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A COMPREHENSIVE EXAMINATION OF 1.5 TESLA MAGNETIC RESONANCE IMAGING (MRI) THROUGH OVERALL EQUIPMENT EFFECTIVENESS ANALYSIS : A STUDY CASE ON THE HOSPITAL SECTOR

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ABSTRACT

The research study focuses on hospitals with Magnetic Resonance Imaging (MRI) facilities which the population process for medical imaging equipment has experienced a higher average of values in every year which is data on the number of medical imaging devices in all Indonesian hospitals like Magnetic Resonance Imaging (MRI). Nowadays Magnetic Resonance Imaging (MRI) is a medical equipment really helpful to save patient for the diagnostic. High machine downtime and large number of lost time when trouble is still become a big problem for hospital when use medical equipment as a research object in this study. This research aim to analize OEE with Magnetic Resonance Imaging (MRI). The test parameters encompassed Performance, Availability, and Quality. Tolerance limits for these parameters were recommended by the World Class Overall Equipment Effectiveness. The study utilized a set to determine the entire workload and calculate the duration of MRI equipment usage. The findings revealed that, over a one-month observational period, only one measurement variable met the standards based on World Class OEE. The results shed light on the performance and efficiency of the MRI equipment in the context of diagnostic processes, providing valuable insights for further improvement and optimization.

Keywords: *Overall Equipment Effectiveness, Magnetic Resonance Imaging, Performance, Availability, Quality*

INTRODUCTION

The current healtcare facility is becoming more conscious of the topic after pandemic Covid 19 in a few past years ago. One of the main goals is to prepare equipment so that usefull in patient. Not only manufacturing activities that focus on maintenance, but also hospital as healthcare facility have begun ton shift towards effectively service into patient. Based on interview with a radiographer at a hospital informed that there is a weekly rise in the number of patients receiving MRI. Despite the MRI tool's extended installation history, unanticipated problems occurred in its third and fourth years of operation. Data from troubleshooting indicates downtime, which means stopping tool use. In addition, the MRI apparatus is undergoing maintenance, which making it useless for patient examination.

The seamless operation of the hospital's service process has been delayed by troubleshooting issues with MRI equipment. Hospitals experience large losses as a result of this disorder. The hospital in this case, the Radiology Department continues to look for ways to maximize the use of the MRI equipment while also addressing the rising number of patients and the high operational costs of maintaining MRI due to the need to replace helium, which eventually runs out. In order to guarantee that medical equipment particularly MRI equipment is used as efficiently as possible, more research must be done. This will allow the hospital to assess the equipment's effectiveness and improve its management of MRI equipment going forward.

The diagnostic process, which is typically associated with X-rays, is beginning to change as a result of additional advancements utilizing radio waves. A non-radiative magnetic source is used in magnetic resonance imaging (MRI), a radiodiagnostic method that helps with a variety of clinical and imaging applications to learn more about an organ's function in the human body [1]. Due to the availability of medical technology with less radiation risk, patients' need for MRIs is increasing. The necessity of the medical examination process today also aligns with the increasing variety of disease types, necessitating the use of a radiodiagnostic tool with appropriate accuracy and speed for the process of diagnosing a disease using imaging results. Thus, it is not surprising that MRI users nowadays are experiencing persistent fatigue. However based on ASPAK data publish by Ministry of Health Indonesia, there many equipment have increasingly significant use by hospital in Indonesia.

