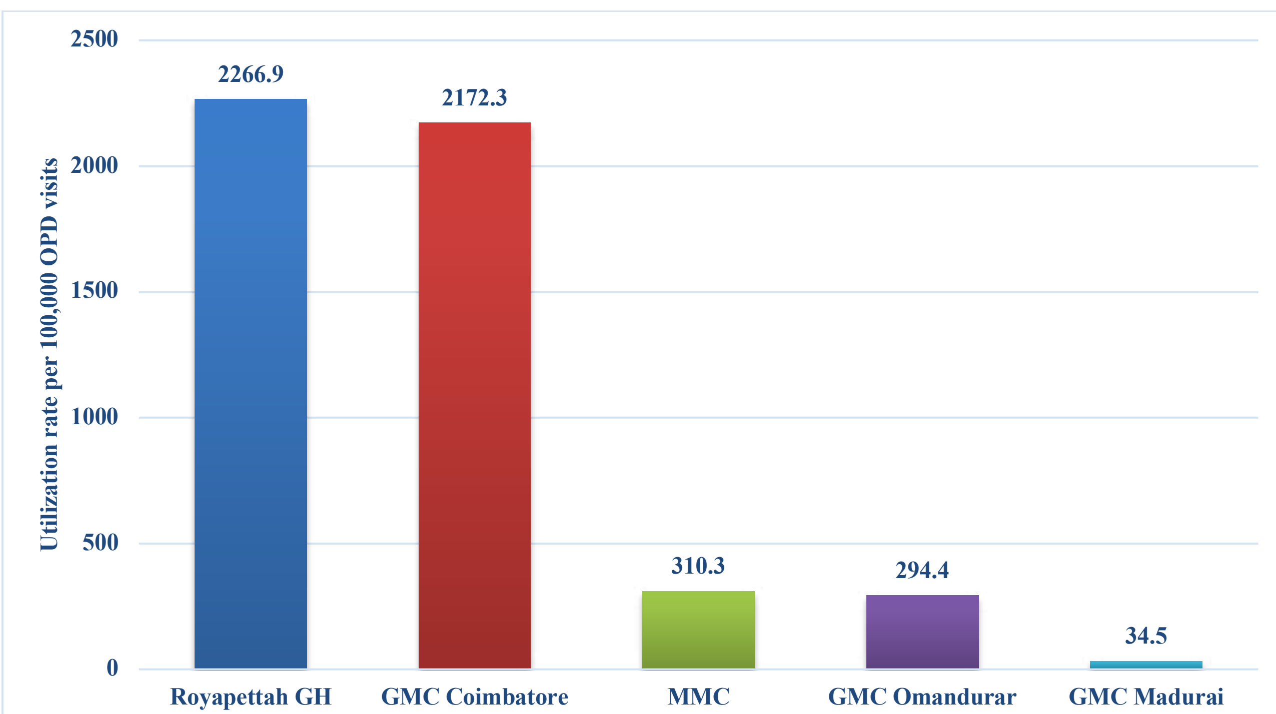


Figure 13C: Utilization of LINAC services (in terms of utilization rate per 100,000 OPD visits) across tertiary care facilities in Tamil Nadu in the year 2020



Equipment utilization – Cobalt therapy unit:

Figure S86-S94 provides year-wise trend of utilization of Cobalt therapy services across various facilities in Tamil Nadu.

Figure S86 shows that the Cobalt therapy is operational in Government Stanley Medical College from 2021 only and the utilization has increased in 2022 compared to the year of inception.

Figure S87 and S88 shows that the Government Royapettah Hospital had a consistent increasing trend in utilization (both absolute numbers and rate per 100,000 OPD visits). However, there was a dip in 2020 due to COVID-19 pandemic. Then the equipment was non-operational in the entire 2021 and most part of 2022. This is because of the newer machine installation, which has led to such a decline in the utilization.

Figure S89 and S90 shows that there has been a consistent declining trend in utilization at Government Tirunelveli Medical College and Hospital followed by non-operational years in 2021 and most part of 2022.

Figure S91 and S92 shows that there was an alternate increasing and declining trend at Government Medical College Hospital with significant dip in the recent years 2021 and 2022.

Figure S93 and S94 shows that Government Mohan Kumaramangalam Medical College and Hospital, Salem was was least affected by COVID-19 pandemic in terms of Cobalt therapy utilization as there was no noticeable dip in the utilization frequency or rate.

Coimbatore and Madurai Medical College Hospital had Cobalt therapy units operational since 2022 and the number of patients who underwent the procedure was 222 (19.35 per 100,000 OPD visits) and 1232 (70.96 per 100,000 OPD visits) respectively.

In Government Villupuram Medical College and Hospital, the Cobalt therapy unit is operational since 2023 and hence, utilization data analysis was not applicable.

Joinpoint regression was not performed for any of the facilities having cobalt therapy as most of the facilities had data for only the last 1-2 years or had zero value in one of the years (as it is not possible to run joinpoint regression with zero value).

Three-Year Trend in Utilization of Cobalt therapy services across various tertiary care facilities in Tamil Nadu:

Figure 14 & 15 depicts the institute-wise trend of Cobalt therapy utilization in terms of absolute numbers and utilization rate per 100,000 OPD visits from 2020 to 2022.

Over the past three years, Government Mohan Kumaramangalam Medical College and Hospital, Salem and Government Medical College Hospital, Thanjavur had the highest number of patients undergoing Cobalt therapy services. This also indirectly reflects the high burden of cancerous conditions necessitating the Cobalt therapy services in these districts.

Government Royapettah Hospital and Government Tirunelveli Medical College and Hospital had the lowest utilization mainly due to their non-operational nature in the recent years.

Figure 14A: Utilization of Cobalt therapy services (in terms of absolute numbers) across tertiary care facilities in Tamil Nadu in the year 2022

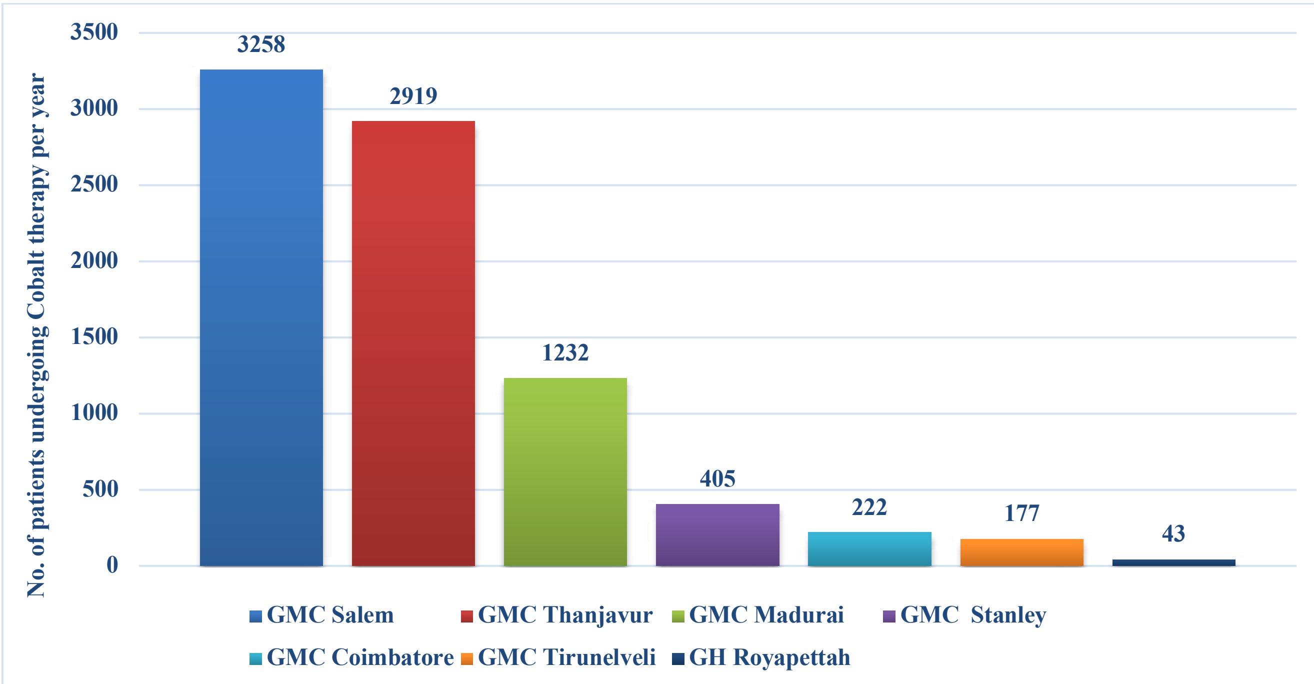


Figure 14B: Utilization of Cobalt therapy services (in terms of absolute numbers) across tertiary care facilities in Tamil Nadu in the year 2021

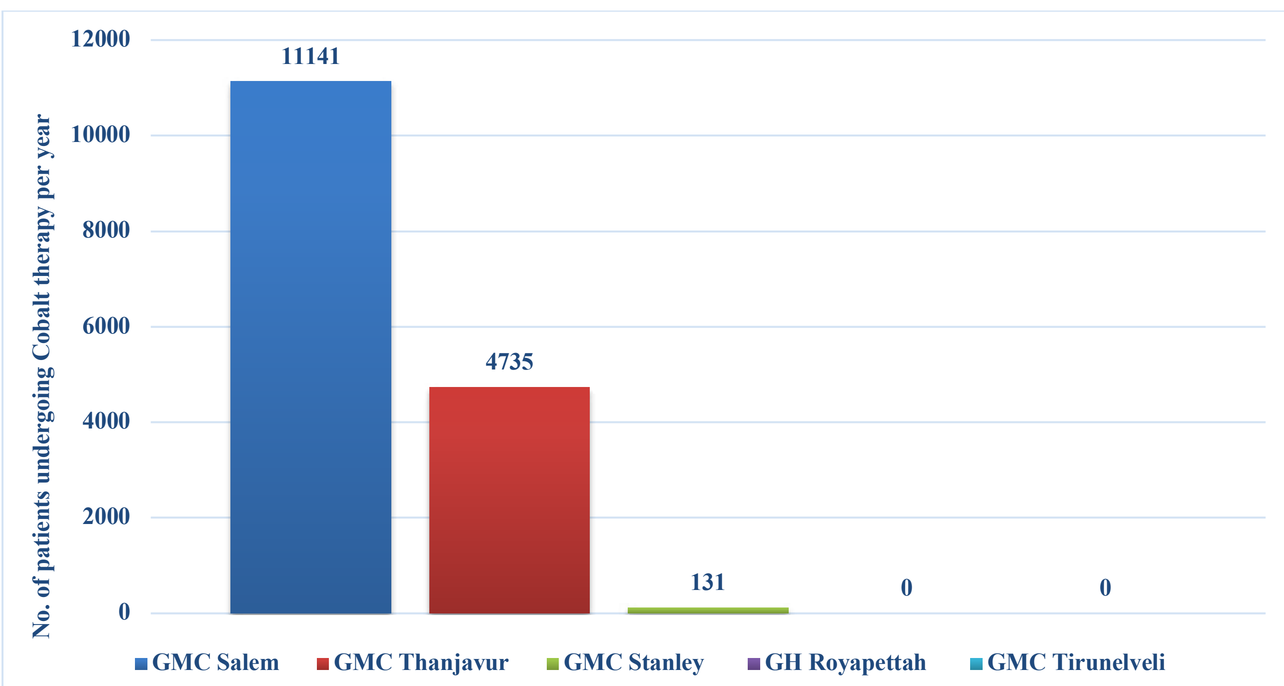


Figure 14C: Utilization of Cobalt therapy services (in terms of absolute numbers) across tertiary care facilities in Tamil Nadu in the year 2020

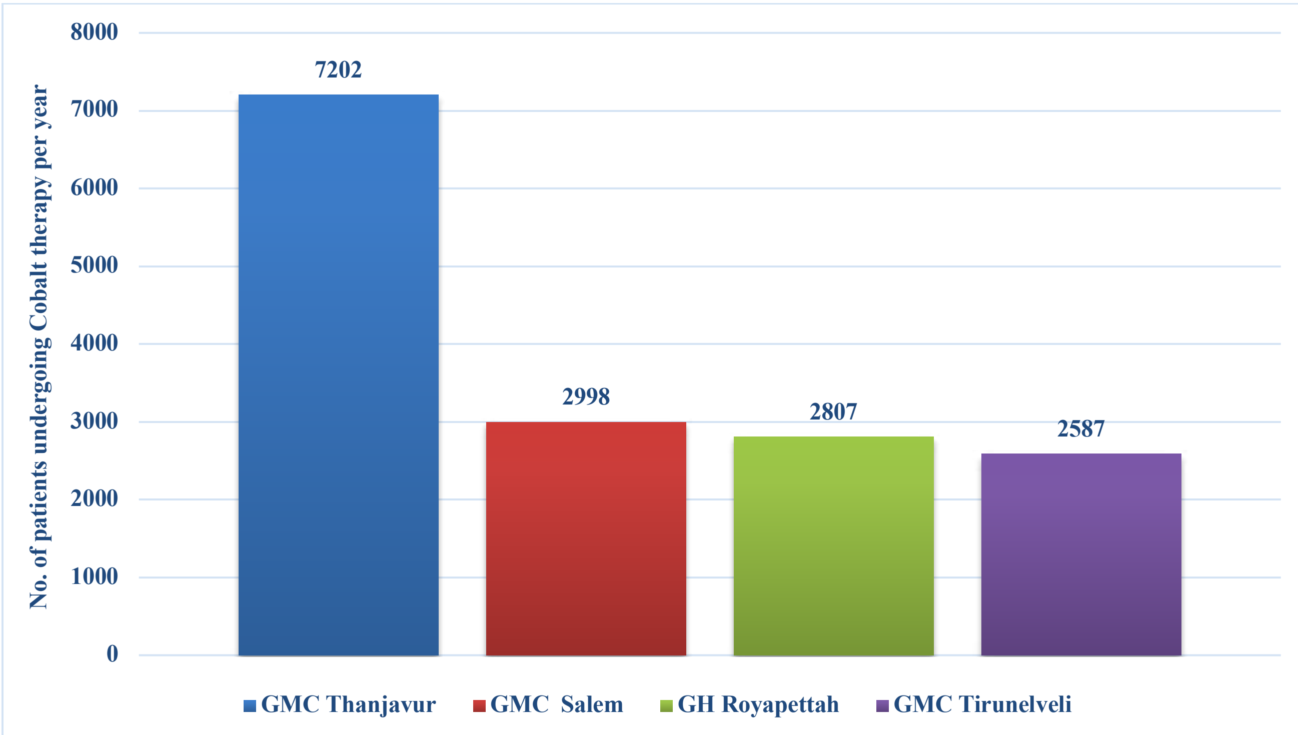


Figure 15A: Utilization of Cobalt therapy services (in terms of utilization rate per 100,000 OPD visits) across tertiary care facilities in Tamil Nadu in the year 2022

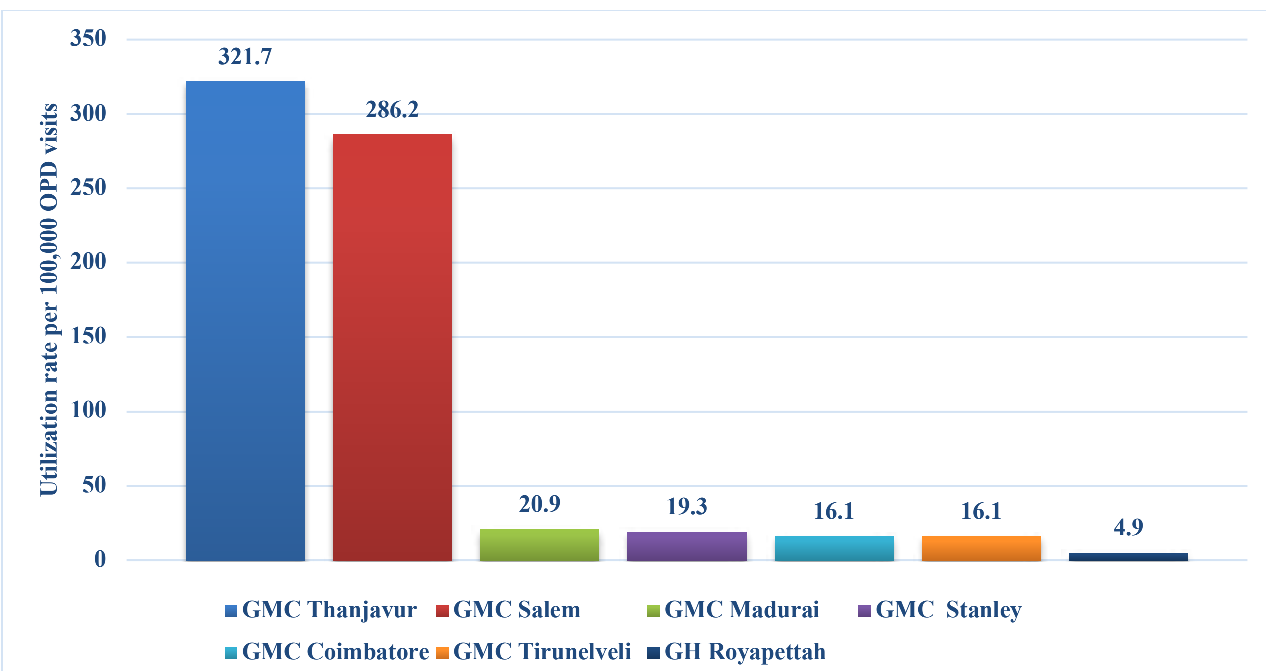


Figure 15B: Utilization of Cobalt therapy services (in terms of utilization rate per 100,000 OPD visits) across tertiary care facilities in Tamil Nadu in the year 2021

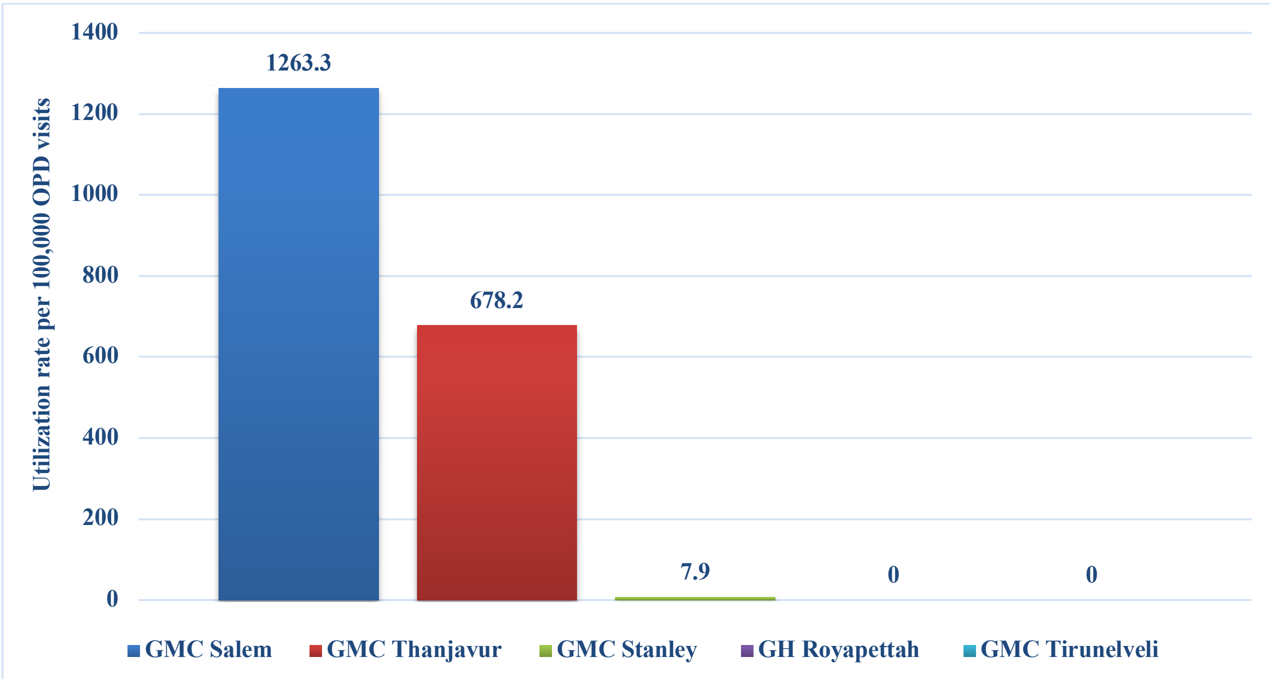
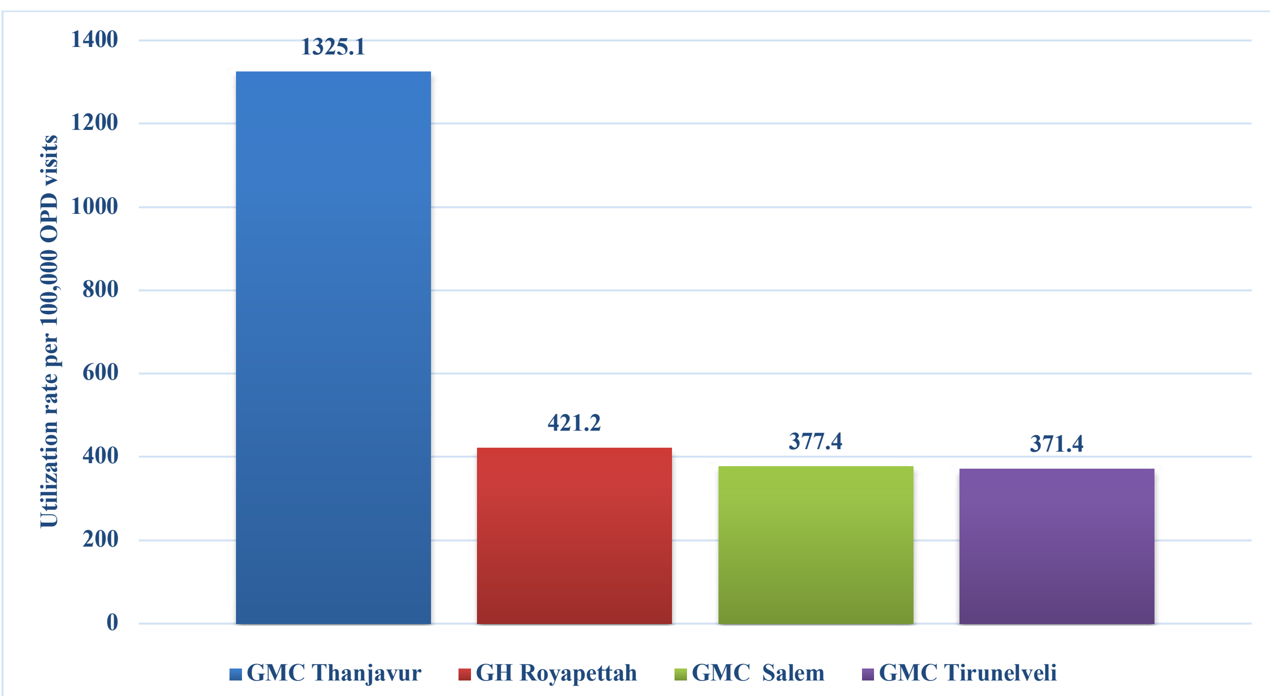


Figure 15C: Utilization of Cobalt therapy services (in terms of utilization rate per 100,000 OPD visits) across tertiary care facilities in Tamil Nadu in the year 2020



Equipment utilization – Brachytherapy:

Figure S95-S100 provides year-wise trend of utilization of Brachytherapy services across various facilities in Tamil Nadu.

Figure S95 & S96 shows that the Brachytherapy is operational in Rajiv Gandhi Government General Hospital (RGGGH) from 2015 and the utilization has been in alternate increasing and decreasing trend throughout this period with maximum dip seen in 2020 and 2022.

Figure S97, S98 & S100 shows that the brachytherapy is operational in Government Royapettah Hospital, Coimbatore Medical College Hospital and Government Tirunelveli Medical College and Hospital since 2021 and the utilization has increased in 2022 since the year of inception.

Figure S99 shows that the brachytherapy is operational in Madurai Medical College Hospital since 2020 and has been in exponential increasing trend since year of inception. Government Medical College, Omandurar and Government Medical College Hospital, Thanjavur started the brachytherapy services since 2022. The service was utilized by 70 patients in Government Medical College, Omandurar and 115 patients in Government Medical College Hospital, Thanjavur.

Joinpoint regression was not performed for any of the facilities having brachytherapy as most of the facilities had data for only the last 1-2 years.

Two-Year Trend in Utilization of Brachytherapy services across various tertiary care facilities in Tamil Nadu:

Figure 16 & 17 depicts the institute-wise trend of brachytherapy utilization in terms of absolute numbers and utilization rate per 100,000 OPD visits from 2021 to 2022.

Over the past three years, Government Mohan Kumaramangalam Medical College and Hospital, Salem and Government Medical College Hospital, Thanjavur had the highest number of patients undergoing brachytherapy services. This also indirectly reflects the high burden of cancerous conditions necessitating the Cobalt therapy services in these districts.

Government Royapettah Hospital and Government Tirunelveli Medical College and Hospital had the lowest utilization mainly due to their non-operational nature in the recent years.

