Journal of Research in Medical and Dental Science
2024, Volume 12, Issue 2, Page No: 06-14

Available Online at: www.jrmds.in
eISSN No. 2347-2367: pISSN No. 2347-2545

Seamless Care, Seamless Operations: Mitigating Medical Equipment Downtime and Maintenance Costs for Uninterrupted Patient Care

Suneetha Raghu[1]*, Krishnappa J[2], Dinesh K[3], Zeanath CJ[4]

[1]Department of Quality & Administration, Sri Devaraj Urs Academy of Higher Education and Research, Karnataka, India

[2]Department of pediatrics, Sri Devaraj Urs Academy of Higher Education and Research, Karnataka, India

[3]Department of Anesthesiology, Sri Devaraj Urs Academy of Higher Education and Research, Karnataka, India

[4]Department of Nursing Administration, Sri Devaraj Urs Academy of Higher Education and Research, Karnataka, India

ABSTRACT

Effectively managing maintenance expenses and medical equipment downtime is essential in modern health-care settings to guarantee continuous patient care. In tertiary care hospitals, where efficient operations are essential for the best possible patient outcomes, this study attempts to explore the intricacies of this problem. Aim/Objectives: In order to provide continuous patient care in tertiary health-care institutions, the major goal of this research is to look into ways to reduce medical equipment downtime and related maintenance expenses. Estimating the effect of downtime on patient care, determining the causes of downtime, estimating the financial impact of maintenance expenditures, and suggesting workable mitigation solutions are some of the specific goals.

Methodology: The study was a longitudinal one that collected data retrospectively for one year. The Biomedical department and the purchase department kept track (soft copy and hard copy) that contained information about the dates of procurement, the frequency and duration of breakdowns, the type of contract, the cost of maintenance, and the down time of the equipment.

Results: Uncertainty about the impact of medical equipment failures on patient care delivery in tertiary institutions is evident from preliminary research, which also reveals higher operating expenses and service interruptions. Technical malfunctions, outdated maintenance plans, and ageing equipment are some of the factors that cause downtime. Effective cost management measures are crucial since maintenance expenditures account for a significant amount of hospital budgets. The study's recommendations are intended to enhance maintenance procedures, expedite processes, and guarantee smooth service delivery in tertiary care environments.

Key words: Continuous medical care, Medical equipment malfunctions, Maintenance expenses, Tertiary care facilities, Seamless provision of care, Efficiency of operations, Strategies for mitigation.

HOW TO CITE THIS ARTICLE: Suneetha Raghu, Krishnappa J, Dinesh K, et al. Seamless Care, Seamless Operations: Mitigating Medical Equipment Downtime and Maintenance Costs for Uninterrupted Patient Care. J Res Med Dent Sci, 2024, 12(2):06-14.

Corresponding author: Suneetha Raghu

e-mail✉: mgr.qualityandadmin@sduaher.ac.in

Received: 25-January -2024, Manuscript No. jrmds-24-127944;

Editor assigned: 27-January-2024, PreQC No. jrmds-24-127944(PQ);

Reviewed: 10-February-2024, QC No. jrmds-24-127944(Q);

Revised: 16-February-2024, Manuscript No. jrmds-24-127944(R);

Published: 22-February-2024

INTRODUCTION

The uninterrupted operation of hospital services is ensured through equipment maintenance. Given all of these considerations, it is important to look into the effects of different types of maintenance contracts and its cost (warranty, AMC, CMC) on medical equipment downtime. Equipment and its maintenance play an important role in all health-care sectors, and it is essential for health-care providers to ensure patient safety. Medical equipment is used for the specific purposes of disease diagnosis and treatment or rehabilitation in the consequences of disease or injury. It can be used alone or in combination with any accessory, consumable, or other piece of medical equipment. The most

expensive equipment at first may end up being less expensive in the long term.