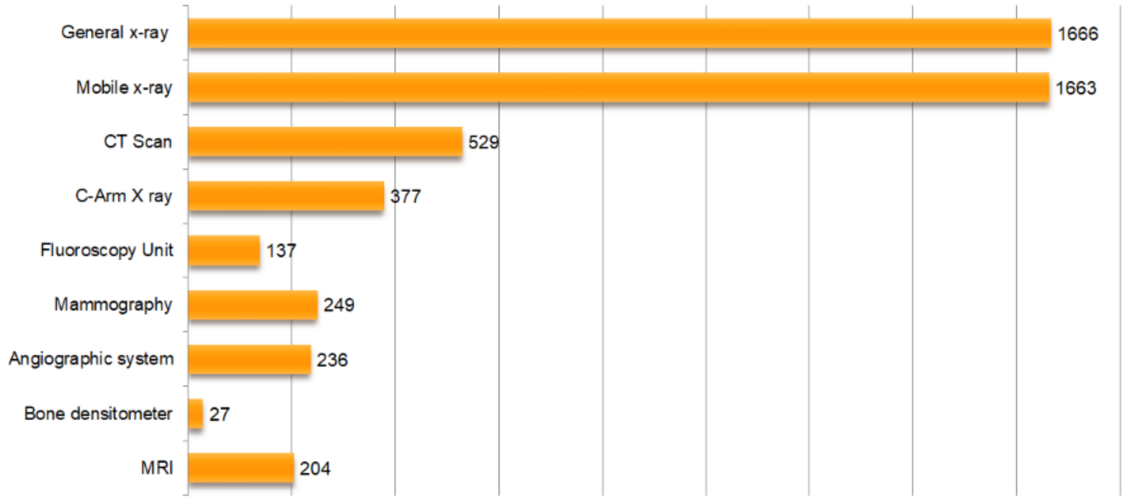

Fig 1 Medical Imaging Population at Indonesia [2]

Figure 1 shown that MRI have 204 equipment overall in Indonesia [2]. Not only does MRI continue to increase in population, modalities such as Angiography are also closely related to needs related to the growing number of heart patients in hospitals [3] [4]. Not just the equipment, but also several kinds of other radiology-related supporting modalities, such as the usage of PACS as a tool to complete the process of creating films from scanned images [5] [6].

Previous research have focused on the use of OEE to medical equipment, specifically to ventilators [7] and linear accelerators [8]. Only these two medical equipment have been researched, and the MRI were the subject of this research [9]. OEE is usually applied heavily to examine how production equipment is used in manufacturing [10]. In addition to concentrating on a tool, OEE is also utilized to examine the work system of a process [11]. But above all, OEE serves as a technique for process optimization and analysis of potential failure sources. Research on medical devices especially is still developing, not only about systems but also about how they are made. As an example, an microcontroller can be used to make digital scales [12] also for needle destroyer [13]. This makes medical equipment research an interesting topic with many connections to scientific perspectives, all leading to the ultimate goal of increasing the productivity of using medical devices.

LITERATURE REVIEW

In this section, we will discuss the literature review that is still related to the materials and methods taken in this study. This grouping of literature studies should be focused and conceptualized between the research methods taken and the literature review used.

A. Magnetic Resonance Imaging

An area of medical science called radiology uses a variety of physics, electronics, and computer techniques to picture different body sections and help in disease diagnosis. Medical diagnostic imaging is performed by using two methods: invasive and non-invasive. A strong magnetic field is used to align the atomic nuclei of muscle molecules, which is how magnetic resonance imaging (MRI) works [1]. Next, radio frequency pulses are supplied vertically to the magnetic field lines, causing a direction change in some of the hydrogen nuclei. Then the radio frequency will be switched off, returning the nuclei to their original condition [14]. This results in the expulsion of radio frequency energy, which the waves around the patient can detect [1]. This signal is captured, and a computer processes the resulting data to create an image of the body part being scanned [15].

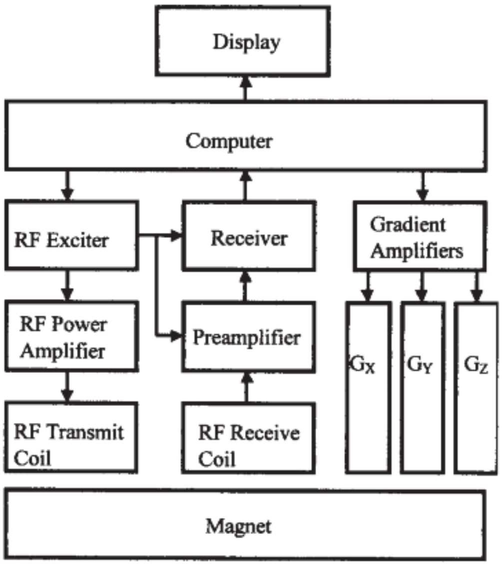

Fig 2 Components composing a MR system [15].

