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Finding Scope for Implementing Correct Strategy for Maintenance of Medical Equipment Using Failure Database

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Abstract: ***Aim/Purpose: The purpose of this research is to develop a framework for deciding the maintenance strategy of medical equipment in hospitals, with the aim of enhancing their functionality. The focus is on the equipment used in the diagnosis of various diseases in patients. This research is particularly relevant during a pandemic, as the availability and precision of medical equipment are crucial requirements for hospitals. Background: Medical equipment plays a vital role in diagnosing diseases and treating patients. Inadequate healthcare services can have negative effects on hospitals' income, and the unavailability of equipment can hinder the treatment and livelihoods of individuals, especially in developing countries like India. Methodology: The research proposes the use of a Preventive or Scheduled Maintenance Management System to design the framework. This system will be developed using a Computerized Maintenance Management System (CMMS). Failure Mode Effect Analysis will be utilized to categorize failures and assess risks in order to minimize the criticality of medical equipment. Contribution: The study aims to measure the importance of medical equipment and its usability after implementing different maintenance practices adopted by organizations to improve their service. By developing this framework, the research contributes to the effective management of medical equipment maintenance. Findings: The classification of medical equipment based on usage and departments can help categorize their functionality and importance. By analyzing the failure database of medical equipment over a three - year period (2019 - 2021), it is possible to identify frequently failed equipment. The implementation of scheduled maintenance can result in a reduction in failure rates and an increase in the availability of medical equipment. Recommendations: for Researchers this research opens up opportunities to design a framework for making maintenance decisions, prioritizing repairs, and ensuring the timely availability of medical equipment for healthcare practitioners. Impact on Society: Healthcare units provide essential services to society, and accurate diagnoses with proper investigations are crucial for human well - being. Inadequate services can hinder the growth of health organizations and negatively impact people's lives. Therefore, the research aims to contribute to improving healthcare services and overall societal well - being. Future Research: Future research could focus on implementing Failure Mode and Effect Analysis and using computerized maintenance management systems (CMMS) based on technologies like Python or Industry 4.0. These advancements could further enhance the maintenance strategies for medical equipment.***

Keywords: Maintenance techniques, Maintenance strategy, Medical Equipment, Maintenance Framework, Essential Medical Equipment

1. Introduction

Medical equipment plays a crucial role in diagnosing and treating patients, and it is important for healthcare organizations to ensure that the devices they use are safe and accurate. This is particularly important in both rural and urban hospitals in India. The maintenance of medical equipment and its availability during times of need, such as the COVID - 19 pandemic, is a critical consideration for hospitals.

A study by S N Gandhare, S K Narad et al (2020) compared healthcare before and after the implementation of the Swachh Bharat Mission in rural hospitals to determine the prevention ratio. This research focused on the importance of maintaining medical devices, especially in critical situations like a pandemic.

To achieve accurate diagnosis and functionality, hospitals have implemented various maintenance strategies through their Biomedical Engineering departments. Some hospitals follow standard operating systems based on guidelines provided by ISO or BIS specifically for medical equipment suitability (Taraneh Yousefinezhadi, 2016). These strategies are often based on preventive or predictive maintenance approaches (H. C. Liu, 2019). Inspection systems have been implemented to monitor maintenance costs effectively.

The objective of the study is to analyze the effectiveness of maintenance strategies currently implemented by various organizations and their impact on society. Additionally, the study aims to design a simple framework that minimizes the efforts of the biomedical department and focuses on scheduled maintenance strategies to provide accurate services. Medical equipment maintenance involves activities conducted to keep the equipment in optimal working

condition. This includes intermittent assessments, preventive maintenance, running repairs, and corrective maintenance (S N Gandhare et al, 2021). These maintenance activities are crucial for ensuring the longevity and functionality of medical equipment.

Here are some examples of basic medical equipment widely used in hospitals:

- Diagnostic equipment: This category includes devices such as X - ray machines, ultrasound scanners, MRI machines, CT scanners, and electrocardiography (ECG) machines used for diagnostic purposes.
- Patient monitoring equipment: These devices are used to monitor vital signs and include equipment like blood pressure monitors, pulse oximeters, cardiac monitors, and respiratory monitors.
- Surgical equipment: This category includes surgical tools, operating tables, anesthesia machines, surgical lights, and other equipment used during surgical procedures.
- Life support equipment: This equipment is essential for critical care units and includes ventilators, defibrillators, infusion pumps, and dialysis machines.
- Laboratory equipment: This includes equipment used in laboratory settings, such as microscopes, centrifuges, autoclaves, and spectrophotometers.