Figure 16A: Utilization of Brachytherapy services (in terms of absolute numbers) across tertiary care facilities in Tamil Nadu in the year 2022

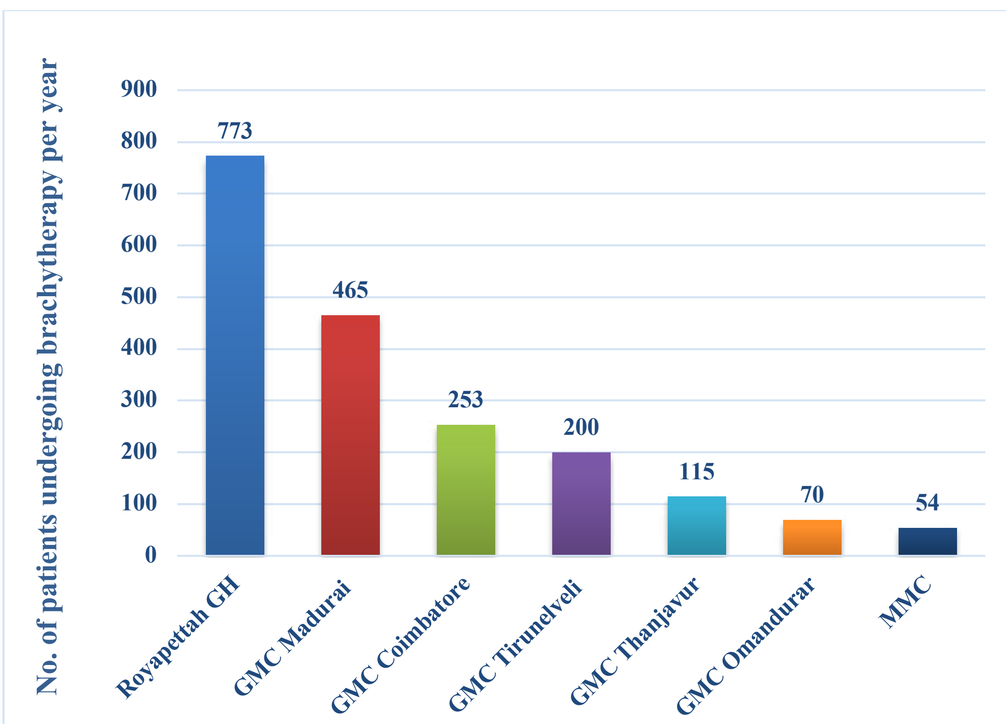


Figure 16B: Utilization of Brachytherapy services (in terms of absolute numbers) across tertiary care facilities in Tamil Nadu in the year 2021

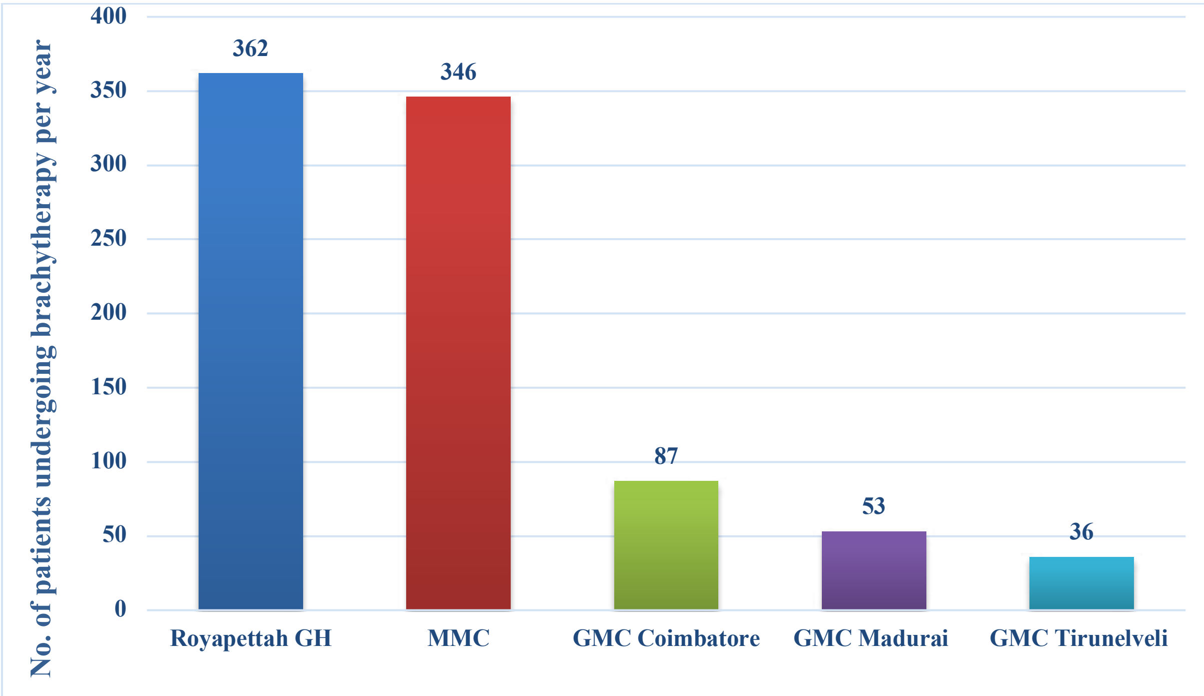


Figure 17A: Utilization of Brachytherapy services (in terms of utilization rate per 100,000 OPD visits) across tertiary care facilities in Tamil Nadu in the year 2022

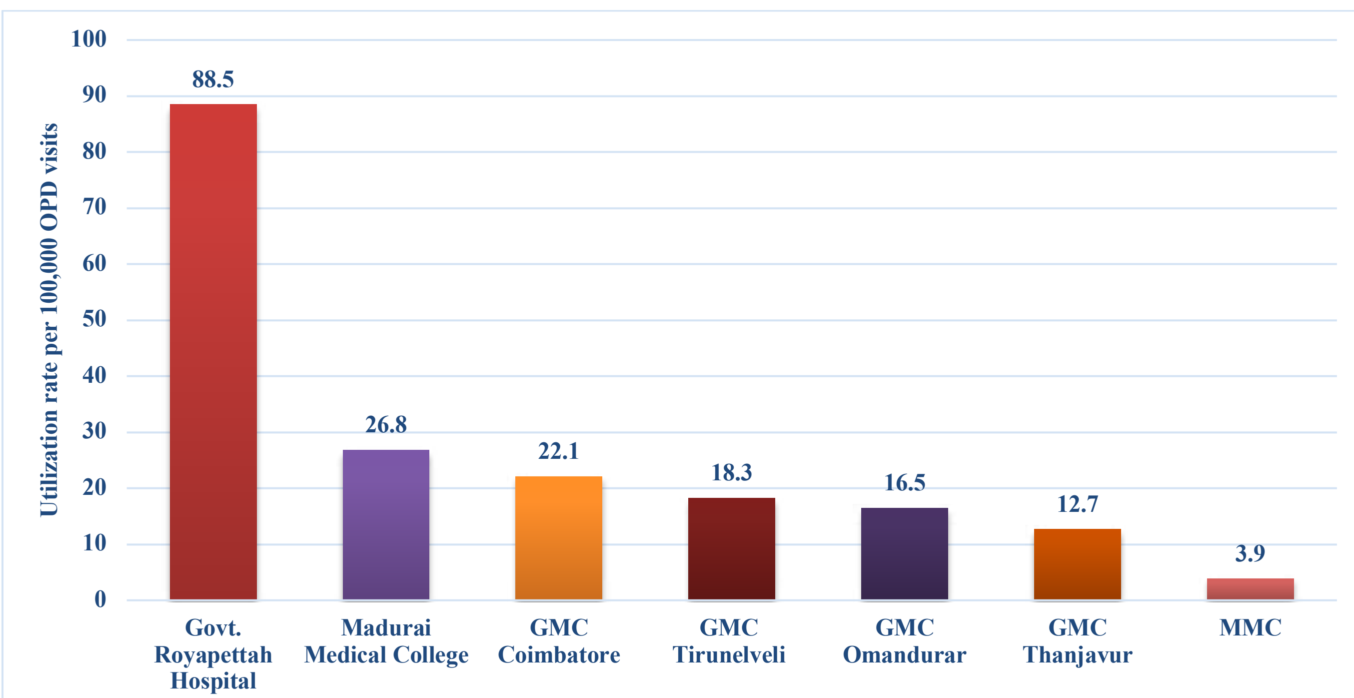
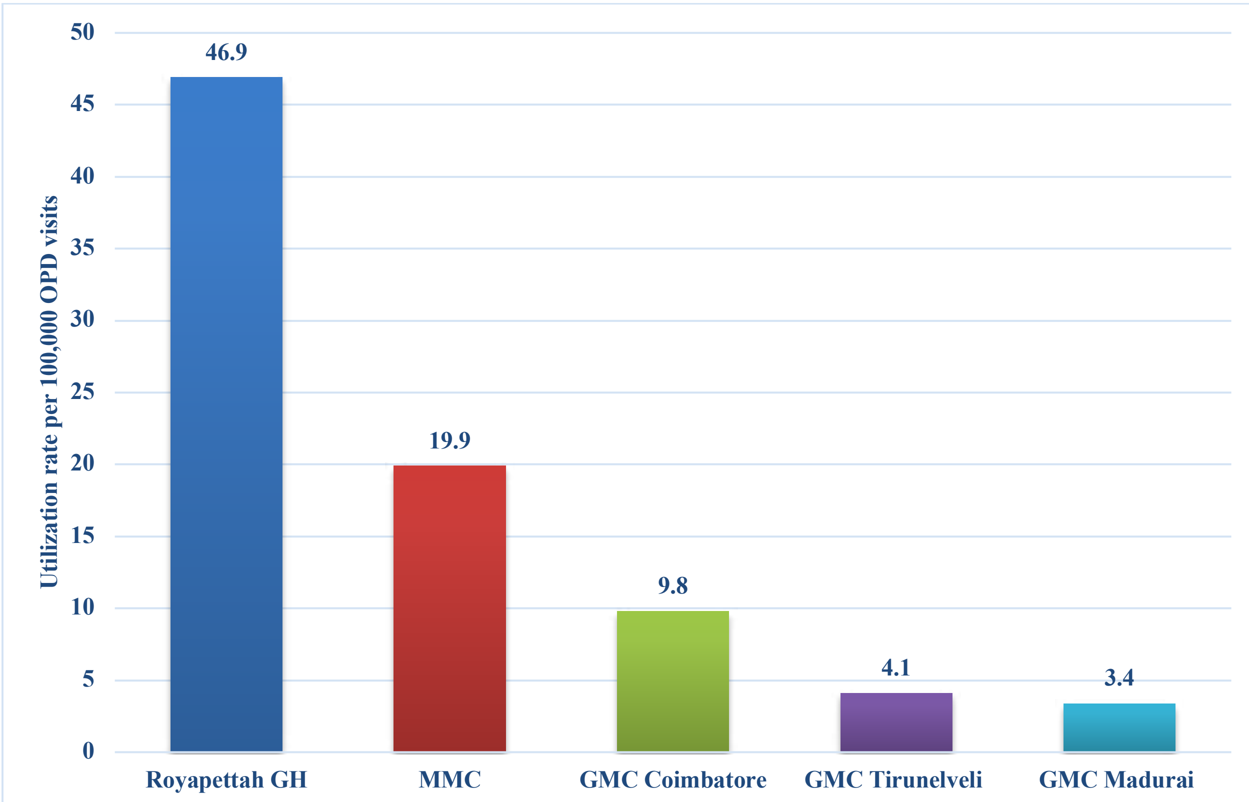


Figure 17B: Utilization of Brachytherapy services (in terms of utilization rate per 100,000 OPD visits) across tertiary care facilities in Tamil Nadu in the year 2021



Correlation between equipment utilization rate and performance indicators:

CT scan services utilization and equipment performance:

Figure S101 shows correlation between overall equipment effectiveness and utilization rate of CT scan services per OPD visit at secondary and tertiary healthcare facilities of Tamil Nadu in the year 2022. There is a very strong positive correlation between Overall equipment effectiveness and utilization rate **(r=0.75, p value: <0.001)**. Overall equipment effectiveness increases with increase in utilization of CT scan services. Tertiary care centres with higher utilization rates for CT scan services demonstrate higher overall equipment effectiveness. Whereas, secondary care centres with low utilization of CT scan services have demonstrated low overall equipment effectiveness for the equipment.

Figure S102 shows correlation between total effective equipment performance and utilization rate of CT scan services per OPD visit at secondary and tertiary healthcare facilities of Tamil Nadu in the year 2022. There is a strong positive correlation between Total effective equipment performance and utilization rate **(r=0.65, p value: <0.001)**. Total effective equipment performance increases with increase in utilization of CT scan services. Tertiary care centres with higher utilization rates for CT scan services demonstrate higher Total effective equipment performance. Whereas, secondary care centres with low utilization of CT scan services have demonstrated total effective equipment performance for the equipment.

MRI scan services utilization and equipment performance:

Figure S103 shows the correlation between overall equipment effectiveness and utilization rate of MRI scan services per OPD visit at secondary and tertiary healthcare facilities of Tamil Nadu in the year 2022. There is a very weak negative correlation between Overall equipment effectiveness and utilization rate and it was not statistically significant **(r= -0.09, p value: 0.79)**. Overall equipment effectiveness remains significantly unaffected with increase in utilization of MRI scan services. This relationship does not vary between secondary and tertiary care centres.

Figure S104 shows Correlation between Total effective equipment performance and Utilization rate of MRI scan services per OPD visit at secondary and tertiary healthcare facilities of Tamil Nadu in the year 2022. There is a weak negative correlation between Total effective equipment performance and utilization rate and it was not statistically significant **(r= -0.5, p value: 0.09)**. Total effective equipment performance appears to decrease with increase in utilization of MRI scan services. However, it was not statistically significant. This relationship does not vary between secondary and tertiary care centres.

Lithotripsy equipment services utilization and equipment performance:

Only two of the 24 facilities observed had a functional lithotripsy machine on the day of the visit. There is a very strong positive correlation between overall equipment effectiveness as well as total effective equipment performance and utilization rate **(r=1, p value: <0.001)**. Because, there are only two facilities, it appears to have a perfect linear correlation. Overall equipment effectiveness and total effective equipment performance increases with increase in utilization of Lithotripsy equipment services.

LINAC equipment services utilisation and equipment performance:

Figure S105 shows the correlation between overall equipment effectiveness and utilization rate of LINAC equipment services per OPD visit in secondary and tertiary healthcare facilities of Tamil Nadu in 2022. There is a strong positive correlation between Overall equipment effectiveness and utilisation rate **(r=0.62, p value: 0.137)**. However, it is statistically not significant. Overall equipment effectiveness appears to increase with increase in utilization of LINAC equipment services. **Figure S106** shows the correlation between total effective equipment performance and utilization rate of LINAC equipment services per OPD visit in secondary and tertiary healthcare facilities of Tamil Nadu in 2022. There is a weak positive correlation between Total effective equipment performance and utilization rate **(r=0.50, p value: 0.250)**. However, it is statistically not significant. Total effective equipment performance appears to increase with increase in utilization of LINAC equipment services.

Cobalt therapy equipment utilization and equipment performance:

Figure S107 shows the correlation between overall equipment effectiveness and utilization rate of Cobalt therapy services per OPD visit at secondary and tertiary healthcare facilities of Tamil Nadu in 2022. There is a strong positive correlation between overall equipment effectiveness and utilization rate **(r=0.61, p value: 0.148)**. However, it is statistically not significant. Overall equipment effectiveness appears to increase with increase in utilization of Cobalt therapy services. **Figure S108** shows Correlation between Total effective equipment performance and Utilization rate of Cobalt therapy services per OPD visit There is a strong positive correlation between Total effective equipment performance and utilization rate **(r=0.61, p value: 0.148)**. However, it is statistically not significant.

Brachytherapy equipment services utilization and equipment performance:

Figure S109 shows the correlation between overall equipment effectiveness and utilization rate of Brachytherapy equipment services per OPD visit at secondary and tertiary healthcare facilities of Tamil Nadu in 2022. There is a strong negative correlation between Overall equipment effectiveness and utilization rate **(r= -0.64, p value: 0.173)**. However, it is statistically not significant. Overall equipment effectiveness appears to decrease with increase in utilization of Brachytherapy equipment services.

Figure S110 shows the correlation between total effective equipment performance and utilization rate of Brachytherapy equipment services per OPD visit at secondary and tertiary healthcare facilities of Tamil Nadu in 2022. There is a strong negative correlation between Total effective equipment performance and utilization rate **(r= -0.71, p value: 0.116)**. However, it is statistically not significant. Total effective equipment performance appears to decrease with increase in utilization of Brachytherapy equipment services.

Economic evaluation of advanced diagnostic and therapeutic equipment in public healthcare facilities of Tamil Nadu

Patient level costing

Sociodemographic and procedure related details of the study participants

In total, 2997 participants were covered during the patient level costing survey. **Table-29** shows the sociodemographic details of the study participants. Age-wise, the largest group was those aged 51-60 years (24.2%), followed by the 41-50 age group (21.0%). In terms of gender, males constituted a majority (54.6%), while females accounted for 45.3%, and transgender individuals represented a minimal portion (0.1%). Regarding education, the highest proportion was high school graduates (26.1%), with a significant number of participants being illiterate (25.7%). The predominant religion was Hinduism (90.7%), with smaller representations of Christians (4.8%) and Muslims (4.2%). Most participants resided in rural areas (69.5%). The majority of the patients underwent the procedure after visiting the outpatient department (OPD, 75.1%). In terms of economic status, based on the Modified BG Prasad Scale (2023), Class II constituted the largest group (32.1%), followed by Class III (27.5%).

Table 30 shows the procedure related details of the total study participants. CT scans were the most utilized equipment, accounting for 64.0% of the cases, followed by MRI scans (15.4%) and LINAC (10.6%). Among CT and MRI scans (n=2380), the majority were plain scans (90.4%), with a smaller percentage involving contrast (4.5%) or both (5.1%). The most frequent site of the procedure was the head and neck (38.7%), followed by the abdomen (20.7%) and thorax (18.7%). Insurance status revealed that 67.9% of the patients were insured, with the CMCHIS covering the vast majority of these (97.3%). Other insurance schemes like PMJAY, ESI, private insurance, and others accounted for a small fraction of the insured patients.

Table 29: Sociodemographic details of the study participants (N=2,997)

S.No	Characteristics	Frequency (%)
1.	**Age category (Years)**	
	≤18	168 (5.6)
	19 - 30	419 (13.9)
	31 – 40	482 (16.1)
	41 – 50	630 (21.0)
	51 – 60	724 (24.2)
	≥61	574 (19.2)
2.	**Gender**	
	Female	1358 (45.3)
	Male	1635 (54.6)
	Transgender	4 (0.1)
3.	**Education Qualification**	
	Illiterate	770 (25.7)
	Primary school	657 (21.9)
	High school	782 (26.1)
	Higher secondary	413 (13.8)
	Bachelor's degree	335 (11.2)
	Master's degree	40 (1.3)
4.	**Religion**	
	Christian	143 (4.8)
	Hindu	2720 (90.7)
	Muslim	125 (4.2)
	Others	9 (0.3)
5.	**Residence**	
	Rural	2083 (69.5)
	Urban	914 (30.5)
6.	**Type of visit**	
	IPD	745 (24.9)
	OPD	2256 (75.1)
7.	**Per capita income (Modified BG Prasad Scale 2023)**	
	Class I	208 (6.9)
	Class II	960 (32.1)
	Class III	824 (27.5)
	Class IV	705 (23.5)
	Class V	300 (10.0)

Table 30: Procedure related details of the study participants (N=2,997)

S.No	Characteristics	Frequency (%)
1.	**Equipment utilized**	
	CT Scan	1919 (64.0)
	MRI Scan	461 (15.4)
	PET Scan	35 (1.2)
	Lithotripsy	82 (2.7)
	LINAC	319 (10.6)
	Cobalt therapy	146 (4.9)
	Brachytherapy	35 (1.2)
2.	**Category of CT/MRI scan (n = 2380)**	
	Plain	2152 (90.4)
	Contrast	108 (4.5)
	Both	120 (5.1)
3.	**Site of Procedure**	
	Head and Neck	1161 (38.7)
	Thorax	559 (18.7)
	Abdomen	620 (20.7)
	Kidney	81 (2.7)
	Pelvis	242 (8.0)
	Spine	171 (5.7)
	Upper limb	56 (1.9)
	Lower limb	107 (3.6)
4.	**Insurance Status**	
	Insured	2036 (67.9)
	Noninsured	961 (32.1)
5.	**Name of insurance**	
	CMCHIS	1980 (97.3)
	PMJAY	22 (1.1)
	ESI	3 (0.1)
	Private	7 (0.3)
	Others	24 (1.2)

Access, Waiting Time and Satisfaction in utilizing the advanced diagnostic and therapeutic services in Tamil Nadu

Table 31 provides insights into access, waiting times, and patient satisfaction for various medical procedures among 2,997 participants. The median distance traveled varied significantly across procedures, with PET scans requiring the longest travel at a median of 200 km. For MRI and PET scans, patients experienced substantially longer waiting times, with medians of 120 and 270 minutes respectively, compared to other procedures like CT scans and cobalt therapy, which had shorter waiting periods (median 30 and 60 minutes).

Despite these variations in access and waiting time, patient satisfaction remained consistently high across all procedures, predominantly scoring a median of 9 out of 10. This uniform satisfaction indicates that factors like distance and waiting time, while important, did not drastically impact the overall patient satisfaction scores.

Table S2 and S3 offer a detailed view of patient satisfaction and the reasons for dissatisfaction among those utilizing advanced diagnostic and therapeutic services in Tamil Nadu, covering 2,997 participants. The overwhelming majority, 94.2%, reported high levels of satisfaction, indicating a generally positive reception of healthcare services. Only a small fraction of patients expressed low (1.0%) or moderate (4.8%) satisfaction levels.

Among the 173 participants who reported dissatisfaction, the primary cause was the long waiting time for procedures, accounting for 76.87% of the dissatisfied responses. This was followed by other factors like lack of proper instruction (9.82%), bad behavior of staff (4.19%), and delay in reporting (2.89%). These findings highlight that while the overall satisfaction with healthcare services is high, specific areas such as wait times and staff interaction require attention to further enhance patient experience.

The total median values for the study reflected a moderate distance of 30 km and a waiting time of 60 minutes, with a high satisfaction score of 9, suggesting that, on average, patients were quite satisfied with their healthcare experiences despite the logistical challenges involved.

Table 31: Access, Waiting Time and Satisfaction based on the type of procedure undergone by the study participants (N=2997)

Equipment	Distance Travelled (in km) Median (IQR)	Waiting time (in minutes) Median (IQR)	Satisfaction score (on a scale of 10) Median (IQR)
CT Scan	25 (12-60)	30 (20-60)	9 (9-10)
MRI Scan	30 (16-65)	120 (60-240)	9 (8-9)
PET Scan	200 (100-290)	270 (210-360)	9 (9-10)
Lithotripsy	45.5 (25-100)	120 (90-180)	9 (9-10)
LINAC	45 (20-120)	120 (60-180)	9 (9-10)
Cobalt Therapy	55 (20-114)	60 (30-90)	9 (9-10)
Brachytherapy	50 (20-150)	60 (20-120)	9 (8-10)
Total	30 (15-68)	60 (30-120)	9 (9-10)

Coverage and Utilization of Health Insurance by study participants

Table 32 provides a comprehensive overview of the coverage and utilization of health insurance for various medical procedures among the study participants at selected government medical colleges in Tamil Nadu, totaling 2,997 individuals. Out of the 2,997 participants, a significant portion, 39.9%, were insured yet chose not to use their insurance. This trend was most pronounced in CT scans, where 53.41% of the total 1,919 procedures were not utilized by insured individuals, despite being the most common procedure. Similarly, in the case of PET scans, a higher percentage of insured individuals (51.43%) did not utilize their insurance compared to those who did. This pattern was observed across most procedures, including MRI scans and lithotripsy, with 28.85% and 18.29% respectively of insured individuals not utilizing their insurance. Interestingly, for high-end treatments like LINAC and cobalt therapy, the non-utilization rates among the insured were remarkably low (1.25% and 0.68%, respectively). These findings underscore a significant gap in the utilization of insurance coverage for various medical procedures, despite the availability of insurance.

Comprehensive Analysis of Out-of-pocket expenditures (OOPE) incurred by the patients undergoing advanced diagnostic and therapeutic procedures in Tamil Nadu

The **Table S1** provides a detailed analysis of the financial burden borne by patients undergoing various medical procedures among 2,997 study participants. It reveals that the costliest procedure was PET scan, with an average outlay of 10,990 INR, mainly attributed to the procedure cost. For procedures like CT scans and MRI scans, while the equipment-specific procedure costs varied (500 and 2,300 INR respectively), additional expenses such as travel, food, and loss of pay significantly contributed to the overall financial burden. Notably, for treatments like lithotripsy, LINAC, and cobalt therapy, the procedure costs were negligible or zero (due to CMCHIS coverage), yet other costs like travel, food, and loss of pay for patients and their attenders constituted a considerable portion of the expenses. The table highlights the diverse nature of out-of-pocket expenditures, underscoring the need to consider various cost types, not just the direct cost of the procedure, when assessing the financial impact on patients.

Table-33 provides an insightful overview of the median costs incurred per patient for different medical procedures, with a focus on direct medical, direct non-medical, indirect costs, and the total cost, all measured in Indian Rupees (INR). For CT scans, the median direct medical cost was INR 500, with the total cost per patient reaching INR 1,460, considering all expense categories. MRI scans showed a higher median direct medical cost of INR 2,300, contributing to a total cost of INR 3,250 per patient. PET scans were the most expensive in terms of direct medical costs, with a median of INR 10,990, escalating the total cost to INR 12,150 per patient.

In contrast, procedures like lithotripsy, LINAC, cobalt therapy, and brachytherapy had minimal or no direct medical costs; however, their total costs per patient were significantly impacted by direct non-medical and indirect expenses, such as travel and loss of pay. The overall median cost across all procedures was INR 1,450 per patient, highlighting the substantial financial burden beyond just the medical expenses.

Overall, 43 (1.43%) of the participants had catastrophic health expenditure (CHE). The CHE was least amongst participants with insurance coverage (only 6 out of 43 patients), while uninsured (22 out of 43 patients) and insured and unutilized patients (15 out of 43 patients) had the highest burden of CHE.