Fig 3 Magnetic Resonance Imaging by Philips [16]

B. Total Productive Maintenance

The aim of total productive maintenance (TPM) is to optimize the efficiency of industrial facilities [17]. This includes not only maintenance but also all aspects of production operations at facilities and installations, including increasing employee motivation. the. TPM started as a maintenance procedure designed to boost output by improving process reliability and reducing waste [18]. Improve every aspect of the production system's functioning on a constant basis by encouraging each employee's daily awareness. Although its advantages may be applied to nearly any process, TPM typically concentrates on manufacturing. Its implementation is based on the technique Toyota initially employed to strengthen its position in the world in 1950 [17]. Suppliers and customers—specifically, the Supply Chain—were involved once TPM's focus expanded.

C. OEE

OEE is a comprehensive measurement that shows the productivity of equipment and machinery as well as its supposed performance [19]. This measurement is crucial to identifying where productivity equipment efficiency needs to be increased. It can also highlight production line bottlenecks [20]. OEE is a measurement instrument that may also be used to assess as well as improve suitable practices that ensure higher productivity when using equipment and machinery [19]. The Availability Rate is 90%, Performance Rate is 95%, and Quality Rate is 99% based on the OEE World Class standard; OEE's standard value is 85% [21]. Here is the mathematical formula for OEE.

$$\text{Availalibility Rate (AR)} = \frac{\text{Loadig Time} - \text{Unplanned Downtime}}{\text{Loading time}} \text{ x } 100\ \% \tag{1}$$

$$\text{Performance Efficiency (PR)} = \frac{\text{Iddle Run Time} - \text{Total Production Part}}{\text{Operating Time}} \text{ x } 100\ \% \tag{2}$$

$$\text{Quality Rate (QR)} = \frac{\text{Total Produced Part} - \text{Total Defect Parts}}{\text{Total Produced Parts}} \text{ x } 100\ \% \tag{3}$$

OEE = Availability x Performance efficiency x Rate of quality product x 100% (4)

. If one is to calculate performance efficiency alone, for example, the working conditions of production machines/equipment will not be adequately shown [22]. The OEE calculation must take into consideration the six significant losses in order to accurately represent the condition of the equipment [19].

METHODOLOGY

This research was conducted in the hospital as radiological service unit. The focus of this research is on the MRI of magnetic wave. This type of research is mixed methods. The design of research is descriptive exploratory which aims to determine the causes of the emergence of losses machine operating time and how to make repairs as reference for user. The types of data needed in this study are primary data and secondary data. Primary data was obtained from direct observation with datasheet that use when MRI works with patient, and also obtained interview with expert which engineer and radiographer as user MRI. While secondary data were obtained from literature, previous research, books, and company report such preventive maintenance procedure and schedule. This study uses systematic steps so that this research is focused and directed. This research steps is divided into 4 stages, namely as follows.

Stege 1 : For this research project, a comprehensive approach was adopted, incorporating literature search, direct data collection, and a month-long observation of Magnetic Resonance Imaging (MRI) activities. The literature search aimed to establish a solid foundation by reviewing existing studies, protocols, and advancements related to MRI technology, with a focus on 1.5 Tesla MRI systems. This phase ensured that the research was well-informed and built upon the latest developments in the field. Direct data collection involved gathering specific information relevant to the study, such as equipment specifications, usage patterns, maintenance data, record all activities on the observation sheet in minutes and create a classification of MRI activity.