It is important to classify and categorize medical equipment properly to ensure effective maintenance strategies. The life cycle of medical equipment in general medical organizations involves procurement, installation, operation, maintenance, and disposal.

Overall, the maintenance of medical equipment is a crucial aspect of healthcare organizations' operations, and implementing effective strategies ensures accurate diagnoses and proper functionality of equipment to serve patients effectively.

Important Medical Equipment with their uses:

1) Diagnostic imaging equipment

Imaging the internal health of a patient can be determined as Diagnostic imaging equipment. Medical practitioners can take efficient decisions through the analysis of Diagnostic imaging equipments (McKay, 1986).

a) Ultra - sound equipment
b) MRIs
c) CT scanners
d) Diagnostic X - ray equipment
e) X - rays, MRI and CT scanners may be less recurrently used, and is generally added if the financial plan is available in a hospital. These are practices are costly for rural hospitals but more effective to spot and cure the patients' health.

2) Laboratory equipment

Many laboratory equipment are used in biochemistry departments to analyse the hematology of the patient. Most of them are measuring instruments in chemical laboratories to investigate.

a) Microscope
b) Incubator/oven
c) Water bath
d) Refrigerator
e) Distillation and purification apparatus
f) Hematology Equipment
g) Analytical balance
h) Spectrophotometer
i) Centrifuge

3) General electro - medical equipment

These are the devices which are electronically operated and accurately analyze the health of patients.

a) Dental chair unit
b) Suction pump
c) OT Light
d) Diathermy unit
e) Portable ECG
f) Defibrillator
g) Anesthesia unit (Mobile)
h) Respirator

4) Other support equipment

Many surgical as well as supporting types of equipment are used in the hospitals for medical treatments.

a) Generator
b) Air conditioner, dehumidifier
c) Power regulator
d) Operating theatre table
e) Delivery table
f) Autoclave.
g) Sterilizing Equipment
h) Cold chain and other preventive medical equipment
i) Well - equipped Ambulance
j) Gynecological examination table

Many organizations establish various maintenance strategies to make available safe and reliable procedure of maintenance of medical equipment and support its useful utilization (Stiefel, 2009). Medical equipment and devices play a crucial role in healthcare settings for diagnosis, treatment, monitoring, and patient care. Here's a brief description of the different categories of medical equipment you mentioned:

- Diagnostic Equipment: These devices are used to identify or determine the nature and cause of a medical condition. Examples include blood counters used for analyzing blood samples and pacemakers used to regulate heart rhythms.
- Therapeutic Equipment: Therapeutic devices are used to correct or treat physical disabilities or surgically created defects in the human body. They can involve the use of radiation energy, prosthetic limbs, orthopedic equipment, and other specialized devices for specific treatments.
- Monitoring Equipment: Monitoring equipment is designed to continuously or periodically measure and display the vital signs or physiological parameters of patients. Electrocardiographs (ECGs) are one example of monitoring devices that provide real - time information about a patient's heart activity.
- General Equipment: This category includes a wide range of equipment used for routine patient care, such as hospital beds, infusion pumps, wheelchairs, surgical instruments, and basic diagnostic tools like thermometers and stethoscopes.

- Educational Equipment: Medical equipment is also used for educational purposes, allowing medical practitioners to learn and enhance their skills. Examples include anatomical models, simulators, and virtual reality - based training tools.