Table 32: Coverage and Utilization of health insurance based on the type of procedure undergone by the study participants (N=2997)

Equipment	Insured and Utilised	Insured and not utilised	Uninsured	Total
CT Scan	131 (6.83%)	1025 (53.41%)	763 (39.76%)	1919
MRI Scan	154 (33.41%)	133 (28.85%)	174 (37.74%)	461
PET Scan	12 (34.29%)	18 (51.43%)	5 (14.29%)	35
Lithotripsy	52 (63.41%)	15 (18.29%)	15 (18.29%)	82
LINAC	311 (97.49%)	4 (1.25%)	4 (1.25%)	319
Cobalt Therapy	145 (99.32%)	1 (0.68%)	0 (0%)	146
Brachytherapy	35 (100%)	0 (0%)	0 (0%)	35
Total	840 (28.0%)	1196 (39.9%)	961 (32.1%)	2997

Table 33: Median Direct (Medical & Non-Medical), Indirect and Total Per-Patient Costs for utilizing advanced diagnostic and therapeutic equipments in Tamil Nadu, (N=2,997)

Equipment	Direct medical cost Median (IQR)	Direct non-medical cost Median (IQR)	Indirect cost Median (IQR)	Total cost per-patient Median (IQR)
CT	500 (500 - 500)	330 (220 - 900)	500 (300 - 800)	1460 (1150-1820)
MRI	2300 (0 - 2500)	450 (300 - 700)	500 (300 - 900)	3250 (1450–3900)
PET	10990 (0 - 10990)	900 (650 - 5200)	400 (0 - 850)	12150 (1400-16190)
Lithotripsy	0 (0 – 5000)*	550 (360 - 870)	800 (500 - 1000)	2110 (1130 -1000)
LINAC	0 (0 - 65000)*	365 (220 - 600)	400 (200 - 700)	900 (500-1250)
Cobalt	0 (0 - 500)*	350 (240 - 520)	400 (200 - 700)	840 (530-1200)
Brachytherapy	0 (0 - 250)*	750 (400 - 1020)	600 (400 - 950)	1550 (1100-1800)
Overall	500 (0-660)	360 (240-570)	500 (300-800)	1450 (1040-2020)

*For activities with median value = 0, range is provided instead of IQR (Interquartile range)

Determinants of out-of-pocket expenditure amongst patients utilizing CT scan services in Tamil Nadu

Table-34 shows the determinants of out-of-pocket expenditure amongst patients undergoing CT scan serviced in secondary and tertiary care facilities of Tamil Nadu, focusing on both median costs and the adjusted exponentiated coefficients obtained through log-linear regression, a key indicator of the relative increase in expenditure across different categories. The table covers 1,919 patients and examines various factors:

Residence:

Urban residents had a median total cost per patient of INR 1,500, while rural residents had INR 1,440. The adjusted exponentiated coefficient for urban residents was 1.13 (95% CI: 1.08-1.18), indicating a statistically significant 13% increase in cost per patient per CT scan compared to rural residents ($p < 0.001$).

Socioeconomic Status:

The cost increased with socioeconomic status. For instance, Class I had a median cost of INR 1,700, with an adjusted exponentiated coefficient of 1.25 (95% CI: 1.14-1.36), showing a significant 25% increase in costs per patient per CT scan compared to the reference group ($p < 0.001$). Similar significant increases were observed for Class II and III.

Insurance Coverage and Utilization:

Insured patients who did not utilize insurance had a median cost of INR 1,460, with an adjusted exponentiated coefficient of 1.75 (95% CI: 1.63-1.87), indicating a 75% increase in costs compared to those who utilized their insurance ($p < 0.001$). Uninsured patients had an even higher increase in cost per patient per CT scan, with an adjusted exponentiated coefficient of 1.89 (95% CI: 1.75-2.03).

Distance Travelled:

As distance increased, so did costs. For instance, the fifth quintile (≥86 km) had a median cost per patient of INR 1,775 and an adjusted exponentiated coefficient of 1.51 (95% CI: 1.42-1.60), signifying a 51% increase in costs per patient per CT scan compared to the first quintile ($p < 0.001$).

Waiting Time:

Longer waiting times (≥120 minutes) showed an adjusted exponentiated coefficient of 1.21 (95% CI: 1.12-1.30), indicating a 21% increase in costs per patient per CT scan compared to shorter waiting times ($p < 0.001$).

Type of Scan:

Undergoing both plain and contrast scans resulted in a higher cost with an adjusted exponentiated coefficient of 1.24 (95% CI: 1.15-1.34), showing a 24% increase in cost per patient per CT scan ($p < 0.001$).

Overall, the table demonstrates that urban residence, higher socioeconomic status, lack of insurance utilization, longer travel distances, longer waiting times, and the type of the scan are statistically significant factors associated with increased out-of-pocket expenditures for CT scans.

Table 34: Determinants of out-of-pocket expenditure amongst patients undergoing CT scan in secondary and tertiary care facilities of Tamil Nadu (N=1919)

S.N.	Characteristic	N	Total cost per patient Median (IQR)	Unadjusted Exponentiated Coefficient (95% CI)	Adjusted Exponentiated Coefficient (95% CI)	P value
1	**Residence**					
	Urban	540	1500 (1220-1855)	1.05 (1.01-1.09)	1.13 (1.08-1.18)	<0.001
	Rural	1379	1440 (1130-1800)	Ref	Ref	
2	**Socioeconomic status**					
	Class I	131	1700 (1200-2150)	1.18 (1.07-1.31)	1.25 (1.14-1.36)	<0.001
	Class II	690	1550 (1250-1850)	1.14 (1.05-1.22)	1.18 (1.11-1.27)	<0.001
	Class III	551	1400 (1120-1760)	1.05 (0.98-1.14)	1.10 (1.03-1.18)	0.005
	Class IV	396	1400 (1100-1740)	1.03 (0.95-1.11)	1.03 (0.96-1.11)	0.85
	Class V	151	1400 (1040-1800)	Ref	Ref	-
3	**Insurance coverage and utilization**					

	Insured and utilized	131	950 (700-1300)	Ref	Ref	-
	Insured and not utilized	1025	1460 (1180-1810)	1.58 (1.47-1.70)	1.75 (1.63-1.87)	<0.001
	Uninsured	763	1530 (1240-2900)	1.66 (1.54-1.79)	1.89 (1.75-2.03)	<0.001
4	**Distance travelled (in kms)**					
	First quintile (0-10)	453	1350 (1040-1640)	Ref	Ref	-
	Second quintile (11-20)	420	1405 (1150-1750)	1.08 (1.02-1.14)	1.08 (1.03-1.13)	0.003
	Third quintile (21-39)	400	1450 (1150-1800)	1.12 (1.06-1.18)	1.16 (1.10-1.22)	<0.001
	Fourth quintile (40-85)	346	1500 (1158-1850)	1.16 (1.10-1.23)	1.22 (1.16-1.29)	<0.001
	Fifth quintile (≥86)	300	1775 (1405-2200)	1.41 (1.33-1.50)	1.51 (1.42-1.60)	<0.001
5	**Waiting time**					
	<120 minutes	1807	1450 (1150-1800)	Ref	Ref	-
	≥120 minutes	112	1650 (1400-2150)	1.22 (1.13-1.32)	1.21 (1.12-1.30)	<0.001
6	**Type of scan**					
	Plain	1707	1450 (1150-1800)	Ref	Ref	-
	Contrast	99	1560 (1200-2150)	1.13 (1.04-1.24)	1.11 (1.02-1.20)	0.01
	Both	113	1750 (1240-2200)	1.13 (1.04-1.22)	1.24 (1.15-1.34)	<0.001

Determinants of out-of-pocket expenditure amongst patients utilizing MRI scan services in Tamil Nadu

Table 35 explores the determinants of out-of-pocket expenditure for patients undergoing MRI scans in secondary and tertiary care facilities in Tamil Nadu, analysing 461 patients. It includes both unadjusted and adjusted exponentiated coefficients from log-linear regression models, providing insights into the factors influencing these costs.

Residence:

The median total cost per patient per MRI scan for urban residents was INR 3,410, compared to INR 3,160 for rural residents. After adjusted analysis, urban residents had a statistically significant 17% increase in costs per patient compared to rural residents, with an exponentiated coefficient of 1.17 (95% CI: 1.06-1.29, p=0.002).

Socioeconomic Status:

The cost varied significantly across socioeconomic classes. Class I, the highest economic group, had a median cost of INR 3,489 per patient per MRI scan and an adjusted exponentiated coefficient of 1.45 (95% CI: 1.20-1.77), indicating a 45% increase in costs per patient compared to the reference group ($p < 0.001$). Class II and III also showed significant increases in costs per patient with adjusted exponentiated coefficients of 1.19 (p=0.03) and 1.25 (p=0.005), respectively. However, Class IV did not show a significant difference in cost from the reference group (Class V).

Insurance Coverage and Utilization:

Patients who were insured and utilized their insurance had a median cost per patient per MRI scan of INR 1,050. In stark contrast, those who were insured but did not utilize their insurance had significantly higher costs, with an adjusted exponentiated coefficient of 3.73 (95% CI: 3.34-4.17), indicating a 273% increase in costs per patient per MRI scan compared to the reference group ($p < 0.001$). Uninsured patients also faced considerably higher costs, with an adjusted exponentiated coefficient of 3.85 (95% CI: 3.47-4.26), denoting a 285% increase in costs ($p < 0.001$).

Distance Travelled:

The median cost per patient per MRI scan varied slightly with the distance travelled. Patients in the fourth quintile (40-85 km) and fifth quintile (≥86 km) experienced higher costs, with adjusted exponentiated coefficients of 1.29 (95% CI: 1.11-1.49, $p=0.001$) and 1.56 (95% CI: 1.33-1.81, $p < 0.001$) respectively, indicating increased costs per patient of 29% and 56% compared to those in the first quintile.

Waiting Time:

The data shows a minimal difference in median costs based on waiting time. For patients who waited less than 120 minutes, the median cost was INR 3,260, while for those waiting 120 minutes or more, the median cost slightly decreased to INR 3,210. The unadjusted exponentiated coefficient for longer waiting times was 0.95 (95% CI: 0.82-1.10), indicating no significant cost difference compared to the reference group.

Type of Scan:

The type of MRI scan also played a role in the costs incurred. For plain scans, the median cost per patient was INR 3,250. Contrast scans, which were less common, had a higher median cost per patient of INR 4,700, but the unadjusted exponentiated coefficient of 1.02 (95% CI: 0.60-1.75) suggests no significant difference in costs. Similarly, for the even less frequent 'both' category, the median cost per patient was INR 2,000, with an unadjusted exponentiated coefficient of 0.97 (95% CI: 0.53-1.78), indicating no significant cost difference based on type of scan.

Overall, the table demonstrates that urban residence, higher socioeconomic status, lack of insurance utilization, and longer travel distances are statistically significant factors associated with increased out-of-pocket expenditures for MRI scans.

However, longer waiting times, and the type of the scan were not significantly associated, unlike cost per patient per CT scan.

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Table 35: Determinants of out-of-pocket expenditure amongst patients undergoing MRI scan in secondary and tertiary care facilities of Tamil Nadu (N=461)

S.N.	Characteristic	N	Total cost per patient Median (IQR)	Unadjusted Exponentiated Coefficient (95% CI)	Adjusted Exponentiated Coefficient (95% CI)	P value
1	**Residence**					
	Urban	163	3410 (2000-3920)	1.14 (0.98-1.33)	1.17 (1.06-1.29)	0.002
	Rural	298	3160 (1300-3840)	Ref	Ref	
2	**Socioeconomic status**					
	Class I	40	3489 (2890-4020)	2.15 (1.55-2.98)	1.45 (1.20-1.77)	<0.001
	Class II	136	3345 (2575-3910)	1.66 (1.29-2.15)	1.19 (1.02-1.38)	0.03
	Class III	109	3360 (1600-4000)	1.62 (1.24-2.11)	1.25 (1.07-1.46)	0.005
	Class IV	127	3000 (980-3850)	1.19 (0.92-1.55)	1.05 (0.90-1.22)	0.52
	Class V	49	2750 (900-3450)	Ref	Ref	-
3	**Insurance coverage and utilization**					

	Insured and utilized	154	1050 (650-1450)	Ref	Ref	
	Insured and not utilized	133	3600 (3200-4000)	3.90 (3.49-4.37)	3.73 (3.34-4.17)	<0.001
	Uninsured	174	3660 (3280-4200)	3.95 (3.55-4.38)	3.85 (3.47-4.26)	<0.001
4	**Distance travelled (in kms)**					
	First quintile (0-10)	77	3200 (1700-3600)	Ref	Ref	
	Second quintile (11-20)	91	3300 (1290-3750)	0.95 (0.74-1.21)	1.05 (0.91-1.21)	0.47
	Third quintile (21-39)	102	3215 (1100-3900)	0.91 (0.72-1.15)	1.09 (0.94-1.25)	0.24
	Fourth quintile (40-85)	108	3250 (1840-4030)	1.15 (0.99-1.45)	1.29 (1.11-1.49)	0.001
	Fifth quintile (≥86)	83	3300 (1450-4400)	1.19 (0.92-1.52)	1.56 (1.33-1.81)	<0.001
5	**Waiting time**					
	<120 minutes	258	3260 (1570-3850)	Ref	[Not included in the model]	
	≥120 minutes	203	3210 (1250-3900)	0.95 (0.82-1.10)		
6	**Type of scan**					
	Plain	445	3250 (1450-3850)	Ref	[Not included in the model]	
	Contrast	9	4700 (2800-4790)	1.02 (0.60-1.75)		
	Both	7	2000 (950-5050)	0.97 (0.53-1.78)		

Determinants of out-of-pocket expenditure amongst patients utilizing lithotripsy services in Tamil Nadu

Table 36 examines the determinants of out-of-pocket expenditure among patients undergoing lithotripsy procedures in Tamil Nadu, with a sample size of 82 patients. The table includes both unadjusted and adjusted exponentiated coefficients from log-linear regression models to assess factors impacting these costs.

Residence:

The median total cost per patient per lithotripsy procedure for urban residents was INR 2,110, compared to INR 2,050 for rural residents. The unadjusted exponentiated coefficient for urban residents was 0.91 (95% CI: 0.59-1.40), suggesting no significant difference in costs compared to rural residents. The residence variable was not included in the adjusted model.

Socioeconomic Status:

The cost per patient varied across socioeconomic classes. Class I, with a median cost per patient of INR 5,880, had an unadjusted exponentiated coefficient of 4.22 (95% CI: 1.31-13.57), indicating a considerable increase in costs. However, this was not statistically significant in the adjusted model (coefficient 1.50, p=0.22). For other classes (II, III, IV), the adjusted coefficients were close to 1, indicating no significant difference in costs compared to the reference group (Class V).

Insurance Coverage and Utilization:

A stark difference in costs is observed based on insurance coverage and utilization. Those who were insured and utilized their insurance had a median cost per patient of INR 1,296. In contrast, insured patients who did not utilize their insurance had significantly higher costs with an adjusted exponentiated coefficient of 5.14 (95% CI: 3.77-7.01), indicating a 414% increase in costs per patient per lithotripsy procedure ($p < 0.001$). Uninsured patients faced the highest costs, with a median of INR 6,800 and an adjusted coefficient of 5.89 (95% CI: 4.38-7.91), denoting a 489% increase in costs per patient per lithotripsy procedure ($p < 0.001$).

Distance Travelled:

The analysis showed that the distance travelled had a varying impact on costs per patient. Patients in the third quintile (21-39 km) had a higher median cost per patient of INR 3,785, but the adjusted exponentiated coefficient of 1.39 (95% CI: 0.91-2.13) was not statistically significant ($p=0.12$). Similar trends were observed for other quintiles, indicating no significant impact of distance on costs after adjusting with other factors.

Waiting Time:

The median cost per patient per lithotripsy procedure was INR 2,150 for those waiting less than 120 minutes and INR 1,950 for those waiting 120 minutes or more. The unadjusted exponentiated coefficient for longer waiting times was 0.90 (95% CI: 0.59-1.37), suggesting no significant difference in costs.

Table 36: Determinants of out-of-pocket expenditure amongst patients undergoing lithotripsy procedure in secondary and tertiary care facilities of Tamil Nadu (N=82)

S.N.	Characteristic	N	Total cost per patient Median (IQR)	Unadjusted Exponentiated Coefficient (95% CI)	Adjusted Exponentiated Coefficient (95% CI)	P value
1	**Residence**					
	Urban	32	2110 (1200-6065)	0.91 (0.59-1.40)	[Not included in the model]	
	Rural	50	2050 (1010-6250)	Ref		
2	**Socioeconomic status**					
	Class I	7	5880 (2350-6770)	4.22 (1.31-13.57)	1.50 (0.78-2.87)	0.22
	Class II	36	2007.5 (1180-6250)	2.26 (0.85-6.03)	1.07 (0.63-1.83)	0.79
	Class III	22	2775 (1000-6250)	2.16 (0.79-5.96)	1.01 (0.59-1.74)	0.97
	Class IV	13	1950 (900-2450)	1.63 (0.56-4.72)	1.24 (0.71-2.16)	0.44
	Class V	4	1100 (815-1435)	Ref	Ref	-
3	**Insurance coverage and utilization**					

	Insured and utilized	52	1296 (880-2012.5)	Ref	Ref	-
	Insured and not utilized	15	6230 (5960-6530)	5.02 (3.77-6.68)	5.14 (3.77-7.01)	<0.001
	Uninsured	15	6800 (6250-8850)	5.97 (4.49-7.94)	5.89 (4.38-7.91)	<0.001
4	**Distance travelled (in kms)**					
	First quintile (0-10)	8	1185 (775-4175)	Ref	Ref	-
	Second quintile (11-20)	10	2087.5 (1312-2450)	1.12 (0.45-2.80)	1.39 (0.86-2.25)	0.17
	Third quintile (21-39)	18	3785 (1010-6130)	1.83 (0.81-4.13)	1.39 (0.91-2.13)	0.12
	Fourth quintile (40-85)	24	2325 (1055-6275)	1.51 (0.69-3.31)	1.09 (0.73-1.63)	0.67
	Fifth quintile (≥86)	22	2050 (1350-6670)	1.66 (0.76-6.66)	1.41 (0.94-2.10)	0.09
5	**Waiting time (in minutes)**					
	<120	43	2150 (1100-6400)	Ref	[Not included in the model]	
	≥120	39	1950 (1170-6130)	0.90 (0.59-1.37)		

Determinants of out-of-pocket expenditure amongst patients utilizing radiotherapy services (LINAC, Cobalt therapy and brachytherapy) in Tamil Nadu

Table 37 investigates the factors affecting out-of-pocket expenditure for patients undergoing various radiotherapy procedures (Cobalt therapy, LINAC, Brachytherapy) in Tamil Nadu, with a total sample of 500 patients. The table includes both unadjusted and adjusted exponentiated coefficients from log-linear regression models, which help in understanding the relative impact of different factors on healthcare costs.

Residence:

The median cost per patient per radiotherapy procedure for urban residents was INR 1,020, compared to INR 835 for rural residents. The unadjusted exponentiated coefficient for urban residents was 1.02 (95% CI: 0.86-1.20), indicating a negligible increase in costs compared to rural residents. The residence variable was not included in the adjusted model.

Socioeconomic Status:

The cost varied across socioeconomic classes. For instance, Class I had a median cost of INR 1,320 and an adjusted exponentiated coefficient of 1.69 (95% CI: 1.16-2.47), suggesting a 69% increase in costs per patient per radiotherapy procedure compared to the reference group (Class V, p=0.007). Classes II, III, and IV also showed significant increases in costs per patient with adjusted exponentiated coefficients of 1.29 (p=0.02), 1.30 (p=0.01), and 1.26 (p=0.02) respectively, indicating that higher socioeconomic status was associated with higher out-of-pocket expenses for radiotherapy procedures.

Insurance Coverage and Utilization:

The majority of patients were insured and utilized their insurance, with a median cost per patient per radiotherapy procedure of INR 900. However, the few who were insured but did not utilize their insurance (5 patients) faced dramatically higher costs, with a median of INR 55,900 and an adjusted exponentiated coefficient of 35.48 (95% CI: 17.73-71.01), indicating a 3448% increase in costs ($p < 0.001$). Uninsured patients (4 patients) also experienced high costs, with a median of INR 37,050 and an adjusted exponentiated coefficient of 35.44 (95% CI: 15.44-81.33), suggesting a similar scale of increase in costs ($p < 0.001$).

Distance Travelled:

The median cost per patient increased with the distance travelled. Patients in the fifth quintile (≥86 km) incurred a median cost of INR 1,000, with an adjusted exponentiated coefficient of 1.90 (95% CI: 1.51-2.38), indicating a 90% increase in costs compared to the first quintile ($p < 0.001$). The third and fourth quintiles also showed significant increases in costs with adjusted coefficients of 1.39 ($p=0.02$) and 1.32 ($p=0.02$) respectively.

Waiting Time:

The median cost per patient for those waiting less than 120 minutes was INR 900. Waiting time was not included in the adjusted model, suggesting it might not have a statistically significant impact on out-of-pocket expenditure due to utilization of radiotherapy procedure.

Table 37: Determinants of out-of-pocket expenditure amongst patients undergoing radiotherapy procedure (Cobalt therapy, LINAC, Brachytherapy) in secondary and tertiary care facilities of Tamil Nadu (N=500)

S.N.	Characteristic	N	Total cost per patient Median (IQR)	Unadjusted Exponentiated Coefficient (95% CI)	Adjusted Exponentiated Coefficient (95% CI)	P value
1	**Residence**					
	Urban	178	1020 (600-1300)	1.02 (0.86-1.20)	[Not included in the model]	
	Rural	322	835 (520-1300)	Ref		
2	**Socioeconomic status**					
	Class I	24	1320 (753-11150)	3.70 (2.47-5.54)	1.69 (1.16-2.47)	0.007
	Class II	87	910 (540-1300)	1.27 (0.98-1.66)	1.29 (1.03-1.62)	0.02
	Class III	135	900 (600-1210)	1.22 (0.96-1.55)	1.30 (1.06-1.59)	0.01
	Class IV	160	950 (570-1400)	1.25 (0.99-1.57)	1.26 (1.04-1.54)	0.02
	Class V	94	810 (370-1270)	Ref	Ref	-
3	**Insurance coverage and utilization**					
	Insured and utilized	491	900 (530-1300)	Ref	Ref	-

	Insured and not utilized	5	55900 (55350-56800)	35.62 (17.66-71.86)	35.48 (17.73-71.01)	<0.001
	Uninsured	4	37050 (18325-60615)	41.19 (18.81-90.20)	35.44 (15.44-81.33)	<0.001
4	**Distance travelled (in kms)**					
	First quintile (0-10)	62	680 (320-1150)	Ref	Ref	-
	Second quintile (11-20)	92	925 (600-1220)	1.18 (0.88-1.59)	1.28 (0.99-1.65)	0.06
	Third quintile (21-39)	64	890 (495-1375)	1.11 (0.80-1.53)	1.39 (1.06-1.82)	0.02
	Fourth quintile (40-85)	121	850 (500-1250)	1.15 (0.86-1.52)	1.32 (1.04-1.68)	0.02
	Fifth quintile (≥86)	163	1000 (730-1650)	1.55 (1.18-2.03)	1.90 (1.51-2.38)	<0.001
5	**Waiting time (in minutes)**					
	<120	360	900 (525-1300)	Ref	[Not included in the model]	
	≥120	140	970 (567.5-1400)	0.99 (0.82-1.19)		

EQUIPMENT LEVEL COSTING ANALYSIS

Overview of the analysis

This report presents a comprehensive cost analysis of advanced diagnostic and therapeutic equipment from both the health system and societal perspectives. Societal perspective results integrates patient out-of-pocket expenses (OOPE), obtained through a patient costing survey, after adjusting for income generated for the health system from these procedures.

The detailed cost information for each piece of equipment observed during our survey across various facilities was collected. This included the direct cost of equipment usage. Missing data were supplemented by inquiries with TNMSC, obtaining available details. For data not retrievable from facilities or TNMSC, assumptions were made after consultation with subject experts. This approach helped in estimating indirect costs associated with equipment usage.

Assumptions regarding the allocation of manpower time and salary were made, especially for departments like radiology handling multiple equipment types (CT, MRI, ultrasonography, etc.). This involved determining the percentage of manpower allocated to each equipment type and the average manpower cost per facility.

Consultations with biomedical engineers, hospital administrators, and technicians informed assumptions about electricity consumption for each equipment type. Using data from a time and motion survey, annual energy consumption and corresponding expenditures were calculated.

The analysis did not include the PET scan due to its operation under a public-private partnership model, and lithotripsy was excluded because of unavailable details about annual maintenance contracts (AMCs) and other recurring expenditures.

We identified various cost drivers from health system and societal perspectives for analysis.

Major Cost Drivers Identified (Health System Perspective):

Capital Costs: This encompasses the purchase cost, infrastructure, installation costs at inception.

Annual Maintenance Cost (AMC): Regular servicing and repair costs paid to the company.

Human Resource Cost: Salaries of various personnel (professors, associate/assistant professors, residents, postgraduates, technicians, data entry operators, nurses, operators, sweepers, security) were proportionally allocated to each equipment based on consultations, focusing on departments like radiology and radiotherapy.

Electricity Consumption Cost: Calculated based on units consumed per minute and total working time of the equipment.

Other Recurring Costs: Includes expenses for films, contrast material, stationeries, covers, etc., as applicable for each equipment.

Societal Perspective Additional Costs: Includes patient out-of-pocket expenses (OOPE), accounting for direct medical and non-medical costs, as well as indirect costs, subtracting the cost of procedures. The total societal cost is obtained by multiplying the average per patient cost for undergoing procedure with each of the five equipments and average utilization rate of the equipment.

Data for each cost driver was meticulously collected for each piece of equipment across all facilities. The final cost output was derived by averaging these costs. To account for variations in utilization rates and facility types (e.g., medical colleges, general hospitals, particularly for CT scans), averages were calculated separately for each stratum. The findings are reported distinctly for different facility types and strata to reflect the nuanced expenditure patterns. This approach ensures a more accurate and representative understanding of the costs associated with medical equipment from both health system and societal viewpoints.

The final output of this analysis was to provide a detailed cost assessment for five key medical equipments (CT, MRI, Cobalt therapy, LINAC, brachytherapy) from both health system and societal perspectives, considering various utilization scenarios and facility types.

Final outputs

Capital Costs: Determined for installing new equipment for each of the five types mentioned.

Average Annual Expenditure: Calculated for the operation of each equipment in a facility.

Average Cost per Procedure: This was assessed for each of the five equipment types. Cost was calculated from both health system and societal perspectives. There was specific focus on the variation in cost per procedure in facilities with low caseload versus high caseload.

Additional Analysis

Separate analysis for different scenarios:

- High utilization vs. low utilization facilities.
- For CT scans, an additional distinction between medical colleges and Government hospitals (GH).
- Separate expenditure reports for each scenario under these categories.
- However, this categorization was not applicable for radiotherapy equipment as the utilization of these services were on the lower side across all the facilities.