In order to maintain patient care in health-care settings, it is imperative that medical equipment downtime and maintenance expenses are effectively managed. This research draws on a wide range of previous studies to address the issues raised by equipment downtime and related expenses. The literature reviews address different facets of technology use and maintenance scheduling in health-care settings. Time value of money is emphasized in Salmasnia, et al discussion of integrated maintenance planning models that take warranty policies and technology levels into account [1]. The usefulness of contractual agreements is clarified by Gupta, et al. analysis of the effect of maintenance contracts on equipment downtime [2]. Lin, et al. investigate performance metrics in medical facilities and use the Balanced Scorecard approach to improve service performance [3]. In order to provide insights into cost management techniques, Aunion-Villa, et al. evaluate the maintenance costs of elector-medical equipment in Spanish hospitals [4]. Mellado-Silva et al. address flow-shop scheduling issues pertaining to repair and maintenance planning, emphasizing the use of scheduling approaches in the health-care sector [5]. Additionally, Rossit et al. offer optimization insights through a combination examination of scheduling difficulties [6]. Smithson, et al. highlight how outsourcing clinical engineering services offers an alternative strategy for maintenance management [7]. In order to minimize tardiness, Lee, et al. explore scheduling issues and provide solutions that increase operational effectiveness [8]. Clark examines replacement planning for medical equipment and highlights the significance of strategic planning for equipment life-cycle management [9]. Corciova, et al. examine maintenance prioritization techniques and offer insights into resource allocation strategies [10]. In order to improve equipment performance and reliability, Shamayleh, et al. suggests a criminality-based reliability-cantered maintenance strategy designed specifically for health-care institutions [11]. In their study, Badnjevic, et al. explores the complexities of maintaining medical devices, emphasizing both advantages and disadvantages [12].

According to Kanamala, creative methods like the use of Artificial Intelligence (AI) in equipment replacement planning show how maintenance management is changing [13]. Udroiu discusses maintenance programme optimization, emphasizing the improvement of programme efficiency [14]. Furthermore, in order to provide insights into maintenance plans, Von Schewelov does statistical analysis of corrective and preventative maintenance in medical equipment [15]. A thorough analysis of medical equipment maintenance in Indian tertiary care hospitals is provided by Tadia, et al. who also point out prospects for improvement in maintenance procedures [16]. Our research endeavor to suggest efficacious approaches for reducing medical equipment maintenance expenses and downtime, taking into account the varied viewpoints and discoveries from these investigations. This will finally ensure smooth operations and continuous patient care in health-care environments.

AIM and OBJECTIVE

Assess the hospital maintenance expenses and medical equipment downtime.

Determine the causes of maintenance expenses and medical equipment downtime in hospital operations.

METHODOLOGY

The study was a longitudinal one that collected data retrospectively for one year. The Biomedical department and the purchase department kept track (soft copy and hard copy) that contained information about the dates of procurement, the frequency and duration of breakdowns, the type of contract, the cost of maintenance, and the down time of the equipment.

The hospital has various specialities centers such as ICUs, OTs, OPDs, Emergency Department, Central Laboratory, Blood Centre, Radiology Department, Physiotherapy Department, CSSD, and so on. All of the hospital's medical equipment is managed by the Biomedical Department through an institution fund under the management's control.

The necessary data was gathered from the biomedical department and documented for each device. All low and high cost items maintained and details documented in the biomedical department were investigated in terms of their

universal utilization and downtime in all sections of the hospital, criticality, and availability of the equipment under warranty, AMC & CMC period, and life cycle. The cost-to-service ratio was computed using the formula shown below.

Cost of service Ratio =Maintenance Cost/ Equipment Acquisition Cost x 100

RESULTS

Various medical departments of medical equipment at the hospital were held accountable. The expenditures of medical equipment were assessed, as was the downtime of the medical devices. Medical equipment maintenance is governed by many types of service contracts between the hospital and the service provider. In our study, the medical equipment was under warranty, the equipment was under AMC/CMC, and the calibration of each piece of equipment was covered. Based on the findings, our management will be able to develop the annual budget plan for the coming years.

