ISSN 2616-5791 Vol. 6, Issue 5: 27-33, DOI: 10.25236/AJMHS.2025.060505

Significance of Maintenance and Repair Practices for Precision Medical Devices: A Comprehensive Analysis

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Abstract: *With the continuous advancement of medical standards in China, most hospitals have implemented comprehensive measures to enhance their overall service capabilities. As a critical clinical department, operating rooms are equipped with sophisticated medical equipment. Notably, precision medical instruments in operating rooms exert significant influence on surgical quality and safety, demonstrating a direct correlation with therapeutic outcomes and patient safety. To maximize the operational efficiency and clinical value of these precision instruments, systematic maintenance and standardized servicing have become imperative. Through unified maintenance protocols and standardized care procedures, the practical benefits of these precision medical devices become substantially evident in clinical practice.*

Keywords: *Precision Medical Instruments; Maintenance and Servicing; Critical Significance*

1. Introduction

The operating room serves as the primary site for the management and maintenance of precision medical equipment. Specifically, operating room equipment refers to consumable medical devices with limited usage cycles as approved by pharmaceutical regulatory authorities, encompassing both single-use and reusable medical apparatus[1-3]. These devices can be systematically categorized based on various parameters and are fundamentally vital to patient survival. Given the substantial inventory of precision medical equipment and the delicate nature of their components, operational wear and age-related degradation are inevitable during clinical utilization. Considering the substantial capital investment required for these devices, replacement procurement would impose significant additional financial burdens. Consequently, implementing comprehensive maintenance and servicing protocols for precision medical equipment has emerged as a critical operational imperative. Such measures ensure optimal deployment of surgical equipment while maximizing both clinical efficacy and cost effectiveness[4].

2. Classification of Precision Medical Equipment in Operating Rooms

Medical practice requires a diverse range of medical devices, and classification standards vary significantly. Most hospitals categorize equipment based on their specific operational needs. Common classification methods include the following:

2.1 Based on Clinical Application, they are categorized into Low-value and High-value Medical Devices

Low-value medical devices refer to consumable medical supplies with relatively low unit prices that do not require implantation or intervention in the human body, such as infusion sets, syringes, and dressings. These devices are widely used in hospital departments on a daily basis. Although their unit prices are relatively low, they are in high demand and utilized across numerous departments, serving as foundational equipment essential for routine diagnostic and therapeutic activities in hospitals. Consequently, they occupy significant storage space and contribute substantially to inventory costs[5]. High-value medical devices, on the other hand, are medical equipment that directly interact with the human body, have stringent safety requirements, are extensively used in clinical settings, carry relatively high price tags, and impose a heavy financial burden on patients. These include vascular intervention devices, orthopedic implants, neurosurgical equipment, electrophysiological devices, pacemakers, and

ISSN 2616-5791 Vol. 6, Issue 5: 27-33, DOI: 10.25236/AJMHS.2025.060505

similar categories[6]. Such devices are typically specialized materials with lower usage volumes compared to low-value devices but come at a high cost, consuming a large portion of hospitals' working capital and inventory expenses.

2.2 Classification Based on Clinical Use: Divided into Seven Categories

According to their uses in clinical medical activities, they are classified into seven categories, including injection and puncture materials and polymer materials, medical hygiene materials and dressings, some commonly used medical devices in the operating room, medical X-ray accessory equipment and components, dialyzers and dialysis pipelines, intraocular lenses, as well as special devices such as catheters, guide wires and stents dedicated to clinical departments.

2.3 Classification Based on Risk Level

The risk level of medical devices is assessed based on factors such as intended use, structural characteristics, and usage methods. Class I: Devices with low risk, where general controls are sufficient to ensure safety and effectiveness. Class II: Devices with moderate risk, requiring stricter management to ensure safety and effectiveness. Class III: Devices with high risk, necessitating special measures and stringent controls to ensure safety and effectiveness.

2.4 Classification Based on Different Characteristics Medical devices can be categorized according to various characteristics

By implantability: They are divided into implantable devices and non-implantable devices.

By production origin: They are classified as domestically produced(domestic) devices or imported devices. By pre-surgical specification determination: They can be categorized as stock-managed devices (pre-determined specifications) or customized devices such as bone plates and screws whose specifications are often determined during surgery. By reusability: They are classified as single-use devices or reusable devices[7].