Cost Range Estimation:

- Presented by establishing lower and upper thresholds for all cost drivers.
- This approach provides a range within which the expenditure can vary.
- Certain cost drivers were treated differently due to the nature of the data available. Notably, values obtained directly from reliable and authoritative sources, such as company quotes for capital costs and Annual Maintenance Costs (AMC), were not subjected to the range-based estimation approach. The rationale behind this decision is grounded in the precision and accuracy of these figures:
    - The values for capital costs and AMC, as quoted by the companies, represent the exact amount expended by the government.
    - Given the accuracy of these figures, they were taken as fixed values in the analysis.
    - Using these precise values ensures the integrity and accuracy of the cost analysis in these specific areas.
    - It provides a clear and straightforward understanding of the government's expenditures on these particular cost drivers.

Sensitivity Analysis:

- Conducted by varying each of the cost drivers individually.
- The impact of these variations was illustrated through Tornado diagrams, offering a visual representation of how changes in each driver affect the overall cost.

Equipment-wise costing findings

Costing Analysis of CT Scan

Table-38 encapsulates the cost analysis for Computed Tomography (CT) scans at medical colleges and government hospitals in Tamil Nadu, considering various utilization rates. The analysis incorporates several key cost drivers: capital costs, Annual Maintenance Costs (AMC), human resource costs, electricity costs, other operational costs, and total patient costs per year.

Costing at Medical Colleges

Base Case Scenario: The base case for medical colleges showed a capital cost of INR 20,088,480, AMC cost of INR 2,800,000, with human resource and electricity costs amounting to INR 4,488,000 and INR 720,000 respectively. Other annual costs were INR 2,719,400, resulting in a total societal cost of INR 22,462,856. The average annual utilization rate was 20,945 scans.

High Utilization Scenario: In scenarios of higher utilization, the societal cost increased to INR 25,154,160 with the utilization rate of 29,945 scans.

Low Utilization Scenario: For lower utilization, the societal cost decreased to INR 21,962,745, with the utilization rate dropping to 8,106 scans.

Costing at Government Hospitals

Base Case Scenario: The base case for government hospitals showed a capital cost of INR 20,088,480, AMC cost of INR 2,800,000, human resource cost at INR 1,920,000, and electricity cost at INR 360,000. Other costs amounted to INR 335,000, leading to a total societal cost of INR 5,000,000, with an average utilization rate of 8,106 scans per year.

High Utilization Scenario: With higher utilization, the societal cost was INR 6,513,576.

Low Utilization Scenario: Conversely, lower utilization led to a societal cost of INR 2,716,740.

For both medical colleges and government hospitals, minimum and maximum thresholds were established for each input parameter, providing a range for potential expenditures. For instance, in medical colleges, the capital cost ranged from INR 15,088,480 to INR 46,488,480, whereas in government hospitals, it varied from INR 15,088,480 to INR 21,788,480.

Cost Analysis of MRI Scan

The **Table-39** outlines the cost analysis for Magnetic Resonance Imaging (MRI) scans in secondary and tertiary care facilities across Tamil Nadu, accounting for variations in utilization rates.

Overall Costs:

Base Case: The capital cost stood at INR 58,961,878, with an AMC of INR 3,556,887. Human resource costs were INR 4,938,000, electricity costs at INR 3,600,000, and other yearly costs at INR 1,568,440. This resulted in a societal cost of INR 7,564,524 annually, with a utilization rate of 8,329 scans.

Minimum and Maximum Scenarios: Costs varied between INR 3,507,564 to INR 14,359,050 per year, aligning with the minimum and maximum threshold values set for input parameters.

Higher Utilization Rate Facilities:

Base Case: The base case for facilities with higher utilization rates showed a capital cost of INR 72,361,878, leading to a societal cost of INR 11,561,940 per year, at a utilization rate of 8,329 scans.

Cost Range: The societal cost ranged from INR 4,912,490 to INR 14,359,050, reflecting the minimum and maximum thresholds.

Lower Utilization Rate Facilities:

Base Case: For facilities with lower utilization rates, the capital cost was INR 58,961,878, resulting in a societal cost of INR 7,564,524 per year, with a utilization rate of 6,318 scans.

Cost Range: In this scenario, the societal cost varied from INR 3,507,564 to INR 10,764,468.

The cost of operating MRI scanners in Tamil Nadu varies significantly based on the utilization rate of the facilities. Higher utilization rates tend to increase the total patient costs due to higher operational and maintenance requirements. The range of costs provided for minimum and maximum scenarios offers a comprehensive understanding of potential expenditure fluctuations.

Cost Analysis of Radiotherapy Equipments

Table-40 delineates the cost analysis for three types of radiotherapy equipment—Cobalt therapy, Linear Accelerator (LINAC), and Brachytherapy—used in secondary and tertiary care facilities across Tamil Nadu.

Cobalt Therapy:

Base Case: The capital cost is INR 44,494,657, with an AMC of INR 1,000,000. Yearly human resource costs are INR 5,094,000, electricity costs at INR 3,276,000, and other costs at INR 8,000, leading to a societal cost of INR 984,368. The annual utilization rate is 1,232 treatments.

Cost Range: The societal cost ranges from INR 53,234 to INR 2,427,210, reflecting minimum and maximum threshold variations.

LINAC:

Base Case: For LINAC, the capital cost is INR 170,775,764, with an AMC of INR 6,400,000. The societal cost is significantly higher at INR 25,607,370 per year, with a utilization rate of 4,710 treatments.

Cost Range: Here, societal costs range from INR 1,133,876 to INR 36,415,062.

Brachytherapy:

Base Case: The capital cost for Brachytherapy is INR 27,632,960, AMC cost at INR 562,500, leading to a societal cost of INR 609,150 annually, for 253 treatments.

Cost Range: This cost ranges from INR 109,242 to INR 1,298,640 based on minimum and maximum thresholds.

The cost analysis highlights significant differences in capital and operational costs among the three types of radiotherapy equipment. LINAC exhibits the highest total patient costs due to its advanced technology and higher capital expenditure. The utilization rate plays a critical role in determining societal costs, with higher utilization rate correlating with increased operation cost.

Table 38: Major cost drivers (input parameters) for the costing analysis of CT scan at secondary and tertiary care facilities in Tamil Nadu

Equipment and Scenario	Capital cost	AMC cost	Human resource cost per year	Electricity cost per year	Other costs per year[$]	Total patient Cost per year	Utilization rate per year
CT Scan at Medical Colleges (Overall)							
Base case	20088480	2800000	4488000	720000	2719400	22462856	20945
Minimum*	15088480	2800000	3192000	360000	1899200	4637500	984
Maximum[#]	46488480	2800000	5505000	1200000	4606000	36647100	34902
CT Scan at Medical Colleges (with higher utilization rate)							
Base case	20088480	2800000	4488000	720000	2800000	25154160	29945
Minimum	17788480	2800000	3192000	360000	1714680	17469836	15767
Maximum	40388480	2800000	5505000	1200000	4052880	36647100	34902
CT Scan at Medical Colleges (with lower utilization rate)							
Base case	20088480	2800000	4488000	500000	2783440	21962745	8106
Minimum	15088480	2800000	3192000	300000	1600000	4637500	6351
Maximum	40388480	2800000	5505000	1000000	2800000	23530018	23435

CT Scan at Government Hospitals (Overall)							
Base case	20088480	2800000	1920000	360000	335000	5000000	8106
Minimum	15088480	2800000	1584000	180000	171000	118200	394
Maximum	21788480	2800000	3036000	720000	1109000	28942225	24003
CT Scan at Government Hospitals (with higher utilization rate)							
Base case	20088480	2800000	1920000	360000	600000	6513576	8106
Minimum	15088480	2800000	1584000	180000	300000	3218082	2984
Maximum	21788480	2800000	3036000	720000	1100000	28942225	24003
CT Scan at Government Hospitals (with lower utilization rate)							
Base case	15488480	2800000	1920000	100000	157000	2716740	3159
Minimum	15088480	2800000	1584000	400000	100000	118200	394
Maximum	21788480	2800000	3036000	200000	295745	10047996	13291

All costs are provided in Indian Rupee (INR)

**Minimum threshold values for all the input parameters*

[#]*Maximum threshold values for all the input parameters*

[$]*Includes films, covers, stationaries, contrast materials etc.,*

AMC – Annual Maintenance cost; CT – Computed Tomography

Table 39: Major cost drivers (input parameters) for the costing analysis of MRI scan at secondary and tertiary care facilities in Tamil Nadu

Equipment and Scenario	Capital cost	AMC cost	Human resource cost per year	Electricity cost per year	Other costs per year[$]	Total patient cost per year	Utilization rate per year
MRI Scan (Overall)							
Base case	58961878	3556887	4938000	3600000	1568440	7564524	8329
Minimum*	46061878	3556887	3480000	1800000	1010200	3507564	3145
Maximum[#]	72461878	3556887	5955000	6000000	2546800	14359050	11053
MRI scan (in facilities with higher utilization rate)							
Base case	72361878	3556887	4938000	3600000	1568440	11561940	8329
Minimum	58961878	3556887	3480000	1800000	1145520	4912490	4080
Maximum	154061878	3556887	5955000	6000000	2546800	14359050	11675

MRI Scan (in facilities with lower utilization rate)							
Base case	58961878	3556887	4938000	3600000	1871040	7564524	6318
Minimum	46061878	3556887	3480000	1800000	1530000	3507564	3145
Maximum	72461878	3556887	5955000	6000000	2036736	10764468	9385

All costs are provided in Indian Rupee (INR)

**Minimum threshold values for all the input parameters*

#Maximum threshold values for all the input parameters

$Includes films, covers, stationaries, contrast materials etc.,

AMC – Annual Maintenance cost; MRI – Magnetic resonance imaging

Table 40: Major cost drivers (input parameters) for the costing analysis of radiotherapy equipments at secondary and tertiary care facilities in Tamil Nadu

Equipment and Scenario	Capital cost	AMC cost	Human resource cost per year	Electricity cost per year	Other costs$	Total patient cost per year	Utilization rate per year
Cobalt therapy							
Base case	44494657	1000000	5094000	3276000	8000	984368	1232
Minimum*	40045191	1000000	3408000	2808000	7500	53234	43
Maximum#	48944122	1000000	6267000	3744000	9600	2427210	3258
LINAC							
Base case	170775764	6400000	5094000	3276000	8000	25607370	4710
Minimum	153698187	6400000	3408000	2808000	7500	1133876	717
Maximum	187853340	6400000	6267000	3744000	9600	36415062	23493

Brachytherapy							
Base case	27632960	562500	5094000	3276000	8000	609150	253
Minimum	24869664	562500	3408000	2808000	7500	109242	54
Maximum	30396256	562500	6267000	3744000	9600	1298640	773

All costs are provided in Indian Rupee (INR)

**Minimum threshold values for all the input parameters (for capital costs = -10% variation was assumed)*

[#]*Maximum threshold values for all the input parameters (for capital costs = +10% variation was assumed)*

[$]*Includes films, covers, stationaries, contrast materials etc.,*

AMC – Annual Maintenance cost;

Final Costing Analysis Results

Costing of CT Scan for the Year of Inception/Installation of Equipment

Costing Analysis at Medical Colleges

In the first year of operation, the average annual cost of operating a CT scanner at medical colleges in Tamil Nadu varied significantly depending on utilization rates (**Table-41**). Under the base case scenario, the cost from the health system perspective was approximately INR 30.82 million, which increased to around INR 53.28 million when viewed from the societal perspective. This increase reflects additional expenses borne by society, including direct and indirect patient costs. The average cost per procedure was INR 1,471 from the health system perspective and INR 2,544 from the societal perspective.

In scenarios where CT scanners were highly utilized, there was a notable decrease in the cost per procedure, dropping to about INR 1,032 (health system) and INR 1,872 (societal), respectively. This suggests that higher utilization rates can significantly enhance cost-effectiveness. Conversely, in low utilization scenarios, the cost per procedure escalated to INR 3,782 and INR 6,492 for the health system and societal perspectives, respectively, underscoring the impact of patient throughput on cost efficiency.

Costing Analysis at Government Hospitals

For government hospitals, the inception year costs painted a similar picture. The base case average annual cost was around INR 25.50 million from the health system perspective and INR 32.02 million from the societal perspective. The per-procedure cost was higher in government hospitals compared to medical colleges, averaging INR 3,146 (health system) and INR 3,950 (societal).

In high utilization settings, the per-procedure costs were marginally lower, indicating better resource utilization. However, in lower utilization scenarios, these costs rose sharply, reflecting the higher per-patient cost burden when equipment is underutilized.

These findings highlight the crucial role of equipment utilization in determining the cost-effectiveness of CT scans in healthcare settings. They also underscore the importance of balancing capital investments with operational expenditures and patient throughput to optimize healthcare delivery and resource allocation in Tamil Nadu's healthcare facilities.

Costing of CT Scan After the Year of Inception (Regular Functioning of Equipment)

Costing Analysis at Medical Colleges

After the initial year of inception, the operational costs for CT scans at both medical colleges and government hospitals in Tamil Nadu exhibit notable variations, influenced primarily by the utilization rates of these facilities (**Table-42**).

In medical colleges, the base case scenario for the health system perspective shows an average annual operational cost of approximately INR 10.73 million. When considered from the societal perspective, this figure rises significantly to around INR 33.19 million, a reflection of the broader economic impact beyond the health system's direct expenses. The average cost per procedure in this scenario is INR 512 from the health system's perspective, increasing to INR 1,585 when societal costs are factored in.

This cost dynamic changes with the utilization rate of the CT scanners. In situations where scanners are utilized more frequently, there is a notable reduction in the cost per procedure. For example, in high utilization scenarios at medical colleges, the cost per procedure drops to INR 361 (health system) and INR 1,201 (societal). Conversely, in low utilization settings, these costs escalate significantly, reaching INR 1,304 (health system) and INR 4,014 (societal), underlining the impact of patient volume on cost efficiency.

Costing Analysis at Government Hospitals

The scenario at government hospitals follows a similar pattern. The base case average annual operational cost from the health system perspective is about INR 5.42 million, which increases to INR 11.93 million from the societal perspective. The cost per procedure is INR 668 from the health system perspective and INR 1,472 from the societal viewpoint. Again, higher utilization rates tend to bring down the cost per procedure, albeit to a lesser extent compared to medical colleges. In contrast, lower utilization rates lead to a substantial increase in the cost per procedure.

These findings highlight the critical role of utilization rates in determining the cost-effectiveness of CT scan services in healthcare facilities. They suggest that maximizing the use of such diagnostic tools can significantly enhance their economic viability, an important consideration for healthcare administrators and policymakers aiming to optimize resource allocation in medical imaging services.

Table 41: Costing analysis Results of CT scan for the inception year (i.e., the year of purchase and installation) at secondary and tertiary care facilities in Tamil Nadu

Equipment and Scenario	Average annual cost per equipment during inception$ Health System Perspective	Average annual cost per equipment during inception& Societal Perspective	Average cost per procedure during inception@ Health System Perspective	Total Societal cost per procedure during inception	Average cost per procedure during inception^ Societal Perspective
CT Scan at Medical Colleges (Overall)					
Base case	30815880	53278736	1471.27	1072.47	2543.74
Minimum*	23339680	27977180	5858.35	1164.03	7022.38
Maximum#	60599480	97246580	1736.27	1050	2786.27
CT Scan at Medical Colleges (with high utilization rate)					
Base case	30896480	56050640	1031.77	840.01	1871.79
Minimum	25855160	43324996	1639.83	1108	2747.83
Maximum	53946360	90593460	1545.65	1050	2595.65
CT Scan at Medical Colleges (with low utilization rate)					
Base case	30659920	52622665	3782.37	2709.44	6491.81
Minimum	22980480	27617980	3618.40	730.20	4348.60

Maximum	52493480	76023498	2239.96	1004.05	3244.01
CT Scan at Government Hospitals (Overall)					
Base case	25503480	32017056	3146.24	803.54	3949.80
Minimum	19823480	19941680	50313.40	300	50613.40
Maximum	39434480	58386705	1642.89	1205.77	2848.67
CT Scan at Government Hospitals (with high utilization rate)					
Base case	25768480	30768480	3178.93	616.83	3795.76
Minimum	19952480	23170562	5008.15	807.75	5815.90
Maximum	29444480	68376705	1226.7	1205.77	2432.47
CT Scan at Government Hospitals (with low utilization rate)					
Base case	20565480	23282220	6510.12	860	7370.12
Minimum	19672480	19790680	49930.15	300	50230.15
Maximum	28320225	38368221	2130.78	756	2886.78

All costs are provided in Indian Rupee (INR)

**Minimum threshold values for all the input parameters*

#Maximum threshold values for all the input parameters

[$]average annual cost per equipment during inception from health system perspective includes the capital cost plus average annual cost of the equipment (i.e., AMC, manpower, electricity, other costs)

[&]average annual cost per equipment during inception from societal perspective includes the capital cost plus average annual cost of the equipment (i.e., AMC, manpower, electricity, other costs) plus annual total societal cost

[@]average cost per procedure during inception from health system perspective is calculated by dividing the average annual cost per equipment from health system perspective by the average number of procedures per year; In this parameter, keeping the value as minimum (like equipment utilization rate) will increase the average cost that the government spends per procedure; This is because lesser the number of patients, more will be the amount spent on each procedure;

^average cost per procedure during inception from societal perspective is calculated by dividing the average annual cost per equipment from societal perspective by the average number of procedures per year;

AMC – Annual Maintenance cost; CT – Computed Tomography

Table 42: Costing analysis Results of CT scan after the year of inception (excluding the capital costs for regular functioning) at secondary and tertiary care facilities in Tamil Nadu

Equipment and Scenario	Average annual cost per equipment for regular functioning$ Health System Perspective	Average annual cost per equipment for regular functioning & Societal Perspective	Average cost per procedure for regular functioning @ Health System Perspective	Total Societal cost per procedure	Average cost per procedure for regular functioning ^ Societal Perspective
CT Scan at Medical Colleges (Overall)					
Base case	10727400	33190256	512.17	1691.20	1584.63
Minimum*	8251200	12888700	2071.08	1692	3235.11
Maximum#	14111000	50758100	404.30	1561	1454.30
CT Scan at Medical Colleges (with high utilization rate)					
Base case	10808000	35962160	360.92	1182.90	1200.94
Minimum	8066680	25536516	511.62	1593.79	1619.62
Maximum	13557880	50204980	388.45	1561.00	1438.45
CT Scan at Medical Colleges (with low utilization rate)					
Base case	10571440	32534185	1304.15	3472.43	4013.59
Minimum	7892000	12529500	516.53	1061.39	1972.83

Maximum	12105000	35635018	1242.64	1532.5	1520.59
CT Scan at Government Hospitals (Overall)					
Base case	5415000	11928576	668.02	1255.15	1471.57
Minimum	4735000	4853200	12017.76	800	12317.76
Maximum	17646000	46588225	735.16	1804.27	1940.93
CT Scan at Government Hospitals (with high utilization rate)					
Base case	5680000	10680000	700.71	1255.15	1317.54
Minimum	4864000	8082082	1220.88	1634.75	2028.63
Maximum	7656000	36598225	318.96	1804.27	1524.73
CT Scan at Government Hospitals (with low utilization rate)					
Base case	5077000	7793740	1607.15	1398	2467.15
Minimum	4584000	4702200	11634.52	800	11934.52
Maximum	6531745	16579741	491.44	1274	1247.44

All costs are provided in Indian Rupee (INR)

**Minimum threshold values for all the input parameters*

#Maximum threshold values for all the input parameters

$^{\$}$*average annual cost per equipment for regular functioning from health system perspective includes the average annual cost of the equipment (i.e., AMC, manpower, electricity, other costs)*

$^{\&}$*average annual cost per equipment for regular functioning from societal perspective includes the average annual cost of the equipment (i.e., AMC, manpower, electricity, other costs) plus annual total societal cost*

$^{@}$*average cost per procedure for regular functioning from health system perspective is calculated by dividing the average annual cost per equipment for regular functioning from health system perspective by the average number of procedures per year*

^*average cost per procedure during inception from societal perspective is calculated by dividing the average annual cost per equipment for regular functioning from societal perspective by the average number of procedures per year*

AMC – Annual Maintenance cost; CT – Computed Tomography

<u>Costing of MRI Scan for the Year of Inception/Installation of Equipment</u>

The inception year cost analysis for MRI scans in healthcare facilities of Tamil Nadu presents a detailed overview of the financial implications from both health system and societal perspectives, factoring in the capital costs and operational expenses during the first year of installation and use (**Table-43**).

For the base case of MRI scans across various facilities, the average annual cost from the health system perspective was about INR 72.63 million. When viewed from the societal perspective, which includes additional costs beyond the direct healthcare expenses, this figure rose to approximately INR 80.19 million. The cost per procedure was significant during the inception year, averaging INR 8,720 (health system) and INR 9,628 (societal).

In scenarios with minimum utilization rates, the cost per procedure escalated dramatically to INR 17,777 (health system) and INR 18,892 (societal), highlighting the impact of patient volume on the cost-efficiency of MRI services. Conversely, in maximum utilization scenarios, these costs were more contained, averaging INR 8,190 (health system) and INR 9,489 (societal).

In facilities with higher rates of MRI utilization, the average annual cost for the health system was around INR 86.03 million and INR 97.59 million from a societal perspective. The cost per procedure in these high-utilization settings was INR 10,328 (health system) and INR 11,717 (societal), indicating that even with higher patient throughput, the cost per procedure remains relatively high due to the substantial initial investment and operational costs.

Facilities with lower utilization rates saw average annual costs of about INR 72.93 million (health system) and INR 80.49 million (societal). The cost per procedure in these scenarios was

INR 11,543 (health system) and INR 12,740 (societal), reinforcing the notion that lower utilization rates lead to higher costs per procedure.

The inception year for MRI scans in Tamil Nadu is marked by significant investment and operational costs, with a clear correlation between the volume of procedures and cost-efficiency. The analysis underscores the need for strategic planning in resource allocation, particularly in balancing the high initial costs with operational expenses and patient throughput to optimize the utility and financial sustainability of MRI services in healthcare facilities.

Costing of MRI Scan After the Year of Inception (Regular Functioning of Equipment)

The cost analysis for MRI scans post the year of inception in healthcare facilities of Tamil Nadu provides insights into the ongoing operational expenditures, excluding initial capital costs (**Table-44**). This analysis is crucial for understanding the long-term financial implications of MRI services in the healthcare system.

During the regular functioning phase, MRI scans show a substantial decrease in costs compared to the inception year. The base case scenario from the health system perspective indicates an average annual cost of approximately INR 13.66 million. When seen from the societal perspective, this cost increases to around INR 21.23 million. The average cost per procedure is INR 1,640 for the health system and INR 2,549 for the societal perspective.

In minimum utilization scenarios, the cost per procedure escalates to INR 3,131 (health system) and INR 4,246 (societal), demonstrating the impact of reduced patient volumes on cost efficiency. Conversely, in maximum utilization scenarios, the costs are somewhat contained at INR 1,634 (health system) and INR 2,933 (societal).

Facilities with high utilization rates see a notable increase in the cost per procedure. The base case scenario shows an average annual cost of INR 13.66 million from the health system perspective and INR 25.23 million from the societal perspective. The per-procedure cost in these settings is INR 2,163 (health system) and INR 3,992 (societal), indicating that while higher patient throughput does reduce the cost per procedure, the operational costs remain significant.

In facilities with lower utilization rates, the average annual cost is around INR 13.97 million (health system) and INR 21.53 million (societal). The cost per procedure is INR 1,677 (health system) and INR 2,585 (societal), further highlighting that reduced utilization leads to higher costs per procedure.

The post-inception year cost analysis for MRI scans in Tamil Nadu's healthcare facilities reveals a complex interplay between utilization rates, operational costs, and the financial sustainability of MRI services. While the costs decrease compared to the inception year, they remain significant, underscoring the importance of strategic resource allocation and operational efficiency in healthcare planning and management.

Table 43: Costing analysis Results of MRI scan for the inception year (i.e., the year of purchase and installation) at secondary and tertiary care facilities in Tamil Nadu

Equipment and Scenario	Average annual cost per equipment during inception[$] Health System Perspective	Average annual cost per equipment during inception[&] Societal Perspective	Average cost per procedure during inception[@] Health System Perspective	Total Societal cost per procedure during inception	Average cost per procedure during inception^ Societal Perspective
MRI Scan (Overall)					
Base case	72625205	80189729	8719.56	908.21	9627.77
Minimum*	55908965	59416529	17777.09	1115.28	18892.38
Maximum[#]	90520565	104879615	8189.68	1299.11	9488.79
MRI Scan at facilities with high utilization rate					
Base case	86025205	97587145	10328.39	1388.15	11716.55
Minimum	68944285	73856775	16898.11	1204.04	18102.15
Maximum	172120565	186479615	14742.66	1229.90	15972.56

MRI Scan at facilities with low utilization rate					
Base case	72927805	80492329	11542.86	1197.30	12740.16
Minimum	56428765	59936329	17942.37	1115.28	10737.88
Maximum	90010501	100774969	9590.89	1146.99	10737.88

All costs are provided in Indian Rupee (INR)

**Minimum threshold values for all the input parameters*

#Maximum threshold values for all the input parameters

$average annual cost per equipment during inception from health system perspective includes the capital cost plus average annual cost of the equipment (i.e., AMC, manpower, electricity, other costs)

&average annual cost per equipment during inception from societal perspective includes the capital cost plus average annual cost of the equipment (i.e., AMC, manpower, electricity, other costs) plus annual total societal cost

@average cost per procedure during inception from health system perspective is calculated by dividing the average annual cost per equipment from health system perspective by the average number of procedures per year; In this parameter, keeping the value as minimum (like equipment utilization rate) will increase the average cost that the government spends per procedure; This is because lesser the number of patients, more will be the amount spent on each procedure;

^average cost per procedure during inception from societal perspective is calculated by dividing the average annual cost per equipment from societal perspective by the average number of procedures per year;

AMC – Annual Maintenance cost; MRI – Magnetic Resonance Imaging

Table 44: Costing analysis Results of MRI scan for the regular functioning (i.e., after the year of inception) at secondary and tertiary care facilities in Tamil Nadu

Equipment and Scenario	Average annual cost per equipment for regular functioning$ Health System Perspective	Average annual cost per equipment for regular functioning & Societal Perspective	Average cost per procedure for regular functioning @ Health System Perspective	Total Societal cost per procedure	Average cost per procedure for regular functioning ^ Societal Perspective
MRI Scan (Overall)					
Base case	13663327	21227851	1640.45	3069.22	2548.66
Minimum*	9847087	13354651	3131.03	2736.87	4246.31
Maximum#	18058687	32417737	1633.83	3170.93	2932.93
MRI Scan at facilities with high utilization rate					
Base case	13663327	25225267	2162.60	3654.00	3992.60
Minimum	9982407	14894897	3174.05	3714.00	4736.06
Maximum	18058687	32417737	1924.21	3461.00	3454.21

MRI Scan at facilities with low utilization rate					
Base case	13965927	21530451	1676.78	3069.22	2584.99
Minimum	10366887	13874451	2540.90	2109.67	3400.60
Maximum	17548623	28313091	1503.09	3002.00	2425.10

All costs are provided in Indian Rupee (INR)

**Minimum threshold values for all the input parameters*

#Maximum threshold values for all the input parameters

$average annual cost per equipment for regular functioning from health system perspective includes the average annual cost of the equipment (i.e., AMC, manpower, electricity, other costs)

&average annual cost per equipment for regular functioning from societal perspective includes the average annual cost of the equipment (i.e., AMC, manpower, electricity, other costs) plus annual total societal cost

@average cost per procedure for regular functioning from health system perspective is calculated by dividing the average annual cost per equipment for regular functioning from health system perspective by the average number of procedures per year

^average cost per procedure during inception from societal perspective is calculated by dividing the average annual cost per equipment for regular functioning from societal perspective by the average number of procedures per year

AMC – Annual Maintenance cost; MRI – Magnetic Resonance Imaging

<u>Costing of Radiotherapy Equipments</u>

The cost analysis for the inception year and post-inception year of radiotherapy equipment, including Cobalt therapy, Linear Accelerator (LINAC), and Brachytherapy, in secondary and tertiary care facilities of Tamil Nadu, reveals significant expenditures that encompass both the capital cost and the initial year of operation and subsequent recurring cost for the regular functioning of the equipments (**Table-45 & 46**).