Stage 2 : The next stepp is to calculate the baseline OEE using the formula. In assessing the overall equipment effectiveness (OEE) of 1.5 Tesla Magnetic Resonance Imaging (MRI) systems, key performance indicators were employed to measure specific aspects. The Availability Rate output value quantifies the proportion of time the MRI equipment is operational and available for use, providing insights into system uptime. The Performance Rate output value measures the efficiency of the MRI system during active scanning periods, indicating how well the equipment performs in comparison to its maximum potential. Additionally, the Quality Rate output value assesses the precision and accuracy of diagnostic imaging, reflecting the system's ability to consistently produce high-quality results. These three output values collectively contribute to a comprehensive evaluation of the 1.5 Tesla MRI system's overall equipment effectiveness, enabling a nuanced understanding of its operational performance, efficiency, and imaging quality.

Stage 3 : The analysis of Overall Equipment Effectiveness (OEE) is a crucial aspect in evaluating the performance and efficiency of equipment, such as the 1.5 Tesla Magnetic Resonance Imaging (MRI) system in this study. OEE serves as a comprehensive metric by combining factors such as Availability, Performance, and Quality rates.

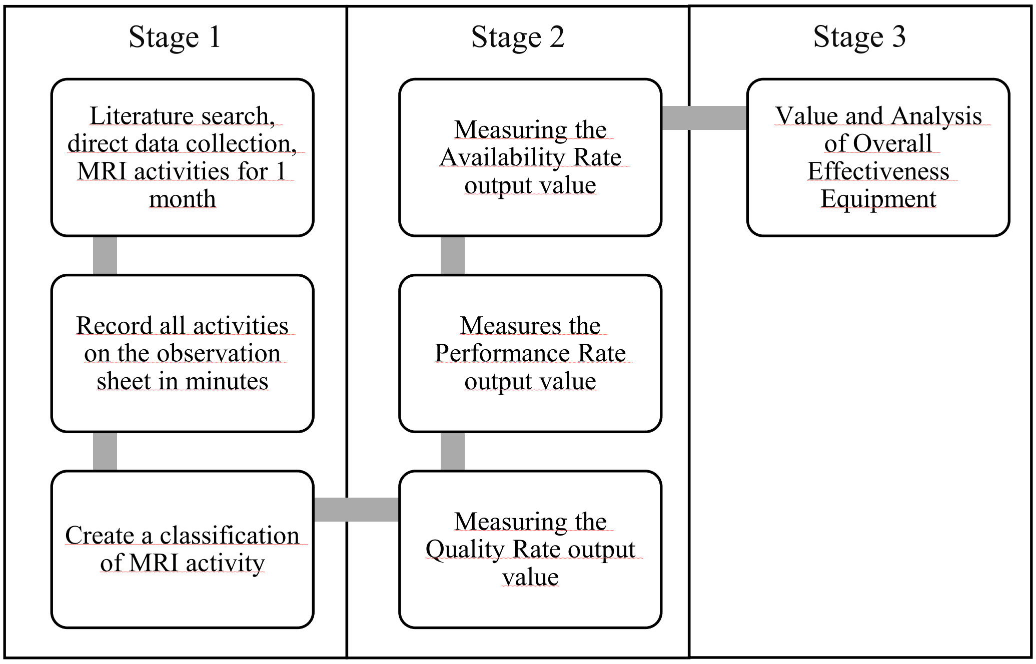

Fig 4 A framework research

RESULT AND DISCUSSION

All activities (primary data) that took place when utilizing the magnetic resonance imaging equipment while at the hospital were measured and recorded in order to gather research data. It was discovered during data collecting that 37 patients' worth of data were collected per week. There were seven users who carried out MRI procedures. The MRI equipment that used in this research is MRI 1,5 Tesla by Philips. Furthermore, only three users have had instruction from Principle on how to use an MRI. Table 1 presents a summary of the six big losses.

