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Implementation and Evaluation of Preventive Maintenance Strategies for Digital X-Ray and Ultrasonography Systems in a Secondary Healthcare Hospital

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ABSTRACT. The reliability and safety of radiological equipment are essential for ensuring diagnostic accuracy, patient safety, and continuity of healthcare services. This study evaluates the implementation of a preventive maintenance program for digital X-ray and ultrasonography systems at Ibnu Sina Hospital, Indonesia. A longitudinal observational study was conducted over two months (August–September 2024) through daily inspections of critical subsystems, including X-ray tubes, detectors, control units, collimators, ultrasound transducers, power supplies, and imaging components. Maintenance records were analyzed to assess functionality and operational stability. The results show that routine preventive maintenance maintained optimal equipment performance without major failures, highlighting its importance in improving reliability, minimizing operational risks, and supporting radiation safety compliance.

1. Introduction

Radiological imaging plays a crucial role in modern healthcare by supporting accurate diagnosis and effective clinical decision-making. The reliability and proper functioning of radiological equipment strongly influence image quality, patient safety, and service continuity within healthcare facilities (Sudrajat, 2011).

Inadequate maintenance of radiological equipment, particularly X-ray and ultrasonography systems, may result in gradual performance degradation, reduced image quality, increased radiation exposure, and unexpected equipment failure. Previous studies have reported that the absence of systematic preventive maintenance contributes to higher failure rates, shortened equipment lifespan, and increased operational risk in healthcare facilities (Sudrajat, 2011; Rahmiyati et al., 2019). Preventive maintenance is therefore required as a proactive strategy to detect early-stage component deterioration, ensure equipment reliability, and maintain diagnostic accuracy. The implementation of structured preventive maintenance programs has been shown to reduce downtime, improve patient safety, and support continuous clinical services (Dewanto dan Tony, 2013; Tampubolon, 2004).

Regulatory frameworks in Indonesia emphasize the responsibility of hospitals to maintain medical equipment through routine inspection, calibration, and systematic documentation to ensure compliance with radiation safety standards (Roza, 2016). Effective maintenance management not only improves diagnostic performance but also enhances radiation protection for patients and healthcare workers (Tampubolon, 2004).

This study aims to evaluate the implementation of a preventive maintenance program for radiological equipment, specifically digital X-ray and ultrasonography systems, at Ibnu Sina Hospital. The study focuses on assessing equipment operational stability, maintenance outcomes, and equipment availability to support patient safety and continuity of diagnostic services.

2. Materials and Methods

2.1 Study Design

This study employed a descriptive observational design with a longitudinal approach. Preventive maintenance activities were analyzed over a two-month period (August–September 2024). The two-month observation period was selected to evaluate routine preventive maintenance activities and short-term operational stability of the equipment within the available clinical maintenance schedule.

2.2 Site and Equipment

The study was conducted at the Radiology Installation of Ibnu Sina Hospital. The evaluated equipment included a digital X-ray system (Fujifilm FDR Smart X) and ultrasonography units serving neurology, obstetrics and gynecology, and rehabilitation departments.

2.3 Equipment System Description

The digital X-ray system consists of an X-ray tube assembly, high-voltage generator, collimator, detector, control console, and image acquisition unit. The system operates using ionizing radiation, which requires preventive maintenance to ensure image quality, operational stability, and radiation safety.

The ultrasonography system consists of ultrasound transducers, central processing units, LCD monitors, printers, and power supply units. Although ultrasonography uses non-ionizing ultrasound waves, preventive maintenance is necessary to maintain image quality and ensure reliable diagnostic performance.

2.4 Preventive Maintenance Procedures

Preventive maintenance activities were carried out daily by radiographers and technical staff, following manufacturer guidelines and hospital standard operating procedures. Inspected components included:

a) X-ray tube and collimator alignment
b) Patient table and bucky stand mechanisms
c) Detectors, regulators, and image acquisition computers
d) Ultrasonography transducers, CPU units, LCD monitors, printers, and UPS systems

Each component was categorized as “functional” or “non-functional” based on visual inspection, operational testing, and system response.