Cobalt Therapy

Inception Year:

For Cobalt therapy, the base case scenario from the health system perspective shows an average annual cost of approximately INR 53.87 million. This figure marginally increases to INR 54.86 million when viewed from the societal perspective. The average cost per procedure is strikingly high in the first year, at INR 43,728 from the health system's view and INR 44,527 when considering the societal costs.

In minimum utilization scenarios, the cost per procedure skyrockets, reflecting the substantial impact of lower patient volumes on cost efficiency. Conversely, in maximum utilization scenarios, the cost per procedure is somewhat reduced but remains significant.

Post-inception year:

In the regular functioning phase, Cobalt therapy shows a substantial reduction in costs compared to the inception year. The base case average annual operational cost from the health system perspective is INR 9.38 million, which slightly increases to INR 10.36 million from a societal perspective. The average cost per procedure is INR 7,612 from the health system's view, rising to INR 8,411 when societal costs are included.

The cost per procedure in minimum utilization scenarios increases dramatically, reflecting the impact of reduced patient volumes on cost efficiency. In maximum utilization scenarios, the cost per procedure decreases to INR 3,383 (health system) and INR 4,128 (societal).

LINAC

Inception Year:

The base case scenario for LINAC indicates an even higher cost, with the health system perspective averaging around INR 185.55 million and the societal perspective at INR 211.16 million. The cost per procedure for LINAC is INR 39,396 (health system) and INR 44,833 (societal).

Similar to Cobalt therapy, lower utilization rates lead to an astronomical increase in cost per procedure, highlighting the importance of patient throughput in managing the financial viability of such advanced equipment.

Post-inception year:

The base case for LINAC indicates an average annual operational cost of about INR 8.37 million from the health system perspective, which significantly jumps to INR 33.98 million from the societal perspective, due to additional societal costs. The cost per procedure is INR 1,777 (health system) and INR 7,214 (societal).

Similar to Cobalt therapy, lower utilization rates lead to an increase in cost per procedure, whereas higher utilization rates tend to make the procedure more cost-effective.

Brachytherapy

Inception Year:

The inception year costs of the brachytherapy are somewhat lower compared to LINAC but still significant. The base case average annual cost is about INR 36.57 million (health system) and INR 37.18 million (societal). The cost per procedure is INR 144,559 (health system) and INR 146,967 (societal), reflecting the high initial investment and operational costs in the first year.

Post-inception year:

In the regular functioning phase for Brachytherapy, the average annual cost is approximately INR 8.37 million (health system) and INR 8.98 million (societal). The cost per procedure is INR 33,083 (health system) and INR 35,491 (societal), slightly lower compared to the other two types of radiotherapy equipment.

The inception year cost analysis for radiotherapy equipment in healthcare facilities of Tamil Nadu underscores the substantial financial investment required in the initial year of operation. These costs are heavily influenced by the utilization rates, with lower throughput leading to much higher costs per procedure. This analysis is crucial for healthcare planners and policymakers, emphasizing the need for strategic resource allocation and utilization to optimize the return on investment in such high-cost healthcare technologies. The post-inception year cost analysis for radiotherapy equipment in healthcare facilities of Tamil Nadu reveals a decrease in costs compared to the inception year, though they remain significant, especially when societal costs are considered. The analysis underscores the importance of high utilization rates in enhancing the cost-efficiency of these high-value healthcare services, highlighting the need for careful planning and strategic utilization to optimize the resources in healthcare facilities.

Table 45: Costing analysis Results of radiotherapy equipments for the inception year (i.e., the year of purchase and installation) at secondary and tertiary care facilities in Tamil Nadu

Equipment and Scenario	Average annual cost per equipment during inception$ Health System Perspective	Average annual cost per equipment during inception& Societal Perspective	Average cost per procedure during inception@ Health System Perspective	Total Societal cost per procedure during inception	Average cost per procedure during inception^ Societal Perspective
Cobalt therapy					
Base case	53872657	54857025	43727.81	799	44526.81
Minimum*	47168391	47221625	1096939.33	1238	1098177.33
Maximum#	60063922	62491132	18435.83	745	19180.82
LINAC					
Base case	185553764	211161134	39395.70	5436.81	44832.51
Minimum	165681388	166815264	231075.85	1581.42	232657.27
Maximum	204913140	241328202	8722.31	1550.04	10272.34

Brachytherapy					
Base case	36573460	37182610	144559.13	2407.71	146966.84
Minimum	31599114	31708356	585168.78	2023	587191.78
Maximum	41034806	42333446	53085.13	1680	54765.13

All costs are provided in Indian Rupee (INR)

**Minimum threshold values for all the input parameters*

#Maximum threshold values for all the input parameters

$average annual cost per equipment during inception from health system perspective includes the capital cost plus average annual cost of the equipment (i.e., AMC, manpower, electricity, other costs)

&average annual cost per equipment during inception from societal perspective includes the capital cost plus average annual cost of the equipment (i.e., AMC, manpower, electricity, other costs) plus annual total societal cost

@average cost per procedure during inception from health system perspective is calculated by dividing the average annual cost per equipment from health system perspective by the average number of procedures per year; In this parameter, keeping the value as minimum (like equipment utilization rate) will increase the average cost that the government spends per procedure; This is because lesser the number of patients, more will be the amount spent on each procedure;

^average cost per procedure during inception from societal perspective is calculated by dividing the average annual cost per equipment from societal perspective by the average number of procedures per year;

AMC – Annual Maintenance cost;

Table 46: Costing analysis Results of radiotherapy equipments for the regular functioning (i.e., after the year of inception) at secondary and tertiary care facilities in Tamil Nadu

Equipment and Scenario	Average annual cost per equipment for regular functioning$ Health System Perspective	Average annual cost per equipment for regular functioning & Societal Perspective	Average cost per procedure for regular functioning @ Health System Perspective	Total Societal cost per procedure	Average cost per procedure for regular functioning ^ Societal Perspective
Cobalt therapy					
Base case	9378000	10362368	7612.01	799	8411.01
Minimum*	7223500	7276734	167988.37	1338	169226.37
Maximum#	11020600	13447810	3382.63	746	4127.62
LINAC					
Base case	8370000	33977370	1777.07	5441.80	7213.87
Minimum	12624000	13757876	17606.69	1581.42	19188.11
Maximum	10011000	46426062	426.12	1550.03	1976.16

Brachytherapy					
Base case	8370000	8979150	33083.00	2407.71	35490.71
Minimum	6216000	6325242	115111.11	2023	117134.11
Maximum	10011000	11309640	12950.84	1680	14630.84

All costs are provided in Indian Rupee (INR)

**Minimum threshold values for all the input parameters*

#*Maximum threshold values for all the input parameters*

$*average annual cost per equipment for regular functioning from health system perspective includes the average annual cost of the equipment (i.e., AMC, manpower, electricity, other costs)*

&*average annual cost per equipment for regular functioning from societal perspective includes the average annual cost of the equipment (i.e., AMC, manpower, electricity, other costs) plus annual total societal cost*

@*average cost per procedure for regular functioning from health system perspective is calculated by dividing the average annual cost per equipment for regular functioning from health system perspective by the average number of procedures per year*

^*average cost per procedure during inception from societal perspective is calculated by dividing the average annual cost per equipment for regular functioning from societal perspective by the average number of procedures per year*

AMC – Annual Maintenance cost;

DISCUSSION

Comparative Analysis of Operational Efficiency Across Tamil Nadu Healthcare Facilities

In a comprehensive overview of CT scan utilization across various healthcare facilities in Tamil Nadu, distinct patterns of operational efficiency and inefficiencies emerge. Facilities like Government Theni Medical College and Hospital, and Government Thiruvarur Medical College demonstrate exemplary operational efficiency, with high operation and functional times, indicating effective utilization and management of CT scanning services. Particularly notable is Government Theni Medical College and Hospital's near-perfect functional time, although it faces challenges with high slow cycles.

On the other hand, institutions such as Government Hospital, Melur, and Government Sivagangai Medical College and Hospital exhibit significant operational inefficiencies. High avoidable losses and slow cycles at these facilities suggest substantial room for improvement in scheduling, patient handling, and equipment maintenance. The high unavoidable losses seen at Government Hospital, Periyakulam, and Government Medical College, Nilgiris, point towards external constraints impacting utilization, necessitating a review of patient flow and scheduling processes.

Moreover, the analysis reveals that while facilities like Rajiv Gandhi Government General Hospital and Government Stanley Medical College Hospital manage to maintain low avoidable losses, indicating strong operational control, there are stark differences in how unavoidable losses are managed across facilities. For example, Government Hospital, Tindivanam, and Lawley Government Hospital, Coonoor, show high percentages of unavoidable losses, suggesting external factors such as patient flow inconsistencies or infrastructural constraints significantly affect their operational efficiency. This aspect underscores the need for a tailored approach to address specific local challenges each facility faces.

Furthermore, the variation in functional time across facilities like Government Hospital, Srirangam, and Government Medical College, Omandurar, highlights differing levels of effectiveness in actual patient scanning. Facilities with lower functional times could benefit from revisiting their patient scheduling protocols and streamlining scanning processes to enhance throughput efficiency. The disparity in slow cycles, especially high in facilities like Government Theni Medical College and Hospital, suggests a need for regular equipment maintenance and potential staff training for optimal equipment operation. Addressing these technical inefficiencies can significantly reduce downtime and improve service quality.[30]

The stark contrast in operational times and functional times at many facilities, such as Government Hospital, Karaikudi, and Coimbatore Medical College Hospital, highlights inefficiencies in converting operation time into actual scanning time. This gap might be attributed to procedural delays or inefficiencies in patient throughput.[31]

Slow cycles, a critical parameter indicating periods of reduced operational speed, are a common issue across several facilities, notably high at Government Headquarters Hospital, Mettur, and Government Sivagangai Medical College and Hospital. Addressing these slow cycles could significantly improve overall operational efficiency.[32] While some facilities showcase high efficiency and optimal utilization of CT scan resources, others face challenges in various operational aspects. Addressing these inefficiencies, particularly in managing unavoidable losses, improving functional time, and reducing slow cycles, will be crucial in enhancing the overall effectiveness and quality of healthcare delivery across these Tamil Nadu healthcare facilities.[33]

Comparative Analysis of Operational Efficiency Across Tamil Nadu Healthcare Facilities for MRI Scans

In evaluating the operational efficiency and inefficiencies of MRI scan utilization across various healthcare facilities in Tamil Nadu, notable variances emerge, highlighting areas of strength and opportunities for improvement.

Facilities like Government Medical College, Nilgiris, and Government Thiruvarur Medical College have demonstrated high operational times, indicating efficient use of MRI scanners. Particularly impressive is the functional time at Government Medical College, Nilgiris, which exceeds its operation time, suggesting highly effective patient processing and scheduling.

Conversely, Government Royapettah Hospital and Coimbatore Medical College Hospital exhibit lower operational and functional times, pointing towards underutilization of MRI resources. These facilities could benefit from revisiting their scheduling protocols and operational strategies to enhance utilization rates.

The phenomenon of negative slow cycles observed in Government Thiruvarur Medical College and Coimbatore Medical College Hospital indicates operational speeds better than the ideal cycle time, an unusual but positive occurrence in efficient equipment utilization.

Unavoidable losses vary significantly across the facilities, with Government Royapettah Hospital and Government Sivagangai Medical College and Hospital facing higher percentages, suggesting external constraints like patient availability or infrastructural limitations impacting their operational efficiency.[32]

Furthermore, avoidable losses, though generally low across most facilities, are still present in institutions like Government Medical College, Nilgiris, and Government Villupuram Medical College and Hospital, indicating areas where operational management could be optimized. Slow cycles are a common issue across several facilities, notably high in Government Thiruvarur Medical College and Government Medical College, Thanjavur. Addressing these slow cycles through regular equipment maintenance and staff training can significantly improve operational efficiency.

In addition to the observed variances, a deeper analysis reveals a correlation between operational times and functional efficiency. Facilities like KAP Vishwanathan Government Medical College and Hospital, Trichy, and Rajiv Gandhi Government General Hospital maintain high operation times, yet their functional times indicate a gap in efficient patient processing. This contrast suggests that while equipment is available, it's not always being used optimally, possibly due to scheduling inefficiencies or procedural delays. Moreover, the discrepancies in avoidable and unavoidable losses across the facilities highlight the diverse challenges each faces. For instance, Government Medical College, Omandurar, and Government Sivagangai Medical College and Hospital show minimal unavoidable losses, indicating effective handling of external factors, a practice other facilities might emulate. The variation in slow cycles, especially the negative values in facilities like Government Thiruvarur Medical College, shows exceptionally efficient procedures that other facilities might investigate and potentially adopt. While some facilities showcase optimal utilization of MRI scanning resources, others face challenges in various aspects of their operations. Addressing these inefficiencies, particularly in managing slow cycles and avoidable losses, as well as enhancing functional times, is crucial for optimizing healthcare delivery and equipment management across these Tamil Nadu healthcare facilities.[34]

Comparative Analysis of Operational Efficiency Across Tamil Nadu Healthcare Facilities for PET Scan and Lithotripsy Equipment

In comparing the operational efficiency and inefficiencies of PET scan and lithotripsy equipment across Tamil Nadu healthcare facilities, distinct patterns and variances emerge, underscoring areas of strength and potential improvement. For PET scans, Madurai Medical College Hospital demonstrates a moderate level of efficiency. While their operation time is commendable, there is a noticeable gap in achieving full functional potential, suggesting room for optimization in patient throughput and scheduling. The absence of avoidable losses reflects strong operational control, but the presence of slow cycles indicates potential technical inefficiencies or procedural delays that could be addressed to enhance throughput.[35]

Lithotripsy equipment utilization at RGGGH and Government Tirunelveli Medical College and Hospital shows higher operational and functional efficiency. RGGGH, in particular, excels in functional time, suggesting effective patient handling and equipment usage. However, both facilities face challenges with slow cycles, indicating periods where equipment operates below optimal capacity. Addressing these slow cycles could significantly improve service quality and patient care. The differences in unavoidable losses across these facilities, particularly high in Government Tirunelveli Medical College and Hospital, highlight external factors impacting equipment utilization. These factors might include patient flow inconsistencies or infrastructural constraints that require tailored strategies for each facility to optimize equipment usage. While some facilities demonstrate efficient use of lithotripsy equipment, opportunities for improvement remain, especially in reducing slow cycles and optimizing functional time. A targeted approach, considering the unique challenges and operational context of each facility, is crucial for enhancing overall healthcare delivery and equipment management efficiency.

Comprehensive Comparative Analysis of LINAC Utilization Across Tamil Nadu Healthcare Facilities

When comparing the operational efficiency of LINAC utilization across different healthcare facilities in Tamil Nadu, distinct patterns emerge, highlighting varying levels of operational success and areas needing improvement.

Facilities like Rajiv Gandhi Government General Hospital (RGGGH) and Government Medical College Hospital, Thanjavur, exhibit high operation times, indicating efficient use of LINAC equipment. Particularly, RGGGH shows exceptional functional efficiency, with its functional time nearly matching the operation time. However, both facilities face challenges with slow cycles, indicating periods of suboptimal operation that could be addressed through technical improvements or procedural optimization.

On the other hand, Government Tirunelveli Medical College and Hospital and Coimbatore Medical College Hospital demonstrate moderate levels of utilization. While their operation times are lower, they maintain a close alignment between operation and functional times, suggesting effective patient treatment during operational hours. However, the presence of slow cycles, notably high in Government Medical College Hospital, Thanjavur, suggests inefficiencies in equipment operation that could be targeted for improvement.

A key observation is the variance in avoidable losses across these facilities. Government Medical College Hospital, Thanjavur, faces significant avoidable losses, indicating potential areas for operational management improvements. In contrast, facilities like Government Tirunelveli Medical College and Hospital manage to avoid these losses, reflecting efficient operational control.

Moreover, the analysis reveals varying degrees of alignment between operational and functional times across the facilities. Facilities like Madurai Medical College Hospital show an unusual pattern where functional time exceeds operation time, which may point to efficient patient management or data recording discrepancies. This contrast with Government Medical College, Omandurar, where both operational and functional times are high, suggests differing operational strategies and efficiencies in patient handling.

Another critical aspect is the management of unavoidable losses. While some facilities like Rajiv Gandhi Government General Hospital (RGGGH) effectively minimize these losses, others like Government Royapettah Hospital experience higher percentages, indicating external challenges that could be mitigated with improved scheduling or infrastructure enhancements.

Lastly, the variations in slow cycle percentages across the facilities highlight differing levels of technical efficiency. High slow cycles, as seen in Government Medical College Hospital, Thanjavur, suggest a need for regular equipment maintenance and potentially staff training for optimal equipment operation. Addressing these technical inefficiencies can significantly reduce downtime and enhance service quality.

While some facilities demonstrate optimal utilization of LINAC resources, others exhibit room for improvement, especially in reducing slow cycles, minimizing avoidable losses, and optimizing functional times. A targeted approach, taking into account the unique operational context of each facility, is crucial for enhancing overall healthcare delivery and equipment management efficiency.[36]

Comparative Analysis of Cobalt Therapy Utilization Across Tamil Nadu Healthcare Facilities

In assessing the operational efficiency of Cobalt therapy across various healthcare facilities in Tamil Nadu, we observe notable variances that highlight distinct operational strengths and areas for improvement.

Facilities like Government Stanley Medical College Hospital and Government Mohan Kumaramangalam Medical College and Hospital, Salem, demonstrate high operational efficiency with their operation times close to or exceeding the scheduled time. Particularly, the Salem facility maintains a high functional time, suggesting effective use of the equipment for patient treatments. However, a common challenge faced by these facilities, including Government Medical College Hospital, Thanjavur, is the high percentage of slow cycles, indicating periods where the equipment operates below optimal capacity. Addressing these technical inefficiencies could significantly enhance service quality. On the other hand, Government Royapettah Hospital and Government Villupuram Medical College Hospital exhibit unique patterns. Royapettah Hospital shows an exceptionally high operation and functional time, indicating extended operation hours and efficient patient management. However, it faces substantial unavoidable losses, pointing towards external constraints severely impacting operation. Villupuram Medical College, despite a high operation time, reveals a considerable gap in functional time, suggesting inefficiencies in converting operation time into effective patient treatments. The variance in unavoidable losses, particularly high in facilities like Villupuram Medical College, highlights the impact of external factors on operational efficiency. These losses might be attributed to patient flow inconsistencies/infrastructural challenges and require tailored strategies to optimize usage.

Furthermore, a deeper analysis of functional times across these facilities indicates varying degrees of efficiency in patient treatment processes. For instance, Government Medical College, Omandurar, and Madurai Medical College Hospital display a disparity between their operational and functional times, suggesting opportunities to streamline patient treatment protocols and reduce procedural delays. This contrast with Government Mohan Kumaramangalam Medical College and Hospital, Salem, which achieves a closer alignment between operation and functional times, exemplifies the potential for improved throughput efficiency.

Additionally, the management of unavoidable and avoidable losses presents a varied picture. While some facilities, like Government Stanley Medical College Hospital, effectively minimize these losses, others like Government Royapettah Hospital face higher percentages of unavoidable losses, indicating the need for enhanced scheduling flexibility and infrastructure support to mitigate these external constraints. The disparities in slow cycle percentages across the facilities, particularly the negative values observed in Madurai Medical College Hospital, suggest differing levels of technical and operational efficiency. High slow cycles in facilities such as Government Medical College Hospital, Thanjavur, call for regular equipment maintenance and potential staff training to optimize equipment operation. Conversely, negative slow cycles, though indicative of operational efficiency, may also warrant a review for data accuracy and procedural validation.

While some facilities showcase optimal utilization and management of Cobalt therapy resources, others face challenges, particularly in reducing slow cycles, managing unavoidable losses, and optimizing functional times. A targeted approach, considering the unique operational context and challenges of each facility, is essential for enhancing overall healthcare delivery and equipment management efficiency.[37]

Comparative Analysis of Brachytherapy Utilization Across Tamil Nadu Healthcare Facilities

In assessing the operational efficiency of brachytherapy services across different healthcare facilities in Tamil Nadu, a spectrum of utilization patterns emerges, each highlighting unique operational strengths and challenges.

At one end of the spectrum, facilities like Government Medical College Hospital, Thanjavur, demonstrate relatively higher utilization rates, with operational times indicating efficient use of brachytherapy equipment. However, this facility, along with others like Madurai Medical College Hospital, experiences considerable slow cycles, suggesting periods where the equipment operates below optimal efficiency. Addressing these slow cycles through technical improvements or procedural refinement could significantly enhance service quality.

Madurai Medical College Hospital, while showing low overall utilization, exhibits a unique pattern where the functional time matches the operation time perfectly. This indicates effective patient treatment during operational hours but also underscores the need to increase overall utilization to meet potential patient demands.

In contrast, Coimbatore Medical College Hospital faces a significant challenge in underutilization, with both operation and functional times markedly low. This suggests a need for review and potential restructuring of brachytherapy services to ensure that the facility meets patient needs effectively.

The absence of data for Government Tirunelveli Medical College and Hospital due to no patient utilization during the observation period is particularly noteworthy. It highlights a potential gap in service availability or demand, requiring further investigation to understand and address the underlying reasons for this absence of utilization.

Furthermore, the variance in functional times across the facilities indicates differing levels of patient treatment efficiency. For instance, Government Stanley Medical College Hospital, despite a high operational time, has a lower functional time, suggesting potential delays in patient setup or treatment execution. This contrasts with Madurai Medical College Hospital, where the operational and functional times are aligned, indicating efficient patient throughput during available operational hours.

The management of unavoidable losses also presents a varied picture across facilities. Government Royapettah Hospital, with high unavoidable losses, faces significant external constraints, impacting its service delivery. This contrasts with facilities like Coimbatore Medical College Hospital, where the lack of both unavoidable and avoidable losses indicates that operational inefficiencies are not due to external factors but rather underutilization of the equipment.

Lastly, the negative slow cycles observed in certain facilities, while indicating efficient operational speeds, also warrant a closer examination to understand the operational practices leading to such efficiency. This aspect could provide valuable insights for other facilities striving to improve their operational speeds.

In summary, while some facilities like Government Medical College Hospital, Thanjavur, demonstrate efficient operational management, others face challenges in underutilization or high slow cycles. A targeted approach, considering each facility's unique context and challenges, is essential for optimizing brachytherapy service delivery and improving patient care.[38]

Comparative Analysis of Factors Contributing to Avoidable Losses in CT Scan Equipment Across Tamil Nadu Healthcare Facilities

In comparing the factors contributing to avoidable losses in CT scan equipment across various healthcare facilities in Tamil Nadu, distinct patterns and key operational challenges emerge:

Planned Stops:

A common factor across several facilities, like Government Stanley Medical College Hospital and KAP Vishwanathan Government Medical College and Hospital, Trichy, planned stops often constitute a significant portion of avoidable losses. These typically involve equipment setup and adjustments. Reducing the duration of planned stops, possibly through streamlined processes or better scheduling, could markedly improve operational efficiency.

Unplanned Stops:

Facilities such as Government Hospital, Melur, and Government Medical College, Nilgiris, experience a high percentage of avoidable losses due to unplanned stops, indicating equipment breakdowns. This suggests a need for enhanced maintenance protocols or possibly equipment upgrades to improve reliability and reduce downtime.

Short Stops:

Short stops, including minor idling or breaks, are significant contributors in facilities like Government Headquarters Hospital, Mettur. Addressing these short stops through better operational management or staff training could lead to improved utilization of the equipment.

Startup Rejects and Procedure Repeats:

While less common, startup rejects and procedure repeats do contribute to avoidable losses in some facilities, such as Government Royapettah Hospital. This indicates a need for quality checks and process improvements to minimize the need for repeated procedures, thereby enhancing service quality and patient satisfaction.

Facilities with Minimal Losses:

Notably, some facilities such as Lawley Government Hospital, Coonoor, Government Thiruvarur Medical College, Government Theni Medical College and Hospital, Government Sivagangai Medical College and Hospital, Government Hospital, Karaikudi and Government Mohan Kumaramangalam Medical College and Hospital, Salem, report no avoidable losses, indicating exemplary operational efficiency. These facilities could serve as models for best practices in operational management of CT scan services.