It's important for healthcare organizations to establish effective maintenance strategies to ensure the safe and reliable operation of medical equipment, as well as maximize their useful life and utilization in providing quality healthcare services. The new devices are normally used to research the various diseases which occurred rarely and can be diagnose as per its biochemistry analysis. (ShararehTaghipour, 2011)

Medical Equipment Management in Hospitals

In Hospital Medical Equipment go through the various phases from requirement to Installation, Maintenance and lastly replacement should be done if the cost of its maintenance goes more than its cost of purchase. The Medical equipment can be differentiated in many ways; it can be working as life support, it can diagnose the disease as well as patient, can be monitored with delivering therapies. Medical equipment can also be used for educational purposes or research work for development. The risk associated with medical equipment can be controlled by life of the equipment, if the device is periodically inspected. (ShararehTaghipour, 2009)

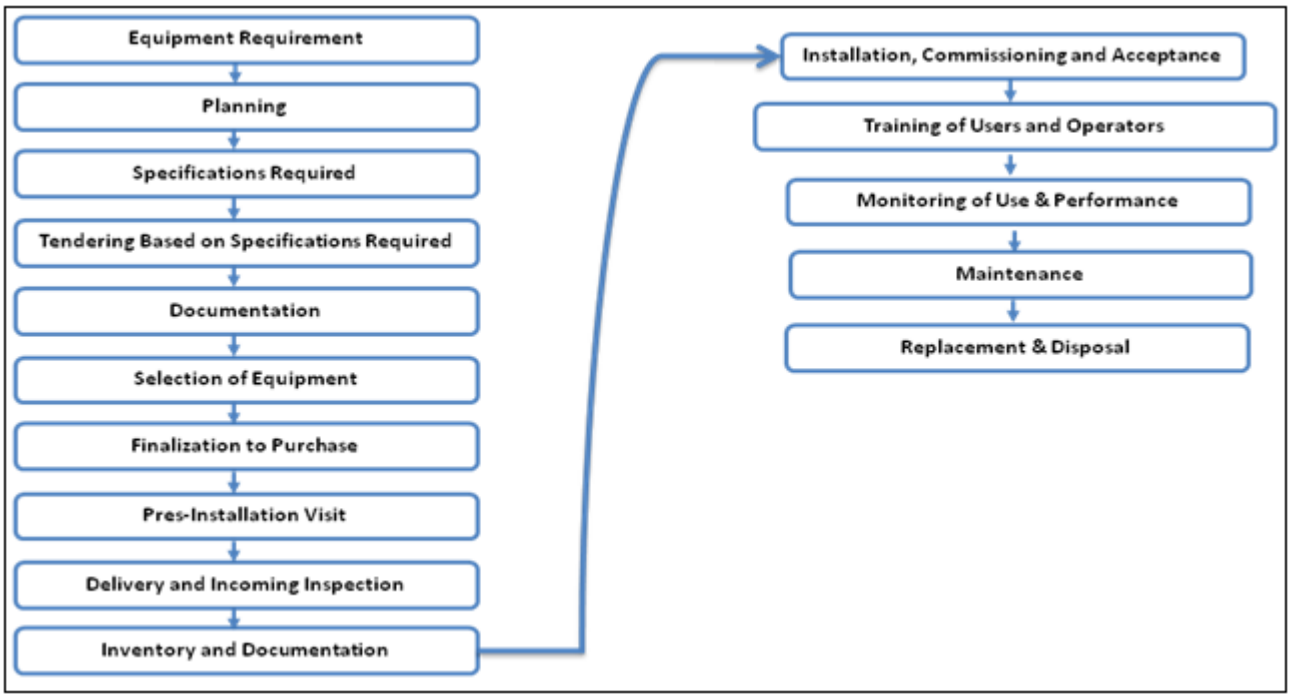


Figure 1: Medical Equipment Management in Hospitals

Maintenance Strategies Implemented

Medical devices are too difficult to repair which may consist of critical components that are desirable to perform their primary function. Many types of equipment are the assembly of the parts of electromechanical devices with monitoring features. Once the equipment fails to perform its actual use can only be satisfactorily restored except for the substitute of the entire device. (Ascher and Feingold, 1984). Medical equipment is repaired with different types of maintenance, which maybe depend on the date of purchase to prolonged use of its last repair cycle.

1) Primary Inspection Method:

While purchasing or ordering new medical equipment, the acceptance test for a newly received device should be taken; its repairing is scheduled to be performed periodically. Acceptance test means, while entering the device it is inspected and its functioning can be monitored on a trial basis to accept the device in an organization. If any dilemma is found at inspection, corrective actions are taken to reinstate the equipment or if defective parts are repaired to an acceptable level. To minimize future failures some preventive actions are taken to refurbish the device. It includes calibration, replacement, etc.