3. Problems in the Maintenance and Repair of Precision Medical Equipment

With the advancement of medical technology, the quantity and variety of medical equipment have significantly increased. However, various factors hinder the effective maintenance and repair of these sophisticated medical devices, ultimately impacting the overall efficiency of healthcare institutions. The specific issues are as follows:

3.1 Operational Errors by Staff in Usage and Maintenance

Precision medical equipment malfunctions often stem from operational or maintenance errors by personnel. Given the extreme complexity of these devices—which integrate numerous high-precision components and advanced technologies—users must not only master standard operating procedures but also possess thorough, in-depth knowledge of each structural component and its corresponding functions. Operating equipment with partial understanding frequently leads to failures. Maintenance presents even greater challenges. Technicians must have comprehensive knowledge of the equipment's architecture, from its macro framework down to microscopic parts, and conduct systematic troubleshooting to accurately diagnose issues. Only through such rigorous analysis can appropriate repair strategies be formulated. Blind repairs risk misidentifying root causes, potentially causing secondary damage during the process. This escalates repair costs, may render equipment irreparable, and severely disrupts medical operations[8].

3.2 Lack of Strict Access Mechanisms for Medical Equipment

Currently, most hospitals lack rigorous approval processes for medical equipment. Many new devices are put into use without undergoing strict evaluation, and even essential bidding procedures may be omitted. Often, clinical departments directly contact suppliers to introduce new products based on immediate needs during treatment activities.

Due to this chaotic access system, the variety of medical equipment in public hospitals continues to

ISSN 2616-5791 Vol. 6, Issue 5: 27-33, DOI: 10.25236/AJMHS.2025.060505

expand, with increasingly complex specifications. In essence, many newly introduced devices do not differ fundamentally from existing ones-they are often the same products under new names or packaging from different manufacturers and suppliers[9].

This failure to ensure equipment quality increases hospital expenditure on consumables, raises the financial burden on patients, and negatively impacts subsequent maintenance and servicing.

3.3 Equipment maintenance and repairs lack sufficient oversight

In medical institutions, the maintenance and servicing of medical equipment are critically important. However, a widespread issue is the lack of robust and well-structured maintenance protocols, which is directly reflected in insufficient oversight. Due to the absence of strict and meticulous supervision mechanisms, management personnel often develop a negligent mindset, approaching repair and maintenance tasks with undue casualness. For instance, when documenting equipment repairs, they may only provide perfunctory and cursory records without delving into the root cause of malfunctions. Similarly, when scheduling maintenance, they may merely follow routine procedures without tailoring them to the actual operational condition of the devices, ultimately leading to half-hearted and superficial maintenance efforts. This careless attitude plants numerous hidden risks in the subsequent use of medical equipment, potentially causing sudden failures during critical diagnostic or treatment procedures, thereby compromising the quality and efficiency of healthcare services. More critically, many personnel responsible for maintenance and servicing lack the necessary professional expertise. They have an insufficient understanding of the intricate structures and working principles of precision medical devices, which may lead to further damage during improper repairs. In terms of maintenance, they often struggle to develop scientifically sound servicing plans tailored to the specific characteristics of the equipment. As a result, even when repairs are completed, the equipment's performance often remains suboptimal, failing to reach its ideal operational state. This not only shortens the device's lifespan but may also adversely affect patient diagnosis and treatment outcomes, ultimately hindering the overall improvement of the hospital's medical standards.

3.4 Lack of Effective Digitalized Screening for Damaged Medical Equipment

In the management of medical equipment, the lack of effective informatization methods significantly impacts equipment maintenance and servicing. Due to the absence of clinical usage data for medical devices, it is impossible to accurately assess their actual clinical utilization and damage levels using the hospital information system. As a result, maintenance and servicing efforts lose critical reference points, making it difficult to promptly determine the extent of equipment wear and tear. This may lead to either excessive maintenance or delayed repairs. Moreover, the silo effect of information systems prevents centralized data analysis, making it challenging to dynamically and effectively monitor the actual usage and damage status of precision medical equipment. For instance, the maintenance department cannot receive real-time feedback from clinical departments regarding abnormal equipment conditions, potentially missing the optimal window for repairs. The entire lifecycle of equipment—from deployment to malfunction—cannot be fully traced, making it difficult for maintenance personnel to accurately access historical repair and servicing records. This hinders the formulation of effective repair plans and the adjustment of maintenance schedules[10]. Currently, reliance on manual screening methods not only wastes significant time and resources but also reduces the efficiency and quality of maintenance and servicing. This fails to meet hospitals' demands for efficient equipment management.