Context-specific strategies to prevent avoidable losses:

Moreover, the analysis underscores the importance of context-specific strategies in addressing avoidable losses. For instance, facilities like Government Hospital, Periyakulam and Government Medical College Hospital, Thanjavur, with avoidable losses solely due to planned stops, might benefit from revisiting their equipment setup protocols and exploring opportunities for efficiency improvements during the setup phase. Conversely, facilities grappling primarily with unplanned stops, such as Government Hospital, Tindivanam, may need to focus more on preventive maintenance and quick response mechanisms to minimize equipment breakdowns.

Additionally, the varied distribution of avoidable losses across facilities highlights the need for tailored training and operational adjustments. For instance, addressing short stops effectively may require staff training in specific facilities, whereas in others, enhancing the quality control procedures could reduce the instances of startup rejects and procedure repeats.

Lastly, the absence of certain types of avoidable losses in some facilities, such as startup rejects and procedure repeats, should not lead to complacency but rather be seen as an opportunity to share best practices across facilities. Collaborative learning from facilities with minimal losses can provide valuable insights into effective operational management and maintenance practices

In summary, while the nature of avoidable losses varies across facilities, common areas for improvement include reducing both planned and unplanned stops, addressing short stops, and improving the quality of procedures to minimize repeats. A targeted approach, considering the unique challenges of each facility, is crucial for enhancing the efficiency and reliability of CT scan services across these Tamil Nadu healthcare facilities.

Comparative Analysis of Factors Contributing to Avoidable Losses in MRI Scan Equipment Across Tamil Nadu Healthcare Facilities

A comparative analysis of the factors contributing to avoidable losses in MRI scan equipment across various Tamil Nadu healthcare facilities reveals diverse operational challenges and highlights specific areas for improvement:

Planned Stops:

Facilities like KAP Vishwanathan Government Medical College and Hospital, Trichy, and Government Mohan Kumaramangalam Medical College and Hospital, Salem, primarily face avoidable losses due to planned stops. These stops, often involving equipment setup and adjustments, suggest a need for streamlined processes or improved scheduling to minimize downtime.

Unplanned Stops:

In contrast, Government Medical College, Nilgiris, encounters avoidable losses exclusively due to unplanned stops, indicative of equipment breakdowns. This points to the necessity for regular maintenance and possibly upgrading equipment to enhance reliability and reduce breakdown-induced losses.

Start-up Rejects:

Government Villupuram Medical College and Hospital and Government Mohan Kumaramangalam Medical College and Hospital, Salem, experience significant avoidable losses due to start-up rejects. Addressing these issues might involve technical adjustments or staff training to optimize the start-up phase of the MRI equipment, ensuring a smoother and more efficient initiation of operations.

Short Stops:

A notable case is Rajiv Gandhi Government General Hospital (RGGGH), where all avoidable losses are attributed to short stops. This indicates operational inefficiencies, possibly related to patient flow or staff coordination, highlighting the need for improved operational management to minimize idling or minor breaks.

Procedure Repeats and Other Factors:

While not a major contributing factor in the observed facilities, procedure repeats and other inefficiencies could still play a role in avoidable losses in some scenarios, necessitating continuous monitoring and quality control.

Facilities with Minimal Losses:

Government Thiruvarur Medical College, Government Sivagangai Medical College and Hospital, Government Medical College Hospital, and Thanjavur Government Royapettah Hospital had no avoidable losses during the days of time and motion observations for MRI.

Furthermore, the diverse nature of avoidable losses across these facilities underscores the importance of customized solutions tailored to the specific challenges each facility faces. For example, facilities like Government Stanley Medical College Hospital, which experience a mix of planned stops and start-up rejects, may benefit from a dual approach focusing on both efficient equipment setup and refining start-up procedures. On the other hand, facilities like Government Medical College, Omandurar, dealing with a combination of unplanned stops and procedure repeats, should focus on enhancing equipment reliability as well as process accuracy to avoid the need for repeated scans.

Additionally, the absence of certain types of avoidable losses in some facilities, such as short stops or procedure repeats, indicates areas of operational strength that can be leveraged as best practices. Sharing strategies and techniques between facilities could foster a collaborative approach to minimizing avoidable losses, thereby improving overall operational efficiency across the board.

Lastly, considering the significant impact of avoidable losses on operational efficiency, continuous monitoring and regular audits of MRI scan services are essential. This proactive approach can help in early identification of potential issues, allowing for timely interventions and ongoing improvements in service delivery

In summary, while each facility faces unique challenges, common areas for improvement include optimizing setup processes, enhancing equipment maintenance, and improving operational management to reduce both planned and unplanned stops. Additionally, addressing startup rejects and ensuring efficient patient handling can further reduce downtime and enhance the efficiency of MRI scan services.

Comparative Analysis of Factors Contributing to Avoidable Losses in PET Scan and Lithotripsy Equipment Across Tamil Nadu Healthcare Facilities

A comparative examination of avoidable losses in PET scan and lithotripsy equipment across different healthcare facilities in Tamil Nadu reveals a striking contrast in operational efficiency:

Exemplary Operation in PET Scan Equipment:

Madurai Medical College Hospital stands out for its exceptional operational management of PET scan equipment, evidenced by the complete absence of avoidable losses. This zero-loss scenario is indicative of highly efficient operational procedures, including effective management of both planned and unplanned stops, as well as successful avoidance of short stops, startup rejects, and procedure repeats.

Challenges in Lithotripsy Equipment Operation:

In contrast, facilities such as Rajiv Gandhi Government General Hospital (RGGGH) and Government Tirunelveli Medical College and Hospital face challenges primarily with short stops in their lithotripsy equipment. These stops, accounting for 100% of the avoidable losses in both facilities, point towards operational inefficiencies, possibly in patient flow management or staff coordination. This recurring issue suggests a need for targeted strategies to optimize operational workflow and reduce idle time.

Opportunities for Improvement and Learning:

The stark difference in operational efficiency between the PET scan and lithotripsy equipment across these facilities highlights an opportunity for cross-learning. The best practices employed in PET scan management at Madurai Medical College Hospital could potentially be adapted to improve lithotripsy services at RGGGH and Government Tirunelveli Medical College and Hospital.

Focus on Operational Management:

The predominant issue of short stops in lithotripsy equipment underscores the importance of refined operational management. Enhancing staff training, improving patient scheduling, and streamlining equipment setup processes could significantly reduce these avoidable losses.

While Madurai Medical College Hospital demonstrates exceptional efficiency in PET scan operations, the lithotripsy services at other facilities reveal a need for improved operational management to minimize downtime. Sharing successful practices and implementing targeted improvements could substantially enhance the overall efficiency and reliability of these vital medical services.

Comparative Analysis of Factors Contributing to Avoidable Losses in LINAC Equipment Across Tamil Nadu Healthcare Facilities

A comprehensive evaluation of the factors contributing to avoidable losses in LINAC equipment across different healthcare facilities in Tamil Nadu reveals varied operational challenges and opportunities for targeted improvements:

Predominance of Planned Stops:

Facilities like Coimbatore Medical College Hospital and Rajiv Gandhi Government General Hospital (RGGGH) exhibit a high percentage of avoidable losses due to planned stops. This suggests that the primary area for operational enhancement lies in streamlining the equipment setup and adjustment processes. Implementing more efficient setup protocols could significantly reduce downtime in these facilities.

Challenges with Unplanned Stops:

Government Medical College Hospital, Thanjavur, faces a substantial amount of avoidable losses due to unplanned stops, indicative of equipment breakdowns. This points towards a need for enhanced preventive maintenance and possibly upgrading or replacing less reliable equipment to improve overall operational efficiency.

Procedure Repeats as a Contributing Factor:

Facilities like Government Royapettah Hospital and Madurai Medical College Hospital encounter procedure repeats as a notable portion of their avoidable losses. This indicates a need for improvements in the accuracy and quality of initial procedures to minimize the necessity for rescans, thereby enhancing patient care and service efficiency.

Facilities with Singular Loss Factors:

Some facilities, such as Government Medical College, Omandurar, face a broader range of challenges, including both unplanned stops and procedure repeats. Addressing these diverse issues requires a multifaceted approach, focusing on both equipment reliability and procedural quality.

Opportunities for Cross-Learning:

The absence of certain types of avoidable losses in some facilities, such as short stops or startup rejects, suggests areas of operational strength. These facilities could serve as models for best practices, sharing their successful strategies and techniques to help other facilities minimize similar types of losses.

In summary, while each facility faces unique challenges in managing LINAC services, common areas for improvement include reducing the duration of planned stops, enhancing equipment maintenance, and improving the quality of procedures. Adopting best practices from facilities with minimal losses and implementing targeted strategies could substantially enhance the efficiency and reliability of LINAC services across the healthcare facilities.

Comparative Analysis of Factors Contributing to Avoidable Losses in Cobalt Therapy Equipment Across Tamil Nadu Healthcare Facilities

A detailed examination of the factors leading to avoidable losses in Cobalt therapy equipment across various healthcare facilities in Tamil Nadu reveals distinct operational challenges and opportunities for improvement:

Planned Stops at Government Royapettah Hospital:

This facility's avoidable losses in Cobalt therapy were solely due to planned stops, accounting for all 14 minutes of reported losses. This suggests that the key area for improvement is in streamlining equipment setup and adjustment processes. Reducing the duration of these planned stops could significantly enhance the efficiency of Cobalt therapy services at this hospital.

Unplanned Stops at Government Medical College Hospital, Thanjavur:

The facility faced avoidable losses entirely due to unplanned stops, indicating that equipment breakdowns are the primary cause of downtime. This points towards a critical need for improved preventive maintenance or potential equipment upgrades to enhance reliability and operational efficiency.

Balanced Challenges at Government Villupuram Medical College Hospital:

The facility experienced avoidable losses due to both planned and unplanned stops, suggesting that operational efficiency can be enhanced by focusing on both efficient equipment setup and reliable maintenance practices. Addressing these issues could lead to a significant reduction in downtime.

Zero Avoidable Losses in Other Facilities:

Notably, several other facilities reported no avoidable losses in their Cobalt therapy services. This absence of reported losses suggests either exemplary operational efficiency or potential underreporting. Facilities with no avoidable losses could serve as models of best practices in operational management for others to emulate.

While the nature and extent of avoidable losses vary across facilities, common strategies for improvement include optimizing setup processes, enhancing equipment maintenance, and adopting best practices from facilities with minimal or no losses. Implementing these strategies could substantially improve the efficiency and reliability of Cobalt therapy services across the healthcare facilities.

Comparative Analysis of Factors Contributing to Avoidable Losses in Brachytherapy Equipment Across Tamil Nadu Healthcare Facilities

The assessment of avoidable losses in Brachytherapy equipment across various healthcare facilities in Tamil Nadu demonstrates an overall high standard of operational efficiency, with noteworthy differences among specific facilities:

Exemplary Performance in Several Facilities:

Rajiv Gandhi Government General Hospital (RGGGH), Coimbatore Medical College Hospital, Madurai Medical College Hospital, and Government Medical College Hospital, Thanjavur, have shown exceptional operational management with zero avoidable losses reported. This indicates highly efficient processes, effective equipment maintenance, and successful patient care management, serving as a benchmark for other facilities.

Minimal Losses Indicating Targeted Improvement Areas:

Government Medical College, Omandurar, and Government Royapettah Hospital reported minimal avoidable losses, solely due to operational time. While these losses are minor, they suggest opportunities for fine-tuning operational processes to achieve even greater efficiency.

Absence of Data at Government Tirunelveli Medical College and Hospital:

The lack of patient utilization of Brachytherapy services during the study period at this facility suggests potential issues in service demand, accessibility, or awareness. This gap highlights the need for further investigation and potentially increased outreach or service availability adjustments.

Uniformity in Service Efficiency:

The absence of factors such as unplanned stops, short stops, startup rejects, and procedure repeats across the majority of facilities indicates a uniform standard of service efficiency in Brachytherapy equipment usage. This uniformity is indicative of robust operational protocols and effective staff training in place across these facilities.

Learning and Improvement Opportunities:

Facilities with no avoidable losses can provide valuable insights and best practices that can be adopted by others. Sharing of strategies, particularly in areas of operational time management, could further enhance service efficiency across all facilities.

While the majority of facilities demonstrate outstanding efficiency in Brachytherapy service delivery, the few with minimal avoidable losses present opportunities for targeted improvements. Additionally, the absence of service utilization in one facility points to a need for further assessment to ensure that Brachytherapy services are effectively meeting patient needs and demands.

Comparative Analysis of CT Scan Equipment Utilization Across Various Healthcare Facilities in Tamil Nadu

The utilization performance of CT scan equipment across multiple healthcare facilities in Tamil Nadu reveals significant variations in efficiency and effectiveness:

High Availability but Varied Performance: Most facilities, including Government Thiruvarur Medical College, Government Medical College, Nilgiris, and Rajiv Gandhi Government General Hospital (RGGGH), demonstrate high to exceptionally high availability rates. However, there is a notable variation in performance. While facilities like Government Thiruvarur Medical College show high performance, others like Government Medical College, Nilgiris, and Lawley Government Hospital, Coonoor, have considerably lower performance rates.

Facilities with lower performance might be encountering issues like longer patient preparation times, technical challenges, patient load or suboptimal workflow management. Benchmarking against high-performing facilities could identify key areas for operational improvement.

Quality Consistently High: A consistent trend across all facilities is the high quality of CT scans, with most institutions achieving a perfect 100% quality score. This indicates that, regardless of other factors, the diagnostic quality of the scans is largely uncompromised. This uniform excellence in quality suggests effective training protocols and adherence to high standards in imaging procedures. It also reflects the commitment to patient care and diagnostic accuracy across these facilities.

Overall Equipment Effectiveness (OEE) Varies:

OEE varies significantly among facilities. For instance, Government Thiruvarur Medical College and Government Stanley Medical College Hospital exhibit high OEE, suggesting efficient utilization of their CT scan equipment. In contrast, facilities like Government Hospital, Tindivanam and Lawley Government Hospital, Coonoor, have much lower OEE, primarily due to their lower performance rates. The variation in OEE could be attributed to differences in patient load, staff proficiency, and maintenance practices. Facilities with lower OEE might benefit from a detailed analysis of their operational workflows and patient management strategies.

Total Effective Equipment Performance (TEEP) Indicates Further Potential:

The TEEP scores, which reflect the efficiency against total calendar time, are generally lower across facilities. This suggests that despite high availability and quality, there is potential to improve the overall utilization of CT scan equipment throughout the year. To improve TEEP, facilities could explore extending operational hours, optimizing scheduling practices, and reducing equipment downtime through preventive maintenance and quick response to technical issues.

Room for Improvement in Performance:

The most significant area for improvement across many facilities is the performance metric. Enhancing operational speed and efficiency can significantly boost the OEE and TEEP scores, leading to better overall utilization of the CT scan equipment. Investing in staff training, streamlining patient throughput, and regularly calibrating equipment could enhance performance. Collaboration with technical experts and adopting technological advancements might also yield significant improvements.

Variation in Utilization and Efficiency:

Facilities like Government Mohan Kumaramangalam Medical College and Hospital, Salem, and Rajiv Gandhi Government General Hospital (RGGGH), balance high availability with reasonable performance and quality, leading to better overall effectiveness. Others, particularly Government Hospital, Karaikudi, and Lawley Government Hospital, Coonoor, face challenges in performance, severely impacting their effectiveness and utilization.

Facilities with lower utilization could explore strategies like community outreach programs to increase service demand, or internal policy changes to better accommodate patient schedules, thus maximizing equipment usage.

The analysis highlights the need for targeted interventions to improve performance rates in several facilities, which, combined with the already high availability and quality, could significantly enhance the overall effectiveness of CT scan services. Sharing best practices from high-performing facilities could be beneficial in addressing these challenges.

Comparative Analysis of MRI Scan Equipment Utilization Across Various Healthcare Facilities in Tamil Nadu

The analysis of MRI scan equipment utilization across different healthcare facilities in Tamil Nadu reveals varied levels of efficiency and effectiveness:

Variability in Availability and Performance:

While facilities like Government Stanley Medical College Hospital and Government Mohan Kumaramangalam Medical College and Hospital, Salem, demonstrate exceptionally high availability and performance, others such as Coimbatore Medical College Hospital and Government Medical College, Nilgiris, exhibit lower performance rates. This disparity suggests differences in operational protocols, patient management strategies, and technical efficiency. Factors contributing to variability may include differences in staff training, patient load, and equipment maintenance schedules. Understanding and addressing these factors can lead to more consistent performance across facilities.[38]

Consistently High Quality Across Facilities:

A notable trend is the consistently high quality of MRI scans across all facilities, with most institutions achieving a perfect 100% quality score. This consistency indicates a strong commitment to diagnostic accuracy and patient care. This trend suggests effective standardization of protocols and quality control measures. Further analysis could identify specific practices that contribute to maintaining high-quality standards, which can be replicated across other facilities.

OEE as a Key Indicator:

OEE varies significantly, with some facilities like Government Stanley Medical College Hospital showing exceptionally high OEE, indicating efficient utilization of their MRI equipment. Facilities with lower OEE, such as Coimbatore Medical College Hospital, might need to focus on enhancing their operational processes and patient throughput. Facilities with lower OEE might benefit from a detailed analysis of operational bottlenecks. Identifying and addressing specific issues such as equipment downtime or inefficient workflow can significantly improve OEE.[39]

TEEP Highlights Utilization Gaps:

The TEEP scores, which reflect efficiency against total calendar time, are varied. Facilities with lower TEEP scores may benefit from strategies to extend operational hours or optimize scheduling to improve year-round utilization. Examining reasons for underutilization, such as limited operational hours or unoptimized scheduling, can provide actionable insights. Implementing extended hours or adjusting appointment schedules could be potential solutions.[40]

Performance as a Critical Area for Improvement:

Performance appears to be a key differentiating factor in MRI equipment utilization. High-performing facilities likely benefit from streamlined operational workflows and efficient patient handling, while lower-performing facilities may need to address issues such as prolonged scan times or technical inefficiencies. Investigating the root causes of low performance, such as technical issues or procedural delays, can reveal opportunities for improvement. Tailored staff training and equipment upgrades may be effective in addressing these challenges.[41]

Efficiency and Patient Throughput:

The efficiency in MRI scan services correlates with patient throughput. Facilities with higher OEE and TEEP scores likely manage higher patient volumes more effectively, suggesting efficient scheduling and minimized equipment downtime.

High patient throughput without compromising quality indicates effective patient flow management. Analyzing and emulating scheduling strategies, patient communication, and staff allocation from these facilities can benefit others.

This comprehensive analysis highlights the need for targeted strategies to enhance performance and efficiency in MRI scan services across various facilities. Sharing best practices and learning from high-performing facilities could help lower-performing institutions improve their operational efficiency.[42] Addressing specific challenges in patient management and technical operation could significantly enhance the effectiveness of MRI services across the Tamil Nadu healthcare system.

Comparative Analysis of PET Scan and Lithotripsy Equipment Utilization Across Healthcare Facilities in Tamil Nadu

PET Scan Utilization at Madurai Medical College Hospital:

Moderate Availability and Performance: The PET scan equipment at Madurai Medical College Hospital exhibits moderate availability and performance. This could indicate specific operational challenges or patient scheduling issues that may be unique to this facility.

Consistent High Quality: The 100% quality score is an excellent indicator of the effectiveness of the diagnostic procedures, suggesting high standards in imaging quality and accuracy.

Room for Improvement in OEE and TEEP: The OEE and TEEP scores, while reasonable, suggest there is room for improved utilization and efficiency in PET scan operations.

Lithotripsy Equipment Utilization at Various Facilities:

Variability in Availability and Performance:

Rajiv Gandhi Government General Hospital (RGGGH) shows high availability but moderate performance, indicating potential areas for operational improvement to enhance speed and efficiency.

Government Tirunelveli Medical College and Hospital has very high availability but lower performance, suggesting that while the equipment is often available, it's not used at its optimal capacity.

High Quality Across the Board: Both facilities maintain a perfect quality score, indicating effective therapeutic procedures with minimal need for repetition.

Differences in OEE and TEEP: The OEE and TEEP scores vary between the two facilities, reflecting differences in how effectively the lithotripsy equipment is utilized throughout the year. This could be influenced by factors such as patient demand, operational efficiency, and scheduling practices.

Additional Insights for PET and Lithotripsy Utilization:

Operational Efficiency: Assessing and benchmarking operational workflows, patient handling, and scheduling practices against facilities with higher performance could provide actionable insights for improvement.

Patient Throughput: Facilities with lower TEEP scores may need to explore strategies to increase patient throughput, such as community outreach or optimized appointment scheduling.

Technical and Staff Training: Continuous technical maintenance and targeted staff training can play a crucial role in enhancing performance and operational speed, directly impacting OEE and TEEP.

Customized Improvement Strategies: Each facility may require tailored strategies based on its unique operational challenges, patient demographics, and equipment types.

Comparative Analysis of LINAC Equipment Utilization Across Healthcare Facilities in Tamil Nadu

This comparative analysis of LINAC equipment utilization across various healthcare facilities in Tamil Nadu reveals significant variations in efficiency, effectiveness, and overall operational dynamics:

Diversity in Availability and Performance:

Facilities like Rajiv Gandhi Government General Hospital (RGGGH) and Government Medical College Hospital, Thanjavur, showcase exceptionally high availability and performance, indicating robust operational protocols and efficient patient management.In contrast, Madurai Medical College Hospital and Government Medical College, Omandurar, display moderate to low performance, pointing towards potential operational inefficiencies or technical challenges.

The varying levels of equipment availability and performance could be influenced by factors like the age and maintenance of LINAC machines, differing patient loads, and the varying levels of staff expertise at each facility.

Quality of Treatment Consistently High:

A common trend across all facilities is the high quality of LINAC procedures, with most achieving near or perfect quality scores. This consistency underscores a commitment to therapeutic effectiveness and patient safety. This uniform excellence in treatment quality suggests effective training, adherence to strict therapeutic protocols, and a high level of technical competency in operating LINAC equipment across facilities.

OEE as a Determinant of Efficiency:

OEE varies notably among the facilities. For instance, Government Medical College Hospital, Thanjavur, and RGGGH demonstrate very high OEE, suggesting optimal use of LINAC equipment. Lower OEE at facilities like Madurai Medical College Hospital indicates room for improvement in operational efficiency. Disparities in OEE may also reflect differences in administrative efficiency, such as how quickly facilities can transition patients through treatment or manage equipment downtime.

TEEP Indicating Year-Round Utilization:

TEEP scores vary, highlighting differences in how effectively LINAC equipment is utilized throughout the year. Higher TEEP at facilities like Government Medical College Hospital, Thanjavur, suggests more consistent and efficient year-round operation. The variation in TEEP scores could be further explored to understand how external factors, like regional patient demographics or healthcare policies, impact the demand and utilization of LINAC services.

Performance: A Key Area for Improvement:

Performance emerges as a critical differentiator in LINAC utilization. Facilities with lower performance may need to address issues like prolonged treatment times, technical inefficiencies, or staff training. Facilities with lower performance might benefit from reviewing and possibly revising their operational workflows, incorporating advanced scheduling software, or investing in staff development programs to enhance efficiency.[43]

Efficiency Correlates with Patient Management:

Higher efficiency in facilities with high OEE and TEEP scores likely correlates with better patient throughput and scheduling strategies, suggesting that effective patient flow management is crucial for optimal equipment utilization.

Efficient patient management often requires a multidisciplinary approach, involving not just the technical staff operating the LINAC equipment but also the administrative and support staff who contribute to the overall patient experience.

This comprehensive analysis underscores the importance of efficient operational management, technical proficiency, and patient flow optimization in maximizing the effectiveness of LINAC services. Facilities with lower performance and utilization rates might benefit from examining and adopting practices from higher-performing institutions. Such cross-institutional learning could lead to enhanced operational efficiency and improved patient care across the Tamil Nadu healthcare system.

Comparative Analysis of Cobalt Therapy Equipment Utilization Across Healthcare Facilities in Tamil Nadu

This comparative analysis of Cobalt therapy equipment utilization across various healthcare facilities in Tamil Nadu reveals a diverse landscape of operational effectiveness and efficiency:

Varying Levels of Availability:

Institutions like Government Stanley Medical College Hospital and Government Villupuram Medical College Hospital show high availability, indicating effective scheduling and equipment management. Conversely, facilities like Government Royapettah Hospital demonstrate extremely high availability, possibly reflecting an overuse or extended operational hours of the equipment. Investigating the reasons behind varying availability rates, such as equipment downtime, maintenance schedules, or administrative decisions, can provide actionable insights for optimizing equipment use.

Wide Range of Performance Efficiency:

Facilities like Government Stanley Medical College Hospital exhibit high performance, suggesting efficient treatment procedures and optimal equipment usage. However, institutions like Government Villupuram Medical College Hospital and Government Royapettah Hospital experience significantly lower performance, indicating possible technical inefficiencies or procedural delays. Facilities with lower performance might benefit from a detailed review of their operational protocols, staff training, and patient management strategies to identify and address inefficiencies.

Consistently High Quality Across Facilities:

All facilities maintain a high quality of treatment, with most achieving near or perfect quality scores, showcasing a commitment to therapeutic effectiveness.

OEE Highlights Operational Dynamics:

High OEE at facilities like Government Stanley Medical College Hospital contrasts sharply with the very low OEE at others like Government Royapettah Hospital, reflecting different operational efficiencies and treatment capacities. Facilities with low OEE could examine specific aspects such as patient flow, equipment maintenance, and staff allocation to identify areas for improvement in operational efficiency.

TEEP as an Indicator of Utilization:

TEEP scores vary significantly, with some facilities showing good utilization of Cobalt therapy equipment throughout the year, while others indicate underutilization, despite the availability. Understanding external factors impacting TEEP, such as regional healthcare demands or referral patterns, could help facilities strategize better to enhance equipment utilization.

Impact of Performance on Overall Utilization:

Performance emerges as a critical factor influencing overall utilization. Facilities with lower performance rates, despite high availability, demonstrate significantly reduced effectiveness in equipment utilization. Performance metrics could be closely monitored and compared against benchmarks to identify best practices in operational speed and efficiency that could be adopted by lower-performing facilities.