2) Preventive Maintenance Method

Preventative maintenance refers to the pre - defined stage of the failure that occurred. The physical monitoring of the device with its proper functionality test can be counted as preventive maintenance. The biomedical Engineer or technician decides the maintenance tasks if found equipment faulty or the device is still running smoothly to avoid future breakdowns or emergency maintenance issues may be occurred. (Neven Saleh, et al 2015) Preventative maintenance can avoid equipment failures and expand the useful life of the medical device. Due to preventive maintenance, the cost of sudden failure can be saved which is one of the important factors to save the resource of the maintenance management system.

3) Predictive Maintenance Method

Predictive maintenance is scheduled maintenance that takes precautionary actions to save the life of the equipment. In recent technology - enhanced monitoring systems like Artificial intelligence can predict or monitor the data

through which the actual condition of the device can be inspected. Using high predictable technology detection systems, performance can be taken to schedule the maintenance task for the work order and equipment can be repaired or saved from its future failure. (S Taghipour et al 2011)

4) Reliability Centred Maintenance

Reliability cantered maintenance adds valuable dimension to conduct the maintenance. It focuses on the avoidance of failures and their far - reaching and costly consequences. (R K Sharma, 2007) Reducing the high cost of failure becomes the most effective means of using a maintenance strategy for the organization. (Siti Hajar Salim, 2019) Reliability cantered maintenance refers to all means that users, like a medical practitioners, staff nurses and biomedical engineers are to be trained to use the equipment and maintain the device for a long period time. RCM can add substantially to the achievement of equipment reliability. (Tomlingson, 2009)

5) Computerized Maintenance Management Systems

Computerised Maintenance Management System is approach that maintains the record in an organization that helps in planning and management functions necessary for effective repairing actions (Gulati and Smith, 2009). Computerized Maintenance Management Systems maintains the electronic record of the equipment. As the database is recorded, it can be transferred to the entire department associated with the same equipment so that compliance related to it will be effectively monitored (Cohen, 2008). The Computerized maintenance management system is helpful as accreditation is required for many hospitals which achieve the quality of maintenance as per the care standards (Cram, 1998).

6) Scheduled Maintenance Management System

As we discussed CMMS is the part of scheduled maintenance, where maintenance strategies are implemented their schedules as per the requirement of equipment like quarterly, half - yearly and yearly. This type of maintenance management system follows the framework designed by the biomedical engineers or the authorities to keep the systematic periodic maintenance of medical devices.

List of Essential Medical Equipments in Hospitals

Hospitals with multispecialty facilities with well - equipped departments have very useful instruments to diagnose the diseases. Those hospitals providing all facilities have to maintain their equipment up to date. The Hospital where research work is going to be conducted is well - equipped multispecialty hospitals with 35 departments and many PHCu. The researchers classify the medical equipment on the basis of the main branches i. e.; medicine and surgery. Biochemistry departments called as Pathology, for child care pediatrics, immense diagnostics through radiology, brain related diseases are psychiatry, neurology, and skin related terms are dermatology emerged from medicine, while women genitals are obstetrics - gynecology, to overcome surgery anesthesiology, bone diseases are covered under orthopedics, eyes are cured in ophthalmology, otorhinolaryngology is the head neck related illness, and neurosurgery branched from surgery. (Eugene Braunwald, 2006) Following is the list of essential equipment commonly found in rural and urban hospital which is advised by medical council of India. (IPHS, Revised 2012 for district hospital with 100 to 500 beds). These equipment also need critical maintenance for the hospitals to provide essential facilities in any hospitals.

Table 1: List of Essential Medical Equipment

Sr. No	Critical Care Equipment
1	Patient monitor
2	Defibrillators
3	Ventilator
4	Infusion Pump
5	Syringe Pump
Sr. No	**Diagnostics & Imaging**
6	EKG/ECG machines
7	Haematology Analyzer / Cell counter
8	Biochemistry Analyzer
9	X - ray Machine
10	Ultrasound
Sr. No	**Operating Theatre (OT)**
11	Surgical lights / OT Light
12	Surgical tables/ OT tables
13	Electrosurgical unit / Cautery machine
14	Anaesthesia machine / Boyle's apparatus
15	Suction apparatus / Suction machine
16	Sterilizer / Autoclave