A financial indicator used to assess the effectiveness of different departments within an organization is the yearly cost service ratio (CSR), which is most commonly applied to health-care institutions such as hospitals. It calculates the ratio between the entire yearly expenses incurred in operating a department and the total yearly income from services rendered by that department. The departments inside a health-care institution are represented by bars in the given [Figure 1].

The corresponding percentage for each department indicates the department's annual cost service ratio and the percentages signify in the above figure.

Central Laboratory

This indicates that 66% of the total income received from the services rendered by the central laboratory is used to cover the annual operating expenses of the facility.

Radiology

In a similar vein, the annual total cost of the radiology department is equal to 72% of the total revenue that the department generates from its services.

Blood Centre

This department's interpretation is also applicable T.

Operating Theatre

The operating theatre's yearly expenses are equal to 70% of the total money received from the services it offers.

ICU (Intensive Care Unit)

The annual cost of the ICU is equivalent to 54% of the entire revenue that the ICU generates from services rendered.

Physiotherapy

The department's entire yearly expenses are equal to 46% of the total money the department receives from the services it offers.

Radiotherapy 56% the annual cost of the radiotherapy department is equal to the total revenue that the department receives from the services it provides. Central Sterile Services Department (CSSD) (38%), which charges 38% of the entire money that, comes in from the services it offers. **Laundry**

The laundry department's entire yearly expenses equal 36% of the total money the department makes from the services it offers. Emergency

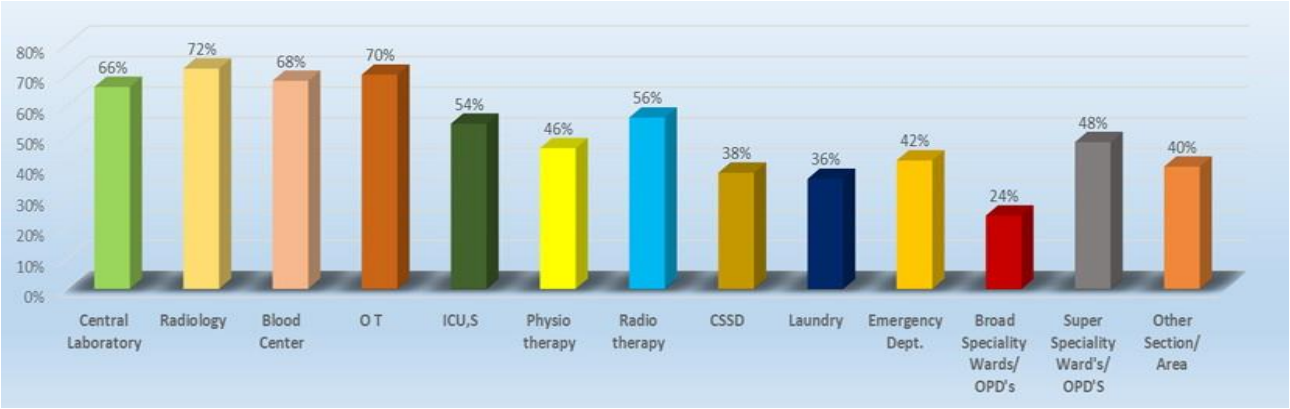

Figure 1: Department Specific Cost Service Ration of Medical Equipment's.

Department (42%), Total Annual Cost 42% of Total Revenue from Services Received by the Emergency Department.

Broad Specialities Wards/OPDs

The entire yearly expenditure for these units is equal to 24% of the overall income from the services they offer.

Super Specialty Wards/OPDs

The annual cost of these facilities is equal to 48% of the entire amount of money received from the services they offer.

Other Section/Area

The annual total expense for other sections/ regions is equal to forty percent of the total income from the services rendered in those areas. In [Figure 2] percentages showing prevalence of each element to overall problems

Appears to reflect different factors contributing to particular problems or failures. Each factor is explained as follows

Inadequate or Inappropriate Maintenance

This category includes cases where equipment or products malfunction as a result of inadequate or ineffective maintenance practices. This indicates that 60% of failures have this reason. Product Failure (64%), which denotes that, independent of external causes, 64% of problems or failures stem from intrinsic flaws or malfunctions in the product itself.