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Tabel 1. Six Big Losses Data

No. Patient	Age	Protocol	Minutes Total	Hours Total	Reject and Losses	Film Total
1	26	Pelvis	94	1'34"00	No	7
2	36	Brain	86	1"26"00	No	6
3	29	Genu Shoudier	85	1'25'00"	No	10
4	60	Abdomen	111	1'51'00"	No	8
5	46	Abdomen	48	00'48'00"	No	12
6	38	Abdomen	64	01'04'00"	No	7
7	30	Abdomen	82	01'22'00	No	9
8	45	Thorak	89	01'29'00"	No	9
9	24	Cervical	72	01'12'00"	No	4
10	49	Cervical	87	1'27'00"	No	4
11	70	Brain	108	01'48'00"	1, Film Reject	4
12	54	Brain	72	01'12'00"	No	8
13	39	Pelvis	69	01'09'00"	No	8
14	41	Lumbal	80	1'20'00"	No	4
15	44	Brain	82	1"22'00"	No	7
16	45	Pelvis	110	1'50'00"	No	5
17	36	Pelvis	98	1'43'00"	Problem with contrast	5
18	48	Lumbal	53	00'53'00"	No	4
19	74	Lumbal	125	2'05'00"	1 Film Reject, condition patient low	4
20	59	Abdomen	118	1'58'00"	No	2
21	44	Lumbal	87	1'27'00"	No	4
22	27	Brain	77	1'17'00"	No	7
23	29	Abdomen	45	0'45'00"	Claustrophobia	No
24	42	Pelvis	109	1'49'00"	Re -Scan T2 Coronal	8
25	51	Pelvis	72	01'12'00"	1 Reject Film	5
26	37	Cervical	69	01'09'00"	No	5
27	58	Lumbal	66	01'06'00"	No	4
28	40	Shoulder	50	0'50'00"	Claustrophobia	No
29	39	Abdomen	83	01'23'00"	No	10
30	39	Brain	71	01'11'00	No	7
31	47	Brain	69	01'09'00"	No	6
32	54	Lumbal	90	02'00'00"	No	4
33	13	Brain	105	1'45'00	No	7
34	27	Lumbal	83	1'23'00	No	6
35	43	Brain	113	01'53'00"	2 Reject Film	4
36	45	Pelvis	93	01'12'00"	1 Reject Film	5
37	35	Brain	64	01'04'00"	No	7

A. Availability Rate

The availability of the MRI medical equipment is measured by its availability rate. Operational and loading time data are required in order to calculate Availability (AR) data. Categories are used to generate classifications of operating time and loading time in the observation sheet of actions performed during use in order to obtain this data. The processed data groups that were utilized to generate classifications during the evaluation of the Overall Effectiveness Equipment variable are explained below.

Table 2.Data for Availibity Calculation

Description	Process	Total *(Minute)*
The procedure for finishing the examination	Finishing	251
Inspection and identification procedure	Introduction	206
User Mistake in Scanning	Man Error	46
Scanning *(work)*	Operation	1359
Kesalahan oleh pasien	Pasien Error	88
The patient's preparations	Preparation	180
The method of producing a film by printing (Work)	Production	276
Registering in the foyer of the radiology department	Registering	233
Protocol configurations	Setting	440
The instrument fails	Down Time (rusak)	0
Avaialabitiy Rate	**Total**	$=\frac{Total\ time-Unplanned\ Downtime}{Total\ time}x\ 100\ \%$ $=\frac{3079\ Minute-0}{3079\ Minute}x\ 100\ \%$ =100%

It is shown by the above data that both the overall time and the actual downtime are used to calculate the availability rate. After combining these findings with the data from the MRI machine's running period, we obtain an AR value of 100. The processed data groups, integral to the evaluation of the Overall Equipment Effectiveness variable, are systematically explained below. Each group represents a distinct set of activities or conditions related to the operational and loading phases of the MRI equipment. By categorizing these activities and conditions, a comprehensive understanding is gained regarding the factors influencing the availability rate. This approach not only facilitates the quantification of equipment availability but also provides insights into the specific aspects that contribute to or detract from the overall effectiveness of the MRI medical equipment. As such, the utilization of codes and categories in data collection and classification becomes a fundamental aspect of assessing and optimizing the operational efficiency of MRI systems in a healthcare setting.