Collection of Failure data for past three years

Biomedical department of the hospital provides past three - year equipment failure data year wise. Equipment provided in the above list is found repeatedly failed with common reason of failure. Past 03 year data is available based on; the statistical presentation of equipment failure is as below;

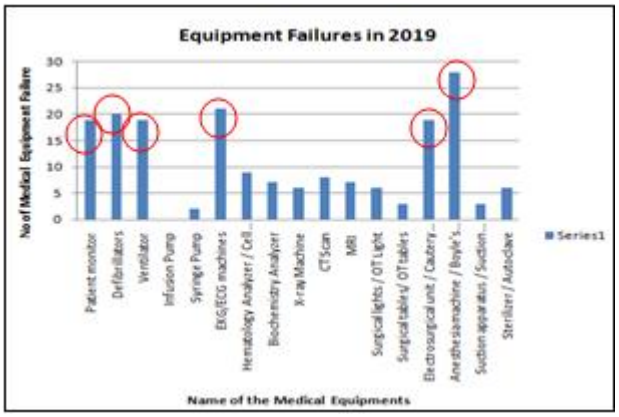
Table 2: No of Medical Equipment Failure observed during Year 2019, 2020 and 2021

Sr. No.	Name of the Department	Name of the Essential Equipment	No of Failures		
			2019	2020	2021
1	Critical Care Equipment	Patient monitor	19	12	22
2		Defibrillators	20	22	24
3		Ventilator	19	24	22
4		Infusion Pump	0	2	3
5		Syringe Pump	2	1	2
6	Diagnostics & Imaging	EKG/ECG machines	21	27	18
7		Haematology Analyzer / Cell counter	9	6	3
8		Biochemistry Analyzer	7	8	6
9		X - ray Machine	6	2	1
10		CT Scan/ Ultrasound	8	6	4
11		MRI	7	3	1
12	Operating Theatre (OT)	Surgical lights / OT Light	6	4	5

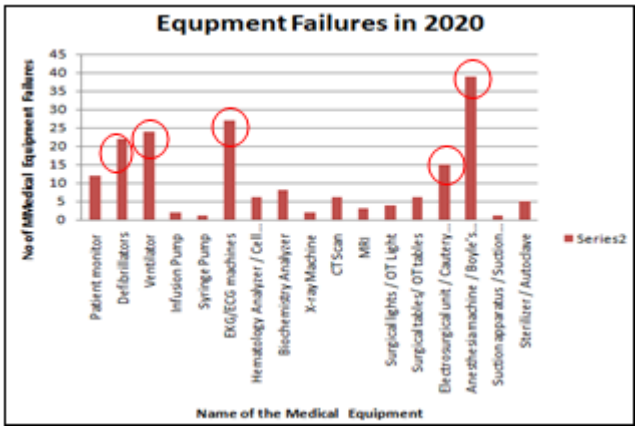
13		Surgical tables/ OT tables	3	6	7
14		Electrosurgical unit / Cautery machine	19	15	11
15		Anaesthesia machine / Boyle's apparatus	28	39	34
16		Suction apparatus / Suction machine	3	1	0
17		Sterilizer / Autoclave	6	5	1
18	All departments Related	Miscellaneous	192	287	182

Statistical Representation of Equipment Failures

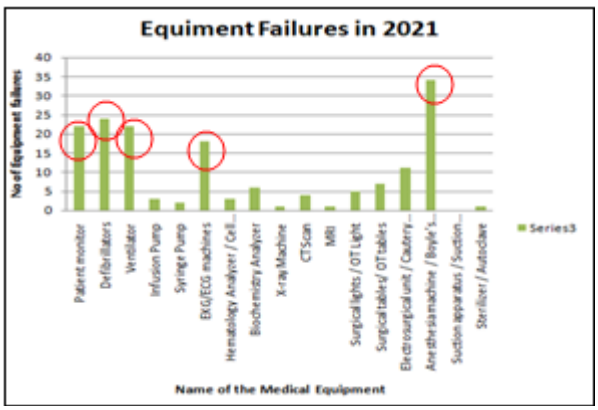
The three consecutive year data of the equipment failure has been collected to know the equipments which required more maintenance as per their failure records. Most essentials equipments are considered under the study which is more essential to save human health as well as diagnosis can be done for the disease to analyses and cure the patient.