Mishandling

When goods or equipment are handled incorrectly or misused, it can result in failure. 74% of the problems are related to this aspect.

Thirty percent of the difficulties are software-related, meaning that problems resulting from bugs, glitches, or compatibility concerns account for thirty percent of the total issues. 60% of the time, administrative constraints are defined as restrictions or impediments imposed by rules, policies, or administrative procedures. They are responsible for 60% of the problems.

Untrained Staff

This shows that 40% of problems are brought on by staff members who do not have the skills or training required to handle goods or machinery safely.

Lack of Spares, Accessories, and Consumables

This factor identifies situations in which problems occur because there are insufficient spare parts, accessories, or consumables needed for upkeep or operation. This factor accounts for 28% of the problems.

Expected Wear and Damage

This category includes problems that arise from expected deterioration of products over time or from natural wear and tear. It makes for 78% of all issues.

Adverse Environmental circumstances

Adverse environmental circumstances (such as temperature, humidity, exposure to elements) leading to product failure, contributing to 28% of the issues. All things considered, these percentages offer insights into the different elements that contribute to particular problems or failures, assisting in the identification of areas in need of development or intervention to lessen such problems in the future.

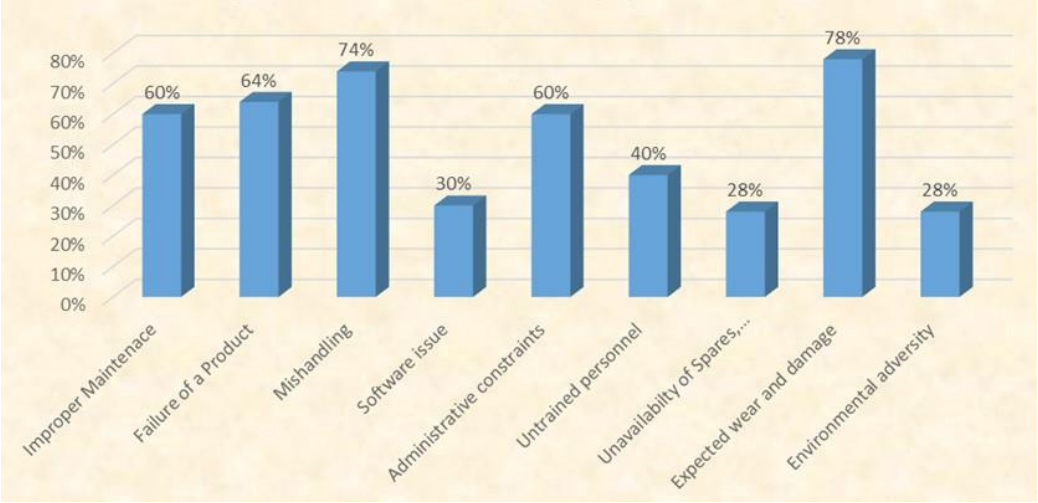

Figure 2: Reasons for Equipment's down time.

Health-care facilities can ensure ongoing patient care by proactively managing equipment maintenance and minimizing downtime through the implementation of these measures. Health-care facilities can ensure ongoing patient care by proactively managing equipment maintenance and minimizing downtime through the implementation of these measures. [Figure 3] shows how different maintenance contracts are used in a particular setting.

Annual Maintenance Contract (AMC)

This suggests that Annual Maintenance Contracts account for 63% of all maintenance agreements used. An AMC usually consists of an agreement between a client and a service provider wherein the provider commits to offer equipment maintenance and repairs in exchange for a set annual price. Preventive maintenance services are typically included by this contract.