B. Performance Efficiency

A medical equipment that uses magnetic resonance imaging (MRI) to do operation is considered to have performance efficiency. This variable shows the difference between the ideal and actual run rate. The Ideal Run Assess value in hospitals is determined by factors that have a high degree of variation, such as different operator abilities; therefore, the Ideal Run Rate value is based on the maximum speed. This is because the research location is not in the Manufacturing Industry, which already has an Ideal Run Rate value. Radiographer in finishing the procedure from start to finish during the inspection, while conducting research. This is corroborated by a reference from Principle—in this case, Philips Healthcare—which states that there is no set amount of time allotted for MRI exams, measured from the moment the patient enters until the exam is completed. The optimal run rate, as determined by a skilled radiographer, was 48 minutes in this study.

Table 3.Data for Performance Calculation

Performance	Total	Information
The quantity of patients attended	37 Patients	Total number of patients examined with magnetic resonance imaging (MRI)
Minutes spent	3079 /Minutes	total all the minutes that were spent.
Duration of use throughout	1776 /Hours	The total of all the hours worked
regular work hours	22 Days	One month is allotted for inspection work.
Average patient rate	83,21622 /Minutes	As a result, a single patient requires 83.21/Minute.
Ideal Run Rate	50 /Minuted *(Hospital-Recomended)*	Perhaps if the average time needed is 50 minutes, MRI could serve 62 persons with a time utilization of 3079 minutes. This is consistent with the minute computation that was applied, which is 3079 divided by 50 minutes.
Performance Rate	$= \frac{\text{Iddle Run Time} - \text{Total Production Part}}{\text{Operating Time}} \times 100\ \%$ $= \frac{50\ \text{Minutes} - 37\ \text{patient}}{22} \times 100\ \%$ $= 60\ \%$	

As can be observed from the previously mentioned information, idle time and total production are used to calculate performance rate. These findings are then combined with operational time data from MRI equipment to produce PR data of 60%.

C. Quality Rate

The ability of an MRI medical equipment to produce high-quality medical results is referred to as quality rate. The operational quality results in this study are based on the film made at the conclusion of the inspection because the research location is not in the manufacturing industry. The quality rate of an MRI is pivotal in ensuring that the medical imaging it provides is accurate, reliable, and meets the standards required for effective diagnosis and treatment planning. In this study, the evaluation of quality rate is not only indicative of the equipment's technical performance but also its clinical utility. As such, the assessment is centered around the visual outputs, typically in the form of diagnostic images, which serve as critical tools for healthcare professionals in making informed decisions about patient care. This distinction underscores the unique considerations and criteria involved in gauging the quality rate of medical equipment, particularly MRI systems, within a healthcare context.

Table 4. Data for Qualitiy Rate

Parameter	Total
Film Production Total	222
Good Film	216
Reject	6
Rework	12
Quality Rate	$= \frac{\text{Total Produced Part } - \text{Total Defect Parts}}{\text{Total Produced Parts}} x\ 100\ \%$ $= \frac{222 - 18}{222\ film} x\ 100\ \%$ $= 92\ \%$

It is shown by the data mentioned above that the Quality Rate is derived from both the total production and the total number of faulty parts. After that, we use the MRI equipment to integrate these results with production data to obtain AR data of 100.

D. OEE Result

The below information was gathered based on studies conducted on the efficacy of magnetic resonance imaging using component variables, specifically the availability rate test, performance rate test, and quality rate test.