4. Strategies for Standardizing Maintenance and Servicing of Precision Medical Equipment

To maximize the value and efficiency of precision medical equipment, it is essential to implement standardized maintenance and servicing protocols. By optimizing the management of operating room equipment, we can enhance its utilization and generate greater operational benefits.

4.1 Standardizing Equipment Maintenance Requirements: Categorized Management of Medical Devices

In hospital operations, it is crucial to standardize equipment repair and maintenance requirements and implement classified management of medical devices. When carrying out equipment repair and maintenance tasks, responsible personnel must strictly adhere to established standards, ensuring every operational step is performed with precision to maintain optimal work efficiency. This not only affects

ISSN 2616-5791 Vol. 6, Issue 5: 27-33, DOI: 10.25236/AJMHS.2025.060505

the proper functioning of the equipment but also indirectly influences the quality and efficiency of medical services. At the same time, the scientific classification of medical devices holds significant importance. Devices can be categorized in detail based on multiple dimensions such as specifications, purpose, and type. For example, by purpose, they can be divided into diagnostic, therapeutic, and laboratory equipment; by specifications, they can range from large imaging devices to small surgical instruments. Through such comprehensive classified management, the subsequent selection of medical devices becomes more convenient and efficient. When clinical departments urgently need certain equipment, they can quickly locate and obtain it. Screening tasks also become more targeted, facilitating the timely identification of potential issues. For staff, classified management enhances their familiarity with the characteristics of different categories of medical equipment, enabling more timely and proficient execution of repair and maintenance tasks. This significantly improves work quality and efficiency, strongly supporting the smooth progress of hospital medical operations.

4.2 Improving Accuracy Through Medical Equipment Data Collection

In the hospital management system, implementing precise supervision over the procurement of precision medical equipment is undoubtedly a top priority. The performance of precision medical devices used in operating rooms directly impacts the quality and safety of surgical procedures, as well as the treatment outcomes and the lives of patients. A high-performance, accurate, and reliable medical device can provide dependable operational support to surgeons, facilitate smooth surgical procedures, and maximize the protection of patients' health rights. Therefore, it is imperative to strictly enforce the accuracy of the access system. By comprehensively collecting detailed information on all devices—including the manufacturer, product specifications, performance parameters, quality certifications, and more—without omission, a complete medical device database can be established. This approach can effectively prevent substandard devices from infiltrating hospitals through false information. Only by ensuring that the medical devices entering hospitals are of superior quality can a solid foundation be laid for high-quality surgical procedures, thereby achieving significant treatment outcomes. Moreover, detailed and accurate device information also provides a precise basis for subsequent maintenance and servicing of medical equipment, enabling these tasks to be carried out according to device-specific characteristics and unified standards, ultimately enhancing the overall quality of medical services[11].

4.3 Breaking the information silos and enhancing the systematic maintenance of medical equipment

In the field of medical equipment management in hospitals, breaking down information silos is crucial for enhancing the systematic maintenance of medical devices. It is essential to achieve comprehensive connectivity in the clinical use of medical equipment and the screening of damaged devices. In the clinical use phase, adding relevant functional modules to the information system enables in-depth analysis of actual clinical needs and consumption patterns. This not only ensures transparency in the submission of clinical demands by departments, making the procurement process open and fair, but also allows real-time monitoring of equipment usage status and detailed billing items. This end-to-end approach prevents discrepancies between records and physical inventory, significantly improving resource utilization efficiency and the accuracy of financial management [12]. Moreover, establishing an intelligent monitoring system for all medical equipment is of great importance. By leveraging advanced technological means, the operational status of devices can be tracked in real time. On one hand, this ensures timely cleaning and quality inspections, maintaining optimal performance. On the other hand, potential issues can be promptly detected. As a result, maintenance and repair efforts become more targeted, allowing for proactive planning and timely resource allocation. This minimizes the risk of equipment failure to the greatest extent, ensuring the efficient and stable operation of medical services.