Comprehensive Maintenance Contract (CMC)

This shows that Comprehensive Maintenance Contracts make up 34% of the maintenance contracts in use. When it comes to maintenance contracts, a CMC is more comprehensive than an AMC. It usually includes services for a larger variety of machinery and systems, including both preventive and corrective maintenance. Only 3% of maintenance contracts are a combination of both annual maintenance contracts and comprehensive maintenance contracts (AMC & CMC - 3%). This means that for certain systems or equipment, a tiny percentage of contracts can include both comprehensive and preventative maintenance services.

With annual maintenance contracts making up the majority, comprehensive maintenance contracts coming in second, and a tiny fraction being a combination of both, figure 3 sheds light on how different types of maintenance contracts are distributed or used within the organization. Different levels of coverage and services are provided by each type of contract, each designed to satisfy particular maintenance requirements and needs.

The table 1 shows the effects of equipment downtime on patient care as well as the amount of downtime that various service contracts had throughout a period.

Name of the Services

A variety of equipment maintenance plans and service contracts are included in this column.

Equipment under Warranty

This is equipment that has a manufacturer's warranty agreement attached to it.

Items Included in a Comprehensive Maintenance Contract (CMC) this category specifies items that are covered by a CMC, which usually includes services for both preventive and breakdown maintenance.

Equipment without a Service Contract

This category designates equipment for which

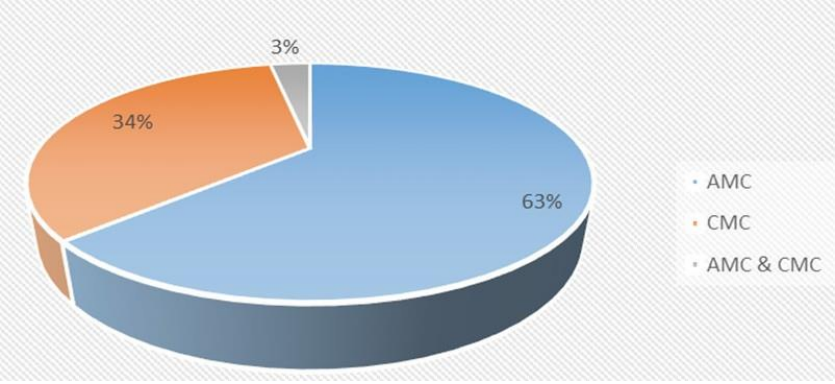

Figure 3: Utilization of Various Contracts

Table 1: Various Service Contracts for the equipment's downtime.

Name of the Services	Equipment Under Warranty	Equipment Under CMC	Equipment Under No Service Contract	Equipment Under AMC	Equipment In-House Maintenance
Down time Service	86%	78%	26%	82%	51%
Break down Maintenance completion rate	72%	80%	20%	86%	48%
Preventive Maintenance completion rate	88%	71%	60%	80%	84%

there isn't a formal service contract in existence, meaning that maintenance is done sporadically or reactively. Equipment Backed by an Annual Maintenance Contract (AMC)

This category includes equipment that is covered by an AMC and usually offers preventive maintenance services.

Equipment In-House Maintenance

This is the term for maintenance done on the organization's own equipment, as opposed to using an outside service provider.

Service Contract Types

This row shows the proportion of equipment downtime for each service contract type. Example: 86% of the equipment was down when it was still under warranty. A Comprehensive Maintenance Contract's (CMC) equipment had 78% downtime. There was 26% downtime for equipment without a service contract. An Annual Maintenance Contract's (AMC) equipment experienced 82% downtime. 51% of the equipment was not in use. It was maintained internally.

Breakdown maintenance completion rate

The proportion of jobs for each type of service contract's equipment that have been completed in terms of breakdown maintenance is shown in this row. As an illustration, 72% of the breakdown maintenance actions for equipment covered by warranty were finished. Eighty percent of the breakdown maintenance actions for equipment covered by a CMC were finished. 20% of breakdown maintenance jobs were finished for equipment without a service contract. 86% of the tasks related to breakdown maintenance were finished for equipment covered by an AMC. 48% of the breakdown maintenance jobs for equipment that was kept in-house were finished.