Graph 1: Equipment failures observed during 2019



Graph 2: Equipment failures observed during 2020



Graph 3: Equipment failures observed during 2021

In the database, it can be observed that some equipment failed frequently, while some of them have not shown any failure during the period. That equipment is noted with the red color circle to highlight them in the above representation. The equipment found commonly failed for the consecutive periods are;

1) Patient monitor
2) Defibrillators &
3) Ventilators

These devices are from critical care departments in the hospital called life - saving medical equipment.

While other equipments from diagnostics and imaging to analyse the diseases are;

1) ECG/ Echo Machines &
2) CT scan/ Ultrasound
3) X - ray machines

ECG machines show more no of failures as compared to CT scan and X - rays, but those are more important to identify the cause of disease, so contend as an important machine in the maintenance

In the next department which is the surgery OT department, is highest equipment required part of the hospitals shows intensive as well as precision devices should be kept for the section. Operation theatres have more emergencies to save the life of critical health of human beings, so maintenance for these departments should give high priority to maintenance - related activity. Following equipment found high no of failures;

1) Electrosurgical unit / Cautery machine
2) Anesthesia machine / Boyle's apparatus.

From the statistical analysis with the help of failure data, it can be brought to a close that equipment or devices from Critical care, surgical or Operation theatre and diagnostic departments should be maintained at high concern equipment to manage the Hospitals.

Classification of Medical Equipment as per their use

In the biomedical department where research is going to be conducted, equipment is classified under the following categories.

Table 3: Classification of Medical Equipment as per research

Category	Use
A	Equipment with high importance as lifesaving Instrument. E. g.; Ventilator, Anesthesia Machine, Defibrillators
B	Equipment as revenue generation as well as Life Saving E. g.; X - ray, CT scan machine
C	Equipment is important but not lifesaving nor revenue generating E. g.; OT table
D	Equipment with less importance but in use. E. g.; Scissors, AC etc.

The above categorization can simplify the medical equipment maintenance and priorities can be given to those devices which are critically required with a minimum time of repairmen.

2. Limitations of this Study

The limitations to the study while assessing failure data of the equipment to study the present maintenance strategy;

1) Many types of equipment haven't their date of warranty, so equipment should be repaired by the organization, though it is in warranty period. The cost of repairing may be increased.
2) To design the new framework, the present maintenance strategy is not exactly defined. The organization is working as on basis of the Equipment category of need, and its criticality. So, developing a new strategy based on the present workforce is a difficult task.
3) All the departments cannot be covered under the study for scheduled maintenance, as many types of equipment need sudden replacement after breakage.

3. Conclusion and Recommendations

Based on the study conducted on the present Failure analysis to develop new maintenance strategy, several fruitful investigations have been made, leading to the following recommendations:

1) Enhancing the system framework: By analyzing the existing equipment data, it is evident that there is room for designing a framework that can improve the system. This suggests that there are opportunities to optimize and upgrade the maintenance strategy, potentially leading to better performance and efficiency.
2) Prioritizing essential equipment: It is recommended to prioritize the maintenance of essential equipment within specific departments. By implementing a priority - based approach, the maintenance strategy can be aligned with outcome - oriented results, which will ultimately enrich the overall function of the maintenance department. This means focusing resources and efforts on critical equipment that significantly impact operations or patient care.
3) Implementing scheduled maintenance using a CMMS: While it may not be possible to suggest a specific type of maintenance for each medical equipment without detailed analysis, the study recommends implementing scheduled maintenance through a Computer - Based Maintenance Management System (CMMS).

This system would allow for accurate tracking of breakdowns, timely maintenance reminders, and precise data management. By proactively addressing maintenance needs, the risk of unplanned breakdowns can be reduced, and the overall cost of repairs can be minimized.

Abbreviations

IPHS	Indian Public Health Standards
BIS	The Bureau of Indian Standards
ISO	International Organization for Standardization
CT	Computed Tomography
MRI	Magnetic resonance imaging
ECG	Electrocardiogram
OT	Operation Theatre
CMMS	Computerized Maintenance Management System
PHCUs	Primary Healthcare Units

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