Table 5. OEE Result

OEE Factors	Standard OEE World Class	Magnetic Resonance Imaging (MRI)
Avaialability Rate (AR)	90,0 %	100 % / 0,001
Performance Rate (PR)	95,0 %	60 % / 0,60
Quality Rate (QR)	99,9 %	92 % / 0,92
Overall Effectiveness Equipment (OEE)	85,0 %	= AR x PR x QR x 100 % = 0,01 x 0,60 x 0,92 x 100 % = 0,5592245 % OEE = 55 %

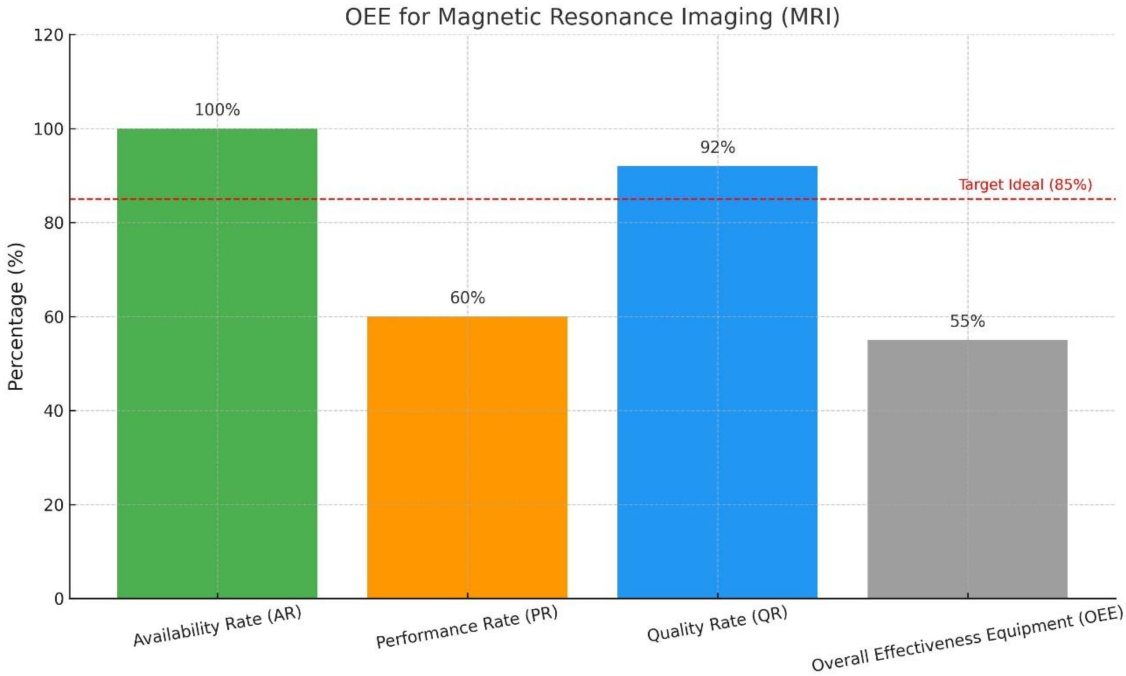

Fig 3 OEE Graph

It is evident from table 1 and fig. 2 above that availability, performance, and quality calculations yield the OEE number. It is evident from these data that the OEE the percentage is 55%.

CONCLUSSION

According to the Overall Equipment Effectiveness (OEE) approach, the effectiveness of MRIs in hospitals is 55%. It is evident from a thorough examination of field data that MRI OEE testing results fall well short of the World Class OEE reference level. The three main variables—Availability Rate, Performance Rate, and Quality of Rate—are mostly responsible for this disparity in performance. Although the Availability Rate is within the intended range, the Performance Rate and Quality of Rate output values are decreasing. Specifically, problems with user reliability, management, and service have led to a decline in the Performance Rate and a faltering Quality of Rate. The results highlight the necessity of enhancing user reliability, management procedures, and service-related elements in order to prevent mistakes in the Quality of Rate evaluation. To improve these weaknesses and the general functionality of the hospital's MRI systems, more thorough research is advised.

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