4.4 Strengthen Training to Ensure High-Quality and Efficient Maintenance and Servicing

In the daily operations of hospitals, the proper functioning of medical equipment is crucial to ensuring the quality of healthcare services. To guarantee efficient maintenance and repair work, it is imperative to significantly strengthen professional training for relevant staff. Through systematic and in-depth training, staff can markedly enhance their understanding of various types of medical equipment. For instance, when dealing with complex imaging diagnostic devices, they will be able to quickly identify key components and core systems, thoroughly grasping their structural principles and functional characteristics. This not only helps in promptly diagnosing issues when equipment malfunctions but also enables maintenance personnel to adopt a more targeted approach during upkeep, optimizing workflows and thereby substantially improving efficiency. Moreover, efficient repair and maintenance can greatly

ISSN 2616-5791 Vol. 6, Issue 5: 27-33, DOI: 10.25236/AJMHS.2025.060505

reduce time costs. Delays in servicing due to insufficient staff familiarity with equipment will be significantly minimized, preventing prolonged equipment downtime that could disrupt patient treatment. This ensures the continuity and timeliness of healthcare services and, fundamentally, elevates the overall standard of medical care and patient satisfaction[13].

5. Significance of Precision Medical Device Maintenance

5.1 Enhanced Overall Work Efficiency

In the complex and critical medical scenario of surgery, the reliance of surgeons and nurses on various medical instruments and equipment is extremely high. Surgeries often last for extended periods, during which the frequent use of these instruments and equipment inevitably leads to functional wear and tear. For instance, the blades of precision surgical scalpels may become dull after repeated incisions, compromising cutting accuracy, while sophisticated laparoscopic devices may experience color deviations or reduced image clarity after prolonged use. Given the vast diversity of medical instruments and equipment, which vary significantly in material, purpose, and management processes, implementing targeted maintenance and servicing strategies becomes particularly crucial. Categorized maintenance based on the characteristics of different instruments—such as rust prevention for metal tools and monitoring circuit aging for electronic medical devices—can effectively extend their service life and ensure stable performance during critical moments. Meanwhile, leveraging information technology for screening and management offers undeniable value. By establishing a medical equipment management information system, device status, maintenance needs, and other relevant data can be quickly identified, significantly reducing the time spent on manual searches, record-keeping, and maintenance scheduling. In traditional manual management, medical staff often had to devote considerable time to locating instruments in storage or compiling maintenance lists, whereas an information-based system can generate reports and reminders with a single click, drastically cutting labor and time costs. Ultimately, this leads to a notable improvement in overall medical workflow efficiency.

5.2 Improved Equipment Quality

In the medical field, the number of precision medical instruments and equipment used is vast, with a wide variety of types and intricate structures. From MRI machines for accurate diagnosis to various high-precision surgical instruments, each plays a critical role in medical practice. The precision of these instruments and equipment dictates extremely high requirements for their usage and maintenance environments. Without effective repair and maintenance measures, a series of serious issues may arise.

On one hand, once the performance of the equipment declines, hospitals may have to purchase new instruments to meet operational demands, resulting in significant financial waste. On the other hand, if deterioration goes unnoticed due to negligence, allowing substandard equipment to re-enter the workflow, it may not only lead to deviations in diagnostic results or suboptimal surgical outcomes but could also pose a threat to patients' lives, severely disrupting the normal functioning of medical operations. Scientific and standardized maintenance and upkeep can significantly mitigate these issues. Through regular inspections, calibrations, and repairs, minor malfunctions and wear can be promptly addressed, ensuring the equipment consistently performs at a high level. This enhances the utility value of existing instruments, extends their service life, and guarantees the safe and efficient execution of medical operations.

5.3 Enhanced Surgical Safety

In medical surgeries, operational safety is of paramount importance, and the stable functioning of precision medical instruments and equipment is a critical factor in ensuring surgical safety. However, improper handling and a casual attitude among some relevant staff can easily lead to equipment damage and nursing errors. For instance, when using a laser scalpel, failure to follow standardized procedures may result in abnormal laser energy output, which could not only damage the equipment but also cause additional harm to the patient’s tissues. Similarly, inadequate cleaning and maintenance of laparoscopic equipment post-surgery may leave residual stains that compromise imaging quality during subsequent use, interfering with the surgeon’s judgment. The repair and maintenance of medical instruments and equipment must be built upon enhancing the professional competence of the staff, making it all the more crucial. By conducting regular specialized training and assessments, staff can become proficient in the operation and maintenance of various precision instruments, thereby reducing errors. As staff deepen

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their knowledge of maintenance, they gain a clearer understanding of equipment performance and potential risks, improving their ability to control such risks. For example, during pre-operative equipment inspections, they can keenly identify potential malfunctions and address them promptly, ensuring smooth surgical procedures and maximizing safety during operations. This safeguards patients' lives and health, fortifying their line of defense.