This analysis underscores the importance of not just high availability but also efficient performance in maximizing the effectiveness of Cobalt therapy services. While the quality of treatment remains consistently high, the varying degrees of availability and performance efficiency across these facilities highlight distinct operational challenges and opportunities for improvement. Enhancing technical efficiency, streamlining operational procedures, and addressing scheduling inefficiencies could significantly improve service delivery in facilities with lower OEE and TEEP scores.[44]

Comparative Analysis of Brachytherapy Equipment Utilization Across Healthcare Facilities in Tamil Nadu

This analysis examines the utilization performance of Brachytherapy equipment across different healthcare facilities in Tamil Nadu, highlighting key differences and areas for improvement:

Variations in Availability and Performance:

There is a notable variation in equipment availability across facilities, with some like Government Medical College Hospital, Thanjavur, having moderate availability, and others like Madurai Medical College Hospital showing low availability. Performance levels also vary significantly, generally remaining low across facilities. This suggests operational inefficiencies and potential gaps in scheduling or patient management. The low availability in some facilities might be linked to equipment maintenance issues or a lack of specialized staff. Analyzing downtime causes and staff training needs could help improve availability.

Consistent Quality Across Facilities:

All the analyzed facilities maintain high standards of treatment quality, as evidenced by their perfect quality scores. This uniformity in quality underscores a commitment to patient care and therapeutic effectiveness. The high-quality scores suggest effective clinical protocols and skilled practitioners. Sharing best practices in clinical protocol management across facilities could benefit overall service quality.

Differences in OEE:

OEE scores vary considerably across facilities. For instance, Government Medical College Hospital, Thanjavur, has a moderately low OEE, while Madurai Medical College Hospital has an even lower score. These variations reflect differences in how effectively each facility utilizes its Brachytherapy equipment. Facilities with lower OEE might benefit from adopting advanced scheduling systems and patient management strategies to enhance equipment utilization efficiency.

TEEP as an Indicator of Year-Round Utilization:

TEEP scores are generally low across the board, indicating underutilization of Brachytherapy equipment throughout the year. This underutilization could be attributed to factors such as limited patient referrals, operational constraints, or lack of awareness about Brachytherapy services. Low TEEP scores may indicate a need for outreach programs to raise awareness about Brachytherapy benefits among potential patient populations and referring physicians.

Impact of Operational Strategies on Utilization:

The observed disparities in equipment utilization could be influenced by each facility's specific operational strategies, patient management protocols, and scheduling efficiencies. Facilities with lower utilization might benefit from a review and overhaul of these operational aspects. Facilities with lower performance could examine their patient flow processes, from referral to treatment completion, for potential bottlenecks. Streamlining these processes could improve both performance and patient experience.[45]

The analysis reveals a need for targeted strategies to enhance the utilization of Brachytherapy equipment across Tamil Nadu healthcare facilities. While the quality of treatment remains consistently high, the varying degrees of availability and performance efficiency highlight distinct operational challenges. Improving scheduling efficiency, increasing patient referrals, and enhancing operational protocols could significantly improve the effectiveness of Brachytherapy services in these facilities.[45]

EQUIPMENT UTILIZATION RATE

CT utilization

The utilization of CT scan services in Tamil Nadu presents a complex picture. Madras Medical College (Rajiv Gandhi Government General Hospital) leads in absolute patient numbers, followed closely by Government Medical College Hospital Madurai. Other high-utilization facilities include those in Salem, Coimbatore, and Stanley Medical College Hospital, while Government Medical College, Nilgiris, and others like Sivagangai, Omandurar, Theni, and Tiruvarur see fewer patients.

However, when considering utilization per 100,000 OPD visits, Government Medical College, Thanjavur, emerges as the leader, followed by Salem, Sivagangai, and Tiruvarur. Intriguingly, facilities with the highest absolute numbers show lower rates when adjusted for OPD visits, like Stanley Medical College Hospital and Madurai.

This discrepancy between absolute numbers and per capita rates reveals differing patterns of healthcare access and demand across the region. Facilities with high absolute numbers but lower per capita utilization may indicate a concentration of healthcare services in certain areas, potentially leading to underutilization in others. Conversely, high utilization rates in facilities with lower absolute numbers could signal efficient use of resources or higher healthcare demand relative to population size. It highlights the need for nuanced approaches in resource allocation and healthcare policy, ensuring equitable access and efficient utilization of CT scan services in varying healthcare settings.[46]

HDI vs CT availability and utilization:

The CT equipments are available more equitably across the high, moderate and low HDI districts, though the concentration is more towards the high HDI districts. Facilities in economically prosperous regions could see higher utilization due to greater healthcare spending power and awareness which is reflected in the absolute numbers of utilization in Chennai. Conversely, areas with economic challenges might show lower utilization number. However, in terms of rate, the districts in moderate and low HDI regions had the highest utilization rate (Thanjavur, Sivagangai, and Thiruvarur), which might indicate that the patient-load for CT scan in these facilities is relatively higher for their corresponding OPD load. This trend could imply that patients in lower HDI areas are more likely to visit healthcare facilities, if they must use such advanced diagnostic services or when facing serious health issues, as opposed to routine or less critical medical needs. The observed trends in CT scan utilization across Tamil Nadu's medical facilities may indicate that patients often present in more advanced stages of illness, necessitating the use of such sophisticated diagnostic tools. This pattern could reflect a delay in seeking medical attention or limited access to early diagnostic services in certain areas, leading to a higher reliance on advanced diagnostics like CT scans at later stages of medical conditions.[47]

Equipment utilization vs performance:

The correlation data from Tamil Nadu healthcare facilities in 2022 reveal a significant relationship between the utilization of CT scan services and equipment performance. There is a very strong positive correlation between overall equipment effectiveness and utilization rates, particularly in tertiary care centers, where higher usage of CT scan services is associated with greater equipment effectiveness. Conversely, secondary care centers with lower utilization rates demonstrate lower overall effectiveness. This pattern is also evident in the correlation between total effective equipment performance and utilization rates, underscoring the importance of regular utilization for maintaining high equipment performance in CT scan services.[48]

The strong positive correlations observed between the utilization rates of CT scan services and both overall equipment effectiveness and total effective equipment performance in Tamil Nadu's healthcare facilities offer critical insights. Higher utilization rates in tertiary care centers align with improved equipment effectiveness and performance, suggesting that regular use of CT scanning technology not only maintains but potentially enhances equipment functionality. This trend warrants a deeper exploration into the potential benefits of consistent equipment usage. Conversely, the lower effectiveness in secondary care centers with reduced utilization highlights a potential area for policy intervention and resource allocation. These findings underscore the importance of balancing equipment distribution and utilization across different care levels to maintain optimal service delivery and equipment condition.[47]

Implications:

Resource Reallocation: There may be a need to reallocate resources to balance the disparities in CT scan service utilization across regions.

Policy Reform: Healthcare policies should address the underlying factors driving these disparities, such as population density, healthcare infrastructure, and regional healthcare needs.

Enhancing Accessibility: Efforts to improve access to CT scan services in underutilized regions could include mobile CT units or telemedicine services.

MRI utilization

There is a consistent pattern of fluctuating MRI scan utilization across facilities, with a general decline until 2020, likely due to the COVID-19 pandemic, followed by a recovery post-2020. In the comparison of MRI utilization across various facilities in Tamil Nadu, Government Royapettah Hospital has shown a consistent and significant increase over the years, marking the highest trend in utilization. In contrast, Rajiv Gandhi Government General Hospital (RGGGH) displayed a declining trend until 2020, with a subsequent increase, though not statistically significant. Government Medical College Hospital Thanjavur and KAP Vishwanathan Government Medical College and Hospital Trichy exhibited alternating trends with notable increases post-2020. Coimbatore Medical College Hospital and Madurai Medical College Hospital both showed recovery and increased utilization post-2020 after initial mixed trends. The pandemic has had a pronounced impact on utilization trends, with most facilities experiencing a notable decline in 2020. The increase in utilization post-2020 could be due to the backlog of cases and normalization of healthcare services.

Over the past five years, Rajiv Gandhi General Government Hospital (RGGGH) had the highest number of patients visiting the facility to utilize MRI scan services compared to other facilities. However, the utilization rate paints a different picture as Government Theni Medical College had the highest utilization rate per 100,000 OPD visits throughout the last five years. Government Medical College, Nilgiris and Government Medical College, Thiruvarur had the next highest utilization rate (though their absolute numbers are lesser than rest of the facilities).

A deeper comparative analysis reveals distinct patterns in MRI utilization. For instance, facilities in urban areas might have higher utilization due to better accessibility and greater awareness among the population. In contrast, rural facilities may face challenges like lack of trained personnel or lower patient influx. Understanding these discrepancies is crucial for formulating targeted interventions. The utilization patterns might also be influenced by economic and demographic factors.

HDI vs MRI availability and utilization:

The MRI equipments are available more equitably across the high, moderate and low HDI districts, though the concentration is more towards the high HDI districts. Facilities in economically prosperous regions could see higher utilization due to greater healthcare spending power and awareness which is reflected in the absolute numbers of utilization in Chennai. Conversely, areas with economic challenges might show lower utilization number. However, in terms of rate, all the districts in low HDI regions had the highest utilization rate (Theni, Nilgiris and Thiruvarur), which might indicate that the patient-load for MRI in these facilities is relatively higher for their corresponding OPD load.[49]

This trend could imply that patients in lower HDI areas are more likely to visit healthcare facilities, if they have to use such advanced diagnostic services or when facing serious health issues, as opposed to routine or less critical medical needs. This also suggests that the patients often reach medical facilities at more advanced stages of their conditions, leading to a greater dependence on advanced diagnostic methods like MRI scans. This trend could be indicative of delayed medical consultations or a lack of early diagnostic interventions in certain regions, necessitating the use of MRI for more comprehensive assessment at later stages.[50]

Equipment Utilization vs Performance:

The weak negative correlation between equipment performance and utilization rates indicates that increased usage does not necessarily lead to decreased effectiveness.

Implications

The findings highlight the need for robust healthcare infrastructure to handle fluctuating demands and ensure consistent service delivery. Tailored policies and resource allocation strategies are required to address the unique challenges and needs of each facility. These insights necessitate a more focused allocation of resources, including skilled staff and modern equipment. This approach should be sensitive to the unique demographic and economic contexts of each facility. Continued monitoring of utilization trends, especially in the post-pandemic period, is crucial for understanding the evolving healthcare landscape. Research exploring barriers to accessing MRI services, especially in regions with declining utilization rates, would provide valuable insights.[51]

The utilization of MRI scan services in Tamil Nadu shows a complex interplay of regional disparities, pandemic impact, and recovery patterns. This underscores the importance of flexible healthcare policies and robust infrastructure to adapt to changing demands and ensure equitable access to essential diagnostic services.

Lithotripsy utilization

There is a clear divergence in utilization trends among different facilities. Rajiv Gandhi Government General Hospital (RGGGH) and Government Tirunelveli Medical College and Hospital showed an overall increase in utilization, particularly post-2020. In contrast, Coimbatore Medical College Hospital and Madurai Medical College Hospital experienced a significant decline, especially post-pandemic. The pandemic has had a noticeable impact on utilization trends. All facilities experienced a decline in 2020, but the recovery patterns post-2020 varied significantly. The post-pandemic increase in utilization could be partially attributed to a shift in patient priorities and increased awareness about the importance of timely medical interventions, especially for conditions requiring Lithotripsy.

The dip in 2020 across all facilities can be attributed to the COVID-19 pandemic, likely due to lockdowns, reduced hospital visits for non-emergency procedures, and reallocation of healthcare resources. The post-pandemic recovery in utilization rates at certain facilities could be due to adaptations in healthcare delivery, increased patient backlog, or changes in patient referral patterns.

The trends in APC and AAPC across different facilities offer a detailed perspective but are not uniformly statistically significant. This variance calls for a cautious interpretation of the trends. Further analysis is needed to understand how disparities in regional health infrastructure may contribute to these trends. This includes evaluating the availability of skilled technicians, support staff, and the proximity of these facilities to patient populations. Investigation of the factors contributing to the variability in post-pandemic service recovery is required across facilities. This should include an analysis of patient outreach efforts, changes in operational protocols, and any additional support services introduced.

The fact that only two of the observed facilities had functional Lithotripsy machines during the data collection period indicates potential issues with equipment maintenance or replacement that could affect service availability.

Equipment Utilization vs Performance:

The strong positive correlation between equipment effectiveness and utilization rate suggests that higher usage may lead to improved performance and reliability of Lithotripsy equipment. The correlation between utilization and equipment effectiveness underscores the importance of regular maintenance and timely upgrades of Lithotripsy machines.

HDI vs Lithotripsy availability and utilization

There was no lithotripsy equipment in any of the low HDI districts. The absence of lithotripsy equipment in low HDI districts highlights a significant gap in healthcare resource allocation. To address this, it is recommended to:

Assess Needs and Allocate Resources:

Conduct thorough assessments in low HDI districts to understand their healthcare needs and prioritize the allocation of essential medical equipment like lithotripsy machines.

Improve Accessibility:

Develop strategies to enhance access to specialized healthcare services in these regions, potentially through mobile medical units or partnerships with better-equipped facilities.

Awareness and Training Programs:

Implement awareness programs to educate local healthcare providers and the public about lithotripsy and its benefits, coupled with training programs for local medical staff.

Implications

The varied trends suggest a need for tailored healthcare policies at the regional level, addressing specific challenges and opportunities at each facility. There is a need to enhance patient trust and communication strategies, especially in facilities that have seen a decline in utilization. This involves addressing patient concerns, providing clear information about the safety and efficacy of Lithotripsy, and ensuring transparent communication about service availability.[52]

Research should continue to monitor the long-term impacts of the COVID-19 pandemic on Lithotripsy service utilization, with a focus on understanding how different facilities have adapted. Studies exploring patient experiences, barriers to accessing Lithotripsy services, and the role of healthcare awareness could provide deeper insights into the utilization trends.

The utilization of Lithotripsy services in Tamil Nadu presents a complex picture, with significant variances among facilities. The COVID-19 pandemic has played a notable role in these trends, impacting both the availability and accessibility of services. Moving forward, a focus on equipment maintenance, regional healthcare policy adaptation, and continued research will be crucial in ensuring the effective delivery of Lithotripsy services across the state. There is a need to have a call for focused efforts towards equitable distribution of Lithotripsy services, ensuring that all regions have adequate access to these essential medical services.

LINAC utilization

Facilities in Chennai, Madurai Medical College Hospital, and Government Medical College, Thanjavur, have shown an increasing trend in LINAC service utilization. This may reflect growing awareness and need for advanced cancer treatments. The increasing trend in these areas could also be due to better infrastructure, accessibility, or higher prevalence of conditions requiring LINAC services. Awareness among healthcare providers and patients about the benefits of LINAC therapy, along with referral patterns, could influence utilization rates.

Government Tirunelveli Medical College Hospital and Coimbatore Medical College Hospital exhibited a declining trend. The reasons for this declining trend needs further investigation. This variation in utilization rates between different regions could be due to differences in healthcare infrastructure, patient demographics, or availability of alternative treatments. The absence of long-term data, as most facilities have had LINAC for only 2-3 years, limits the ability to perform comprehensive trend analyses like joinpoint regression.

In addition to the general trends, specific attention should be given to individual facilities. For example, Government Royapettah Hospital, leading in patient numbers, may offer insights into successful LINAC service implementation. Contrastingly, the substantial reduction in Coimbatore Medical College Hospital's utilization in 2022 warrants a focused case study to understand the underlying causes. The divergent trends observed in facilities at Chennai versus those in Coimbatore and Tirunelveli suggest a need for a comparative analysis. This should explore factors like patient access, referral systems, and local health policies that might influence these trends.

Equipment Utilization vs. Performance:

There is a positive correlation between overall equipment effectiveness and utilization rate, suggesting that increased usage might lead to improved efficiency and performance of LINAC services. An investigation into the equipment upgrade and maintenance cycles at these facilities could provide insights. Periodic upgrades and maintenance might correlate with utilization trends, particularly in facilities with declining usage.[53]

HDI vs LINAC availability and utilization:

The distribution and utilization of LINAC equipment in Tamil Nadu reveals a concerning trend about healthcare equity. In this study, we covered 7 out of the 11 LINAC units in Tamil Nadu. With 5 of the 7 LINAC units covered in the study located in high Human Development Index (HDI) districts and the remaining 2 in moderate HDI districts, there is a noticeable absence of such facilities in low HDI areas. Even the four LINAC units not included in the study are in high HDI districts, such as Kancheepuram, Thoothukudi, and additional facilities in Chennai. Furthermore, the highest utilization rates are observed in moderate HDI districts. This suggests a potential mismatch between availability of advanced cancer treatment technology and needs of population.

The absence of LINAC in low HDI districts and the concentration of such equipment in high HDI areas, including those not covered in the study, point towards a significant disparity in healthcare access. Addressing this requires targeted policies to ensure equitable distribution of advanced medical technologies across all HDI regions, particularly focusing on the underserved low HDI districts. This should be accompanied by initiatives to enhance awareness and accessibility, ensuring that all patients, irrespective of their geographic location, have access to critical cancer treatment services.

Implications

The findings highlight the need for equitable distribution of LINAC services across Tamil Nadu to ensure that all patients have access to advanced cancer treatment options. Regular maintenance of LINAC machines and continuous training for medical staff are vital for sustaining high equipment effectiveness and service quality. The findings should inform state-level health policy, especially concerning the allocation and development of LINAC infrastructure. Special attention should be given to areas with declining utilization to identify and address potential barriers.[54]

Studies over a longer period are essential to understand trends and make more robust policy decisions. Research focusing on patient outcomes and satisfaction with LINAC services could provide insights into the quality of care and areas for improvement. Further research is needed to understand the reasons behind the declining utilization in some facilities and devise strategies to address these challenges. Future research should explore how advancements in LINAC technology influence utilization patterns. This includes studying the impact of new LINAC models, software upgrades, and ancillary support technologies on service delivery and patient outcomes.

The utilization of LINAC services in Tamil Nadu presents a mixed picture with increasing trends in some facilities and declining in others. This underscores the need for a more nuanced understanding of the factors influencing these trends. Ensuring equitable access to these advanced treatments, coupled with effective maintenance and staff training, will be key to improving cancer care in the region. A strategic focus on understanding and addressing the challenges faced by underutilized facilities can lead to more balanced healthcare delivery and improved patient outcomes across the state.

Cobalt therapy utilization

Different facilities have shown unique trends in the utilization of Cobalt therapy services. For example, Government Stanley Medical College has seen an increase since its inception in 2021, while Government Royapettah Hospital experienced a dip due to COVID-19 and equipment upgrades. The pandemic significantly affected utilization rates, particularly at Government Royapettah Hospital and Government Tirunelveli Medical College and Hospital. Non-operational periods due to equipment upgrades or other reasons also influenced the utilization trends. Non-operational periods due to equipment upgrades, as seen in Government Royapettah Hospital, likely contributed to a temporary decline in utilization but could result in improved service quality and efficiency in the long run.

The decrease in utilization in some facilities during the COVID-19 pandemic could be attributed to reduced hospital visits, reallocation of healthcare resources, or temporary closure of services. Factors such as staffing levels, technical expertise, and local healthcare policies could also play a significant role in equipment utilization. At patient level, awareness, healthcare literacy, and socio-economic barriers could significantly impact the utilization patterns.

Facilities like Government Mohan Kumaramangalam Medical College and Hospital, Salem, and Government Medical College Hospital, Thanjavur had higher utilization rates, indicating a potential higher burden of cancerous conditions in these regions. Also, facilities with higher utilization rates might be more accessible or better publicized, impacting patient choice and travel distance for treatment. The lack of long-term data and the presence of zero values in certain years limit the ability to perform comprehensive analyses like joinpoint regression, which could provide more nuanced insights into utilization trends.

HDI vs Cobalt therapy availability and utililzation

The distribution of Cobalt therapy units in Tamil Nadu presents a more equitable landscape compared to other advanced medical technologies. Notably, these units are available in both low and moderate Human Development Index (HDI) districts, including Villupuram and Tiruvannamalai. This fairer distribution extends to moderate HDI districts like Madurai, Salem, Pudukottai, and Dharmapuri. The presence of Cobalt therapy in these diverse regions reflects a more balanced approach to healthcare resource allocation, ensuring broader access to essential cancer treatment services across varying socio-economic landscapes. The utilization was again highest amongst the facilities in moderate HDI districts, requiring further in-depth exploration to identify the reasons behind such findings.

Equipment Utilization vs. Performance:

There is a positive correlation between overall equipment effectiveness and utilization rate, suggesting that increased usage might enhance the efficiency of the equipment. This positive correlation might be influenced by regular maintenance and recent upgrades in some facilities.

Implications

The data underscores the need for balanced distribution of resources and services, particularly in areas with high utilization rates. The impact of COVID-19 highlights the need for resilient healthcare systems that can maintain essential services during crises. Well-trained personnel are crucial for efficient operation, patient safety, and optimal utilization of these services. Longer-term studies encompassing more years of data would provide a more comprehensive understanding of utilization trends. Further research on the relationship between equipment performance and utilization could inform maintenance schedules and equipment upgrades.[55] Studies examining the impact of external factors such as policy changes, healthcare funding, and public health emergencies on Cobalt therapy utilization would be valuable.

This analysis reveals the complexity of managing Cobalt therapy services across Tamil Nadu. It highlights the need for adaptive strategies, equitable resource distribution, and robust maintenance protocols to ensure the effective and efficient delivery of these critical services. More holistic approach towards healthcare delivery is required, where Cobalt therapy is integrated seamlessly with other cancer treatment modalities, ensuring a comprehensive care pathway for patients.

Brachytherapy utilization

The utilization of brachytherapy services has shown varied trends across different facilities. For instance, Rajiv Gandhi Government General Hospital (RGGGH) experienced fluctuating utilization with notable dips in 2020 and 2022. In contrast, newer facilities like Government Royapettah Hospital, Coimbatore Medical College Hospital, and others have shown an increase in utilization since their inception.

The alternating increase and decrease in utilization at RGGGH might be influenced by external factors such as changes in patient demographics, policy shifts, or resource availability. The dip in 2020 and 2022 could be attributed to the impact of the COVID-19 pandemic. The impact of external factors such as policy changes, healthcare funding, and public health crises like COVID-19 must be considered. These can significantly affect both the availability and utilization of brachytherapy services.

Government Mohan Kumaramangalam Medical College and Hospital, Salem, and Government Medical College Hospital, Thanjavur, recorded the highest number of patients undergoing brachytherapy, indicating a possible higher prevalence of cancerous conditions in these areas. The lack of long-term data for newer facilities like Government Medical College, Omandurar, and others, limits the ability to perform a comprehensive trend analysis, such as joinpoint regression.

HDI vs Brachytherapy availability and utilization:

The distribution and utilization of brachytherapy services in Tamil Nadu, predominantly in high Human Development Index (HDI) districts with only two facilities in moderate HDI districts and none in low HDI areas, underscores a significant regional disparity in healthcare resources. The fact that the highest utilization rates are observed in the two facilities located in moderate HDI districts further highlights an imbalance. This calls for:

Equitable Distribution of Resources: There's a clear need for equitable distribution of advanced medical services like brachytherapy across all HDI regions, particularly focusing on low HDI districts.

Enhanced Accessibility and Awareness: Strategies to improve awareness about brachytherapy's benefits in low HDI districts, coupled with initiatives to make these services more accessible, are essential. This could include mobile treatment units or establishing satellite centers in underserved areas.

Infrastructure Development: Investment in healthcare infrastructure in lower HDI districts is crucial. This includes not just the installation of equipment but also training local healthcare providers to operate and maintain these facilities effectively.

Research on Utilization Patterns: Further research to understand why utilization is higher in moderate HDI districts despite a greater number of facilities in high HDI areas could provide insights into patient preferences and barriers to access.

These measures are essential to ensure that advanced cancer treatments like brachytherapy are available to all segments of the population, regardless of their geographic location or socio-economic status.[56]

Equipment Utilization vs. Performance:

There appears to be a negative correlation between overall equipment effectiveness and utilization rate, suggesting that increased usage may impact the efficiency of the equipment. The negative correlation between utilization and equipment effectiveness could be due to wear and tear or inadequate maintenance schedules, exacerbated by increased usage.

Implications

The data highlights the need for equitable distribution of brachytherapy services across Tamil Nadu. Regions with higher utilization may require additional resources or alternative strategies to manage the demand. Regular maintenance and potential upgradation of equipment are crucial to ensure consistent service quality, especially in high-utilization facilities. Comprehensive studies over a longer duration across all facilities will provide more robust data, aiding in effective policy formulation. Research focusing on the impact of external factors on the utilization of brachytherapy services can offer insights into effective healthcare management strategies. Further studies are needed to explore the relationship between equipment utilization and performance, to ensure optimal functionality and service delivery.

This analysis underscores the importance of continuous monitoring and evaluation of brachytherapy services in Tamil Nadu. It highlights the need for balanced resource allocation, regular equipment maintenance, and adaptive strategies to cater to the evolving healthcare needs of the population.

ECONOMIC EVALUATION OF ADVANCED DIAGNOSTIC AND THERAPEUTIC EQUIPMENT IN TAMIL NADU

Coverage and utilization of health insurance for diagnostic and therapeutic procedures

The analysis of health insurance coverage and utilization among 2,997 individuals at government medical colleges in Tamil Nadu reveals critical insights into healthcare behaviours. Despite a significant proportion of participants (39.9%) having insurance, there is a noticeable trend of non-utilization, particularly in CT scans, where 53.41% of insured individuals did not use their insurance. This pattern extends to PET scans and MRI scans, with 51.43% and 28.85% of insured individuals, respectively, not utilizing their insurance.

One possible explanation for this could be the low cost of certain procedures like CT scans (500 INR), which might be perceived as more accessible out-of-pocket rather than going through potentially time-consuming insurance processes. This is compounded by a lack of awareness about eligibility for coverage under schemes like CMCHIS. In contrast, for more expensive treatments like LINAC and cobalt therapy, where costs can be prohibitive, the rates of insurance non-utilization are significantly lower.

The findings indicate that despite the efforts of the government to provide comprehensive health insurance schemes, there is a gap in their effective utilization. This could be due to various factors, including a lack of awareness among patients about their eligibility, perceived complexities in availing insurance benefits, and possibly a lack of proactive communication by healthcare providers regarding the use of insurance for certain procedures.[57,58]

Implications and Recommendations:

Enhancing Awareness Programs: There is a critical need for robust awareness campaigns about health insurance coverage, particularly focusing on the eligibility and benefits under schemes like CMCHIS.