Rate of Completion of Preventive Maintenance

The proportion of preventative maintenance tasks accomplished for each type of service contract's equipment is shown in this row. Taking the equipment covered by warranty as an example, 88% of the preventative maintenance chores were finished. 71% of the scheduled maintenance forequipmentcovered by a CMC was finished. 60% of preventive maintenance tasks were finished for equipment without a service contract. Eighty percent of the preventative maintenance chores for equipment covered by an AMC were finished. 84% of the preventative maintenance activities for equipment that was kept in-house were finished.

In terms of equipment downtime, breakdown maintenance completion rates, and preventive maintenance completion rates, these statistics offer valuable insights into the efficacy of various service contracts. Additionally, it draws attention to the effect that downtime has on patient care, emphasizing that longer downtime may result in delays in patient care and medical services.

The impact of equipment downtime on patient care

The concept of "downtime of equipment" describes the time that machinery or equipment is not operating or usable. Downtime in medical equipment can have a big impact on patient care, safety, and overall operational effectiveness.

Prolonged Diagnosis and Treatment

The diagnosis of medical issues and the start of suitable treatment programs may become delayed by equipment downtime, which can cause delays in the performance of diagnostic tests like MRIs and CT scans. In particular, patients with urgent or life-threatening diseases may suffer as a result of this delay.

Compromised Patient Safety

While essential equipment, such ventilators, anesthetic machines, or heart monitors goes down, it can put patients at risk for complications during surgery or critical care treatment. Equipment malfunctions might put patients in danger of serious consequences, unfavorable outcomes, or even death.

Continuity of Care Disruption

Delays in equipment maintenance might cause infusion therapies or critical monitoring procedures to stop. This disruption could compromise the overall management of patients' diseases and recovery paths by creating gaps in therapeutic treatments, drug supply, or patient monitoring.

Increased stress and Stress on personnel

When hospital equipment is unavailable, troubleshooting, repairs, or replacements are required, which adds to the strain and stress of the personnel. To account for equipment failures, health-care providers may need to reorganize work-flows, reorganize schedules, or reorder patient care duties. The impact of downtime on

patient outcomes can be further exacerbated by this increased burden, which can result in weariness, burnout, and potential mistakes in the delivery of patient care.

Resource Allocation Issues

Equipment downtime necessitates the allocation of resources for maintenance, repair, or replacement, diverting attention and resources away from vital patient care operations. This may put a burden on hospital resources and reduce the overall ability to provide timely and effective care to patients across departments and units.

Negative Patient Experience

Equipment downtime could lead to dissatisfaction with the level of care provided. Patients may interpret delays, disturbances, or inconveniences caused by equipment failures as evidence of poor care, lowering their trust in the hospital and healthcare providers. Addressing equipment downtime in a timely and effective manner is critical for preserving patient satisfaction and trust in the hospital's services.

Equipment downtime at tertiary care hospitals can have serious consequences for patient care, safety, and overall hospital operations. Proactive maintenance techniques, strong equipment management rules, and rapid reaction mechanisms are critical for reducing downtime and assuring continuous delivery of high-quality treatment to patients in these settings [17].

DISCUSSION

To safeguard patient care in hospital settings, the conversation explores the conclusions and ramifications of numerous studies about minimizing maintenance expenses and medical equipment downtime. Despite parallels in other studies, our results for the calendar year where management can take effective planning on medical equipment maintenance and important action for its downtime were different. In other studies, a budget was set aside for in-house maintenance, which included engineer salaries, spare part and accessory inventory, and so on. In our research, we focused on outsourced maintenance, including calibrations.

A comprehensive maintenance planning model taking into account pricing strategies, technology levels, and warranty policies. The significance of strategic planning in reducing disruptions is highlighted by this method. Findings regarding the effect of maintenance contracts on equipment downtime. By coordinating organizational objectives with maintenance plans the use of the Balanced Scorecard technique to monitor service performance in medical facilities. An important point raised is the necessity of cost-effective maintenance procedures while evaluating the upkeep costs of electro-medical equipment in Spanish hospitals. The importance of effective scheduling strategies in maximizing maintenance procedures is emphasized. Discussion of flow-shop scheduling issues in repair and maintenance planning. Through their combination analysis of flow shop scheduling issues, provide valuable insights into the optimization of scheduling for maintenance tasks.