5.4 Reduce Medical Operational Costs

In the healthcare sector, cost control is of paramount importance, and the maintenance and servicing of precision medical equipment play a pivotal role in reducing operational expenses. Regular maintenance incurs far lower costs compared to emergency repairs following a breakdown. Preventive maintenance requires only a small team of specialized personnel, keeping labor costs low. Hospitals can also leverage long-term partnerships or strategic procurement opportunities to purchase universal spare parts in advance or secure discounts, significantly cutting repair expenses. Moreover, preventive servicing allows for planned short-term downtime, enabling departments to adjust schedules proactively, minimizing disruptions to daily operations and keeping financial losses within manageable limits. Additionally, routine cleaning, calibration, and timely replacement of wear-prone components act as a protective shield for equipment, preventing minor issues from escalating due to neglect and causing severe damage to core parts. This safeguards devices from premature obsolescence. From a long-term perspective, systematic maintenance extends equipment lifespan, reduces capital expenditures on new purchases, and substantially optimizes the cost structure of medical operations, allowing hospitals to allocate resources more efficiently.

6. The Practical Value of Maintenance and Preservation of Precision Medical Equipment

Precision medical equipment plays a crucial role in medical operations and is intrinsically linked to their smooth functioning. With advancements in science and technology, medical techniques have become increasingly diverse, leading to a rising demand for precision medical devices. Consequently, standardized and systematic maintenance and preservation of such equipment are of paramount importance. Properly regulated maintenance and upkeep not only ensure the provision of high-quality equipment but also guarantee the safety and efficacy of medical procedures, thereby reducing economic costs and alleviating hospital inventory pressures. Thus, the maintenance and preservation of medical equipment contribute to enhancing both the economic and social benefits of healthcare institutions, highlighting their necessity. Such practices help ensure medical safety and quality. By standardizing processes such as equipment usage, procurement, regulatory screening, and maintenance, the incidence of medical errors and accidents can be minimized, improving overall healthcare quality and safety. Moreover, the maintenance and preservation of medical equipment aid in controlling healthcare costs by reducing waste and unnecessary expenditures, thereby boosting hospitals' financial efficiency[14].

7. Experience Summary on Maintenance and Repair of Precision Medical Equipment

The approaches to maintenance and repair must evolve with the times, incorporating innovative thinking[15]. By leveraging the basic information, structure, and functions of precision medical equipment, combined with advanced technologies, precise monitoring of medical devices can be achieved. This enhances the technical proficiency and efficiency of maintenance and repair, thereby ensuring patient safety. Standardization of maintenance and repair procedures should be strengthened, with increased regulatory oversight of medical equipment. Relevant staff should be encouraged to participate in training programs to improve their professional skills, enabling them to fully understand the fundamental information and maintenance methods of the equipment. Additionally, greater attention should be paid to the usage and wear conditions of the devices. The screening of medical equipment should aim for intelligent and information-driven objectives. By employing advanced technologies, the sensitivity of screening processes can be improved, leading to enhanced surgical efficiency and optimal treatment outcomes.

8. Conclusions

The operating room is the primary setting for the maintenance and management of precision medical equipment. These devices refer to consumable medical instruments approved by drug regulatory

ISSN 2616-5791 Vol. 6, Issue 5: 27-33, DOI: 10.25236/AJMHS.2025.060505

authorities with limited usage, including both disposable and reusable medical equipment. Depending on different criteria, these devices can be classified into various categories and are often regarded as lifesaving tools for patients. Due to the large quantity and intricate components of precision medical equipment, wear and tear during use, as well as aging over time, are inevitable. Given their high cost, replacing them entirely would impose additional financial burdens. Therefore, repair and maintenance of these devices become crucial tasks, ensuring their optimal application in the operating room and maximizing their benefits. In conclusion, standardized repair and maintenance of precision medical equipment in the operating room enhance the safety and effectiveness of medical procedures. This approach reduces management costs, alleviates hospital inventory pressures, improves healthcare quality and safety, and boosts the financial efficiency of medical institutions.

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