Streamlining Insurance Processes: Simplifying and speeding up the insurance claim process, especially for less expensive procedures like CT scans, could encourage higher utilization rates.

Proactive Healthcare Provider Involvement: Healthcare providers should be encouraged to actively inform and guide patients about their insurance options, especially for diagnostic procedures.

Targeted Communication for Expensive Procedures: For high-cost treatments, such as MRI scans and radiotherapy, ensure that patients are aware of and utilize their insurance benefits to reduce out-of-pocket expenses.

Monitoring and Feedback Mechanisms: Implementing monitoring systems to track insurance utilization and gathering patient feedback can help identify barriers and improve the effectiveness of health insurance schemes.

While the Government of Tamil Nadu has made commendable efforts in providing health insurance, there is a clear need to bridge the gap between coverage and utilization. This requires a multifaceted approach involving awareness, process simplification, and proactive communication from healthcare providers to ensure that more individuals can access and benefit from their health insurance.

Patient level Costing Analysis

Overview of financial burden

The financial burden analysis for 2,997 patients undergoing various medical procedures in Tamil Nadu reveals a multifaceted economic impact. PET scans, the costliest procedure, averaged 10,990 INR, primarily due to procedure costs. CT and MRI scans, while cheaper in direct medical costs (500 and 2,300 INR respectively), incurred significant additional expenses like travel and loss of pay. Treatments like lithotripsy, LINAC, and cobalt therapy had minimal direct medical costs due to CMCHIS coverage, but non-medical and indirect costs contributed substantially to the total expense. The median cost analysis across procedures showed PET scans as the most expensive and highlighted the significant financial burden beyond medical expenses.

Direct Medical vs Non-Medical Costs

In analyzing the direct medical versus non-medical costs of medical procedures in Tamil Nadu, a clear dichotomy emerges. Direct medical costs, such as procedure fees, are often the primary focus when assessing healthcare expenses. However, this analysis reveals those direct non-medical costs - including travel, food, and loss of pay - significantly contribute to the overall financial burden on patients. For instance, while CT scans and MRI scans have relatively lower procedure costs (500 and 2,300 INR respectively), the total cost of these procedures, when accounting for direct non-medical expenses, escalates substantially.[59] This observation underscores the necessity of considering the full spectrum of costs incurred by patients in healthcare planning and policy-making, highlighting that the financial impact of medical care extends beyond just the direct medical expenses.

Catastrophic health expenditure

In our analysis, even a single round of diagnostic or therapeutic procedure led to Catastrophic Health Expenditure (CHE) for some participants. This was observed despite annualizing the overall expenditure, as these are not recurrent monthly procedures. If we were to reanalyze considering the expenditure only for the month in which the procedure was conducted, the incidence of CHE would likely exceed 50% due to the substantial costs involved. This scenario highlights the acute financial impact these medical procedures can have, underscoring the necessity of more comprehensive financial safeguards for patients. This comprehensive financial assessment underscores the need for broader cost considerations in healthcare policy, emphasizing the impact of indirect expenses and the importance of insurance utilization in mitigating financial strain.

Procedure specific Cost Analysis

The Procedure-Specific Cost Analysis reveals varying financial burdens across different medical procedures. CT scans, for instance, showed a median direct medical cost of INR 500, but the total cost per patient, accounting for all expense categories, reached INR 1,460. MRI scans, with a higher median direct medical cost of INR 2,300, culminated in a total expense of INR 3,250 per patient. The most striking case was PET scans, where the median direct medical cost stood at INR 10,990, pushing the total cost to INR 12,150 per patient. Conversely, procedures like lithotripsy and LINAC, typically covered by insurance, had minimal direct medical costs. However, their total cost still accumulated significantly due to indirect expenses such as travel and loss of pay. This analysis underscores the varied financial implications of different procedures, highlighting the substantial impact of non-medical and indirect costs on patients' total healthcare expenditure.

Implications

The implications for healthcare policy from this analysis are multifaceted. Firstly, policies need to address the broader spectrum of healthcare costs, beyond just the direct medical expenses. This includes considering indirect costs like travel and loss of pay, which significantly contribute to the overall financial burden on patients. Additionally, there is a need to enhance awareness and utilization of health insurance, especially given its impact in mitigating catastrophic health expenditure. Streamlining insurance processes and ensuring healthcare providers actively inform patients about their insurance options could also be beneficial. Finally, these findings call for targeted interventions to support uninsured and underinsured populations, who are most vulnerable to financial strain due to healthcare costs.[60]

For future research, it is recommended to explore the long-term financial impact of medical expenses on the overall economic well-being of the patients. Further research into patient awareness about insurance benefits and barriers to utilization is crucial. Additionally, examining the healthcare decision-making process of uninsured and underinsured populations can provide insights for policy improvements. Finally, evaluating the efficiency of current healthcare financing models in addressing the disparities in financial burden across different procedures is essential.

Determinant of out-of-pocket expenditure amongst patients utilizing CT scan services in Tamil Nadu

The overview of the determinants of out-of-pocket expenditure (OOPE) for CT scan services in Tamil Nadu involves a comprehensive analysis of 1,919 patients across secondary and tertiary care facilities. This study meticulously examines various factors influencing the financial burden, including residence, socioeconomic status, insurance coverage, distance travelled, waiting time, and type of scan. The impact of each factor on costs is quantified using median costs and adjusted exponentiated coefficients from log-linear regression, providing a nuanced understanding of how these elements collectively contribute to the financial load on patients undergoing CT scans.

Urban residents face a 13% higher cost than rural counterparts, highlighting urban-rural disparities. The disparities in CT scan costs based on residence suggest a deeper urban-rural divide in healthcare expenses. This could be influenced by varying healthcare facility infrastructures and living costs.[61]

Increasing costs with higher socioeconomic status indicate a financial burden gradient, where wealthier patients incur more expenses. The correlation between higher socioeconomic status and increased costs might reflect a tendency for wealthier individuals to opt for more comprehensive healthcare services.[62]

Notably, insured patients not utilizing their insurance and uninsured patients experience significantly higher costs, emphasizing the role of insurance in cost mitigation. The substantial cost difference for insured patients not using their insurance, and for uninsured patients, highlights a critical gap in health insurance literacy and utilization.[63]

Travel distance also escalates expenses, reflecting geographical barriers to healthcare access. Travel distance as a cost determinant underscores the need for more evenly distributed healthcare resources to minimize travel-related expenses. Additionally, longer waiting times and undergoing more complex scans further increase costs. The higher costs associated with longer waiting times and more complex scans might point towards inefficiencies in healthcare delivery and the need for streamlined processes.[64]

These findings collectively call for nuanced healthcare reforms focused on bridging urban-rural gaps, enhancing insurance coverage awareness, and improving healthcare accessibility and efficiency.

Determinant of out-of-pocket expenditure amongst patients utilizing MRI scan services in Tamil Nadu

The determinants of out-of-pocket expenditure for MRI scan services in Tamil Nadu, analyzed across 461 patients, reveal significant insights. Urban residents face a 17% higher cost than rural residents, underscoring the impact of urban living costs and healthcare service disparities. Tailored healthcare policies are required to balance the urban-rural cost disparity. Subsidies or financial support mechanisms could be introduced for residents of urban slums facing higher costs.

Higher socioeconomic groups (Classes I, II, III) bear more significant financial burdens for MRI services, indicating a correlation between wealth and healthcare expenditure. Policies focusing on sliding scale fees based on income could help mitigate the higher costs faced by higher socioeconomic classes.[65]

The stark contrast in costs between insured patients who utilized their insurance and those who did not is notable. Insured but non-utilizing patients and uninsured patients face significantly higher costs, highlighting the crucial role of insurance utilization in reducing out-of-pocket expenses. Increasing awareness and simplifying the insurance claim process could encourage more insured patients to utilize their benefits, thereby reducing their out-of-pocket expenses.[65]

Patients traveling longer distances for MRI scans incur higher costs, reflecting geographical barriers and the added financial burden of travel. Implementing local diagnostic centers and services in remote areas could significantly reduce travel-related costs for patients.[64]

Interestingly, waiting time and the type of MRI scan (plain vs. contrast) did not significantly impact the cost, contrary to the case of CT scans.

Overall, the study reveals complex interplays of residence, socioeconomic status, insurance usage, and travel in determining MRI costs, necessitating policy interventions to address these disparities and improve healthcare accessibility and affordability.

This analysis further underscores the need for targeted healthcare policy reforms. The marked difference in costs between insured patients who utilize their insurance and those who don't highlights a critical area for intervention. Education and outreach programs focusing on the benefits and utilization of health insurance could significantly alleviate the financial burden for patients. Moreover, addressing the urban-rural disparity in healthcare costs requires a multi-faceted approach, including improving rural healthcare infrastructure and enhancing access to affordable care in urban settings. This comprehensive understanding of the factors influencing MRI costs is pivotal in guiding effective policy decisions aimed at reducing out-of-pocket healthcare expenditures and ensuring equitable access to essential medical services.[66]

Determinant of out-of-pocket expenditure amongst patients utilizing lithotripsy services in Tamil Nadu

The analysis of out-of-pocket expenditures for lithotripsy services among 82 patients in Tamil Nadu reveals several key insights. There is no significant cost difference between urban and rural residents, indicating a uniform financial burden across regions for lithotripsy procedures. Higher costs are associated with higher socioeconomic status, although this is not statistically significant in the adjusted model. This suggests a possible but not definitive correlation between wealth and healthcare spending in this context.

The most striking finding is the dramatic cost difference based on insurance coverage. Insured patients who did not utilize their insurance, and uninsured patients, faced substantially higher costs, underscoring the critical role of insurance in reducing out-of-pocket expenses.

Distance does not significantly impact costs in the adjusted analysis, suggesting that travel distance is a less critical factor in lithotripsy procedure costs, unlike other medical services. Waiting time also does not significantly affect the costs, indicating that time factors play a minimal role in the financial aspects of lithotripsy procedures.

These findings suggest a complex interplay of socioeconomic factors and insurance coverage in determining the financial burden of lithotripsy services, with significant implications for healthcare policy and insurance program designs.[67]

Determinant of out-of-pocket expenditure amongst patients utilizing radiotherapy services (Cobalt therapy, LINAC and brachytherapy) in Tamil Nadu

The analysis of out-of-pocket expenditures for radiotherapy services in Tamil Nadu, covering 500 patients and procedures like Cobalt therapy, LINAC, and Brachytherapy, also reveals critical insights. Urban patients incur slightly higher costs than rural patients, but the difference is negligible, suggesting a relatively uniform financial burden across geographic locations. Higher socioeconomic classes face significantly increased costs, with Class I experiencing a 69% increase compared to the lowest economic group. This trend is consistent across other higher socioeconomic classes, indicating a direct correlation between wealth and healthcare spending.

The stark contrast in costs between insured patients utilizing their insurance and those who do not is pronounced. Insured patients not utilizing their insurance and uninsured patients face exorbitantly higher costs, highlighting the crucial role of insurance in reducing out-of-pocket expenses. Longer travel distances significantly increase costs, reflecting the added financial burden of accessing healthcare facilities located far from residences of the patients.[68]

These findings suggest a complex interplay of socioeconomic factors, insurance coverage, and geography in determining the financial burden of radiotherapy services, with significant implications for healthcare policy and insurance program designs.

EQUIPMENT WISE COSTING FROM HEALTH SYSTEM AND SOCIETAL PERSPECTIVE:

ECONOMIC COSTING OF CT SCAN:

The cost analysis of CT scans in medical colleges and government hospitals of Tamil Nadu reveals significant variations in operational costs, influenced chiefly by equipment utilization rates. In medical colleges, the base case scenario shows a substantial difference in costs from the health system and societal perspectives, indicating the additional economic burden borne by society. This disparity is echoed in government hospitals, where lower utilization rates lead to increased costs per procedure, emphasizing the need for efficient utilization of CT scans to optimize resource allocation.

The findings underscore the significant impact of patient throughput on cost efficiency. In high utilization scenarios, costs per procedure drop notably, demonstrating the cost-effectiveness of maximizing equipment usage. Conversely, in low utilization settings, the cost per procedure escalates, indicating inefficiencies and the potential for financial strain on the healthcare system. The primary mechanism driving these cost variations is the fixed nature of capital and operational expenditures. Capital costs, such as the purchase and installation of CT scanners, remain constant regardless of utilization rates. However, when these fixed costs are spread over a larger number of procedures (as in high utilization scenarios), the cost per procedure decreases. This phenomenon is less pronounced in government hospitals, likely due to differences in patient demographics, operational efficiencies, and institutional policies. Operational costs, including AMC, human resources, and electricity, also play a significant role. These recurring expenses, while somewhat variable, can substantially increase the total cost of running CT scan services, especially when the equipment is underutilized.

The costing analysis of CT scans in healthcare facilities of Tamil Nadu highlights the critical role of utilization rates in determining the cost-effectiveness of these diagnostic tools. These findings provide valuable insights for healthcare administrators, policymakers, and public health planners in optimizing the use and allocation of resources for CT scan services. By addressing the identified challenges and implementing strategic recommendations, the economic viability of CT scans can be significantly enhanced, contributing to more efficient and equitable healthcare delivery.

ECONOMIC COSTING OF MRI SCAN

The cost analysis for Magnetic Resonance Imaging (MRI) scans in Tamil Nadu's healthcare facilities highlights the significant influence of utilization rates on the operational and societal costs. The data indicates that both initial investment and ongoing operational expenses are considerable, but their impact per procedure can vary greatly depending on how frequently the MRI scanners are used.

The initial capital investment in MRI equipment is substantial, but this cost is constant regardless of usage. Operational costs, including AMC, manpower, and electricity, also contribute significantly to the overall expenses. These costs are more flexible and can be influenced by the frequency of equipment use.

Higher utilization rates of MRI scanners generally lead to a decrease in the cost per procedure. This is because the fixed costs (like capital investment) are distributed over a larger number of procedures. Conversely, underutilization leads to higher costs per procedure due to these fixed costs being spread over fewer scans.

The cost analysis of MRI scans in public healthcare facilities underscores the complex interplay between initial capital expenditure, ongoing operational costs, and equipment utilization rates. Strategic planning and efficient resource utilization are key to optimizing the cost-effectiveness of MRI services, ensuring they provide value for both the healthcare system and the wider society. By addressing these challenges, healthcare facilities can improve the economic viability of MRI services, contributing to more efficient and equitable healthcare delivery.

ECONOMIC COSTING OF RADIOTHERAPY EQUIPMENTS

The cost analysis of radiotherapy equipment, including Cobalt therapy, Linear Accelerator (LINAC), and Brachytherapy, in Tamil Nadu's healthcare facilities highlights the substantial financial implications of these technologies. The analysis reveals significant variations in costs between the inception year and subsequent years, emphasizing the critical role of utilization rates in determining cost-effectiveness.

The high capital costs of radiotherapy equipment are a significant contributor to the overall expenses, particularly in the inception year. Operational costs, including AMC, manpower, and electricity, add to the financial burden. However, these costs become more manageable when distributed over a larger number of treatments, as seen in facilities with higher utilization rates.

The analysis clearly demonstrates that higher utilization rates can mitigate the cost per procedure, making the investment in radiotherapy more cost-effective. Conversely, underutilization leads to higher per-procedure costs, underscoring the importance of optimizing patient throughput.

The cost analysis of radiotherapy equipment in healthcare facilities of Tamil Nadu underscores the significant financial investment required for these technologies. The findings highlight the necessity of efficient utilization to ensure the financial sustainability of radiotherapy services. By addressing the challenges identified and implementing strategic recommendations, healthcare facilities can improve the cost-effectiveness of radiotherapy services, contributing to more efficient and equitable healthcare delivery in the region.

Implications and Recommendations

Optimizing Utilization Rates: To maximize cost-efficiency, healthcare facilities should aim to increase the utilization rates of the equipments. This can be achieved through better patient scheduling, extending operating hours, or integrating CT/MRI services into diagnostic pathways.

Strategic Resource Allocation: Policymakers and healthcare administrators must balance capital investments with operational expenditures. Investments in advanced diagnostic and therapeutic technology should be matched with strategies to ensure high utilization rates, thus enhancing cost-effectiveness.

Public Health Planning: The government should consider these findings in public health planning, particularly in allocating resources for diagnostic and therapeutic services. Emphasis should be placed on ensuring that advanced diagnostic and therapeutic facilities are accessible and adequately utilized across different regions.

Training and Awareness: Improving training for medical staff on the efficient use of advanced healthcare equipments and raising awareness among healthcare professionals about the economic implications of utilization rates can contribute to more cost-effective healthcare delivery.

Policy Interventions: The government could introduce policy interventions to support optimal utilization of advanced equipments, such as incentivizing high-utilization facilities, subsidizing utilization costs in underutilized areas or initiatives to increase patient referrals to ensure equitable access.

SUMMARY OF THE STUDY FINDINGS & RECOMMENDATIONS

EQUIPMENT AVAILABILITY AND UTILIZATION

KEY FINDINGS:

- **Non-availability of advanced therapeutic equipment in low HDI districts:** Advanced diagnostic equipments like CT and MRI are available in districts across all HDI levels, but advanced therapeutic equipment like lithotripsy, brachytherapy and LINAC are more concentrated in high HDI districts and fewer in moderate HDI districts.
- **High utilization rate in moderate and low HDI districts**: The utilization rate per 100,000 OPD visits was highest in moderate and low HDI districts such as Salem, Thiruvarur, Nilgiris, Sivagangai for equipments like CT and MRI scan. The radiotherapy equipment utilization was also highest in moderate HDI districts (Salem and Madurai).
- **Highest CT utilization rate during COVID-19 pandemic:** Despite a decline in absolute numbers in 2020, there was a marked increase in the utilization rate of CT scans, with the highest usage observed in 2021, indicative of the extensive reliance on CT during the second wave of the pandemic.
- **Shift from Cobalt therapy to Brachytherapy:** Recent years have seen a decrease in Cobalt therapy utilization, coupled with a significant increase in Brachytherapy usage, indicating a trend towards adopting newer, more advanced radiation technologies.
- **Equipment Utilization vs Performance:** Increased utilization of CT, lithotripsy, and LINAC positively impacts overall equipment effectiveness and total performance, while other equipment types did not show any significant correlation.

EQUIPMENT AVAILABILITY AND UTILIZATION

RECOMMENDATIONS:

- **Needs assessment in low HDI districts:** Conduct a thorough needs assessment to identify the requirement for advanced therapeutic equipment in low HDI districts, ensuring equitable healthcare resource distribution.
- **Optimized scheduling and referral system:** Implement a robust scheduling system, preparing weekly charts in advance based on patient inflow pathway and referrals, to efficiently direct patients to facilities with available advanced therapeutic equipment.
- **Uniformity in scheduled time for equipments**: Recommend establishing uniform scheduled times for equipment across all facilities to enhance utilization efficiency and consistency.
- **Public Awareness on Availability of Advanced Healthcare Equipment in Government Facilities:** Enhance public awareness about the availability of advanced therapeutic equipment in their districts to improve utilization rates and encourage patients to utilize government-provided services instead of incurring higher costs in private facilities.
- **Transition from Cobalt to Brachytherapy in Low HDI districts:** The shift from Cobalt to Brachytherapy in institutes with the latter available reflects growing need for targeted treatments for specific cancers. Given that Cobalt therapy, an external beam therapy with high radiation exposure, is the only advanced option in low HDI districts, it is essential to facilitate this transition, replacing Cobalt with Brachytherapy to address the inequity in accessing up-to-date, effective cancer treatments.

CMCHIS COVERAGE AND UTILIZATION

KEY FINDINGS:

- **Coverage of CMCHIS scheme**: Nearly 40% of individuals undergoing advanced diagnostic and therapeutic equipment were covered with health insurance with more than 97% covered under CMCHIS.
- **Underutilization of CMCHIS scheme for diagnostic procedures:** Significant non-utilization of CMCHIS for diagnostic procedures like CT scan (53.4%), PET (51.4%) and MRI (28.9%).
- **Adequate utilization of CMCHIS for advanced therapeutic procedures**: Almost all the patients undergoing various forms of radiotherapy equipments had utilized the CMCHIS scheme.
- **Reasons for underutilization (as reported by patients)**:
    - Lack of awareness about the CMCHIS coverage for CT and MRI scan;
    - Time intensive process for claiming the insurance, causing diagnostic delay;
    - Complexities in the process of claiming the insurance for diagnostic procedures
    - Doctors emphasize completing CMCHIS processes before starting radiotherapy, but often do not inform patients about claiming CT and MRI scans under CMCHIS.

CMCHIS COVERAGE AND UTILIZATION

RECOMMENDATIONS:

- **Awareness Programs and Helpdesks:** Implement strong awareness initiatives about CMCHIS-claimable services, and establish helpdesks, prioritizing facilities with higher CMCHIS non-utilization for CT and MRI.
- **Streamlining Insurance Processes:** Simplifying and speeding up the insurance claim process/provision for claim after undergoing procedure, especially for less expensive procedures like CT scans, could encourage higher utilization rates.
- **Proactive Healthcare Provider Involvement:** Healthcare providers should be encouraged to actively inform and guide the patients about their insurance options, especially for diagnostic procedures.
- **Targeted Communication for Expensive Procedures:** For high-cost diagnostics and therapeutics, such as MRI scans and radiotherapy, ensure that patients are aware of and utilize their insurance benefits to reduce out-of-pocket expenses.
- **Monitoring and Feedback Mechanisms:** Implementing monitoring systems to track insurance utilization and gathering patient feedback can help identify barriers and improve the effectiveness of health insurance schemes.

ECONOMIC COSTING OF ADVANCED HEALTHCARE EQUIPMENTS

KEY FINDINGS:

- **Cost Disparity Linked to Utilization Rates of Advanced Healthcare Equipments from Health System Perspective**:
  - The Government spends almost five times higher the cost per CT scan procedure in low utilization facilities, compared to high utilization facilities
  - For radiotherapy equipments, the cost per procedure spent by the Government was about 10-100 times more in low utilization facilities when compared to high utilization facilities.
  - Higher utilization rate increases the cost-efficiency of the equipment from health system perspective
- **High Out-of-Pocket Expenditure in Societal Perspective:** From a societal perspective, patients spend twice as much as the health system to access services, even after excluding the procedure costs of uninsured patients or those not utilizing their insurance.

ECONOMIC COSTING OF ADVANCED HEALTHCARE EQUIPMENTS

RECOMMENDATIONS:

- **Needs assessment prior to installation of newer advanced equipments:** Conduct thorough needs assessments before installation of new advanced diagnostic or therapeutic equipment, as government expenditure remains nearly equal in areas of both higher and lower utilization rates.
- **Strategy to improve cost-efficiency of equipments:** Improve the utilization and cost-efficiency by mobilizing patients from neighboring districts or sharing catchment areas with high-load facilities to optimize equipment utilization.
- **Government Support to reduce OOPE:** Consider covering a portion of direct non-medical and indirect costs borne by patients, particularly for those undergoing advanced diagnostic procedures (MRI/PET) and therapeutic treatments (Lithotripsy, Cobalt therapy, LINAC, Brachytherapy).

STRENGTHS AND LIMITATIONS OF THE STUDY

Strengths

1. This was the first study to assess the utilization and performance of advanced diagnostic and therapeutic equipment in public health facilities of Tamil Nadu.
2. We did a comprehensive assessment of the time use patterns of 81 equipments in 23 health care facilities from 12 districts, observing nearly 1503 hours or 90,163 minutes of total observation time.
3. We did a comprehensive assessment of annual expenditure of advanced diagnostic and therapeutic equipment from health system and societal perspective.
4. We have estimated the annual percent change in utilization of diagnostic and therapeutic equipment over the past few years.
5. We did data triangulation to confirming the findings for utilization and expenditure. Data triangulation was done through the findings obtained from time motion study, equipment costing, patient level costing and secondary data of utilization rates and annual expenditure. This further enhances the credibility of the study findings.
6. We have also adopted a geographically representative sampling strategy stratified by human development index, which might increase the external validity of our study findings.
7. Higher sample size with 3231 observations for time motion study and 2997 patients for patient level costing.
8. High response rate and cooperation from patients, HCWs and administrative heads of the facilities were added strengths of the study.

Limitations

1. Observer bias was possible during time motion observations, as the Dean/MS/RMO were informed that such observations will be made in a defined period. Hence, the communication of this information to the respective department and direct observation of the procedures might have influenced their practices during the survey.
2. We were not able to observe the equipment over a 24-hour period due to feasibility issues. However, we contacted the technician on the next day to collect the required missing information.
3. We restricted the data collection to expenditures during the current visit to undergo diagnostic and therapeutic procedures in the current facility. We did not collect information about the complete care pathway for their ailment. Future studies can focus on complete care pathway selectively for each clinical condition.
4. We could not collect primary data for certain costs like electricity as they were not available. We have made assumptions for the missing variables. We have performed sensitivity analysis for these variables and reported the expenditure range.

CONCLUSION

Our study found that advanced therapeutic equipment like lithotripsy, brachytherapy and LINAC are more concentrated in high HDI districts and fewer in moderate HDI districts. There is an increasing trend in the utilization of these equipment since their inception except Cobalt therapy and CT scan. Cobalt therapy utilization is declining across all institutes with increase in utilization of brachytherapy. There is a peak in the utilization of CT scan during the COVID-19 pandemic and it is followed by a decline in the subsequent year. Almost all the equipments were available throughout the scheduled time in all institutions, but their performance decreased due to decreased patient load in some institutions. Increase in the utilization rates positively impacts the overall equipment effectiveness and total performance of CT, lithotripsy, and LINAC where the duration of procedure is small, while other equipment types did not show any significant correlation. Implementing robust scheduling system, establishing uniform operating time, and sharing of patient catchment areas between institutions high and low patient load would improve availability and performance of the equipment.

There is underutilization of CMCHIS scheme for diagnostic procedures. Implementing strong awareness initiatives about CMCHIS-claimable services, and establish helpdesks, prioritizing facilities with higher CMCHIS non-utilization for CT and MRI and provision for claim after undergoing procedure would improve insurance claims and reduce direct medical costs for the patients. The Government spends almost five times higher the cost per CT scan procedure and 10-100 times more in low utilization facilities when compared to high utilization facilities. Needs assessment of facility before installation of new advanced equipment and improving utilization rates with awareness campaigns and mobilizing patients from neighboring districts/sharing catchment areas with high-load facilities would improve the cost-efficiency of equipment.

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