There is an alternative to maintenance management in the form of outsourcing clinical engineering services, which may result in lower operating expenses. In their study, it provides ways to increase operational effectiveness by reducing tardiness in flow shop scheduling. The significance of strategic planning in equipment life-cycle management is emphasized in his discussion of medical equipment replacement planning. Insights into maintenance prioritization are offered, which makes resource allocation for the best possible maintenance outcomes easier. In order to improve equipment performance and reliability, suggest a criticality-based reliability-centered maintenance strategy designed specifically for the health-care industry. In their study, explore the complexities of maintaining medical devices, emphasizing both advantages and disadvantages. According to creative methods like the use of Artificial Intelligence (AI) in equipment replacement planning show how maintenance management is changing concentrates on maintenance programme optimization with the goal of increasing programme effectiveness. Statistical analysis of preventive and corrective maintenance in medical equipment sheds light on the efficacy of maintenance. The extensive research on medical equipment maintenance in tertiary care hospitals conducted it provides insightful information about maintenance procedures and difficulties in health-care settings.

These studies aid in the creation of practical plans for reducing maintenance expenses and

medical equipment downtime, which in turn guarantees smooth operations and continuous patient care in hospital environments.

Strategies for prevent the equipment downtime

Health-care facilities can ensure ongoing patient care by proactively managing equipment maintenance and minimizing downtime through the implementation of these measures.

Frequent Inspections and Maintenance

Put in place a thorough maintenance plan for every piece of equipment. To spot such problems early on and take action before they become more serious, conduct routine inspections.

Testing and Calibration

Make sure that the equipment is tested and calibrated correctly in accordance with the manufacturer's instructions. Check important instruments' accuracy and functionality on a regular basis.

Employee Education and Training

Educate employees on how to use, maintain, and care for equipment. Make sure they are aware of the warning indicators of equipment failure and know what to do in the event that they do.

Inventory control

Monitor the amount of equipment in order to make sure that wear-out parts and components are replaced on schedule. Keep enough replacement parts on hand to quickly fix small problems.

Make Use of Predictive Maintenance

Predictive maintenance methods, such as predictive paralytics and condition monitoring, can help you identify equipment problems before they happen. This can reduce downtime by proactively scheduling maintenance procedures.

The creation of a thorough emergency response plan that outlines what to do in the event that equipment fails is highly recommended. Assign employees the task of carrying out the strategy, and make sure they receive the appropriate training.

Vendor Support and Service Agreements

Form ties with dependable suppliers and make sure essential equipment has service agreements in place. When technical support or repairs are required, get in touch with vendors right away.

Backup Equipment

To maintain care during unplanned downtime, think about keeping backup equipment on hand for important devices.

Remote Monitoring and Support

Whenever feasible, use the equipment's remote monitoring features. This makes it possible to track the performance of the equipment in real time and identify problems early on, possibly avoiding downtime.

Documentation and Record-Keeping

Keep thorough records of all scheduled maintenance, repairs, inspections, and replacements for your equipment. Future maintenance decisions are informed by the equipment history tracked by this paperwork.

Environment Control

To avoid premature wear and tear, make sure that equipment is operated in settings with the right humidity, temperature, and other pertinent factors.

Continuous Improvement

To find patterns and opportunities for improvement, examine equipment performance data and downtime issues on a regular basis. Utilize this data to improve your maintenance plans and reduce downtime in the future.

CONCLUSION

A suitable annual budget plan that will be taken into consideration for in-house and external maintenance costs for proper planning and estimation of the expenses is recommended to reduce the interruption of the continuous patient care by implementing the strategic plans. The maintenance costs of the equipment, ranging from lower to higher costs, were analyzed, and downtime duration was taken into consideration for further future courses of action.

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