2.5 Data Collection and Analysis

Maintenance data were collected using standardized maintenance checklists documented daily. Data were analyzed descriptively to identify trends in equipment functionality, frequency of faults, and maintenance consistency across the observation period.

3. Results

3.1 Preventive Maintenance Results for Digital X-Ray System

This section presents a summary of preventive maintenance results for the digital X-ray system (Fujifilm FDR Smart X) during August–September 2024.

Preventive maintenance of the digital X-ray system was conducted through routine inspection and operational testing of critical components, including the X-ray tube assembly, collimator alignment, patient table, bucky stand, detectors, and image processing units. The mechanism focused on ensuring stable system response,
proper alignment, and consistent image acquisition performance, considering the use of ionizing radiation and high-voltage components.

Table 1. Preventive Maintenance Results of Digital X-Ray System

Component	August 2024	September 2024	Operational Status
Control console	Functional	Functional	Stable
Patient table	Functional	Functional	Stable
X-ray tube assembly	Functional	Functional	Stable
Collimator	Functional	Functional	Stable
Bucky stand	Functional	Functional	Stable
Detector	Functional	Functional	Stable
Voltage regulator	Functional	Functional	Stable
Image processing computer	Functional	Functional	Stable
Printer	Functional	Functional	Stable

The results indicate that all critical subsystems of the digital X-ray unit remained fully functional throughout the observation period. No mechanical misalignment, electrical instability, or imaging failure was recorded. High-risk components such as the X-ray tube and detector exhibited consistent performance, indicating effective routine inspection and environmental control.

3.2 Preventive Maintenance Results for Ultrasonography Systems

Ultrasonography units serving neurology, obstetrics and gynecology, and rehabilitation departments were subjected to the same daily preventive maintenance protocol.

Preventive maintenance of ultrasonography systems was performed by inspecting transducers, CPU units, LCD monitors, and power supply systems. Functional testing and routine cleaning were applied to maintain signal stability and image clarity, reflecting the non-ionizing operating principle of ultrasonography systems.

Table 2. Preventive Maintenance Results of Ultrasonography Systems

Component	August 2024	September 2024	Operational Status
Table board	Functional	Functional	Stable
CPU	Functional	Functional	Stable

Transducer	Functional	Functional	Stable
LCD monitor	Functional	Functional	Stable
UPS	Functional	Functional	Stable
Detector	Functional	Functional	Stable

All ultrasonography components were consistently recorded as functional. Ultrasound transducers, which are the most critical elements influencing image quality, showed no signal degradation, noise, or artifacts during clinical operation.

3.3 Equipment Availability and Downtime

Throughout the two-month observation period (August–September 2024), preventive maintenance records indicate that no downtime events occurred across all evaluated radiological modalities, including digital X-ray and ultrasonography systems. All equipment units remained fully operational during scheduled clinical hours, and no imaging procedures were delayed or cancelled due to equipment malfunction.

Daily maintenance logs confirmed continuous functionality of critical components such as X-ray tubes, detectors, control consoles, ultrasound transducers, and power supply systems. Minor operational checks performed as part of routine preventive maintenance enabled early identification of potential irregularities, thereby preventing escalation into system failures that could result in downtime.

4. Discussion

4.1 Impact of Preventive Maintenance on Equipment Reliability

The results demonstrate that systematic preventive maintenance effectively maintained the operational reliability of both digital X-ray and ultrasonography systems. Continuous functionality of high-risk components such as X-ray tubes, detectors, and ultrasound transducers indicates that routine inspections successfully prevented early-stage faults from developing into critical failures.

These findings are consistent with maintenance management principles stating that early detection through daily inspection reduces mechanical stress, electrical instability, and imaging degradation (Sudrajat, 2011).

For the digital X-ray system, the preventive maintenance results indicate that routine inspection successfully maintained the stability of high-risk components such as the X-ray tube, detector, and collimator, which are critical to radiation output control and image quality. The absence of functional degradation suggests that preventive maintenance effectively addressed the potential risks associated with ionizing radiation systems.

In ultrasonography systems, preventive maintenance ensured stable performance of transducers and signal processing units, which directly influence image clarity and diagnostic accuracy. These results indicate that routine maintenance was effective in preventing early functional deterioration despite the different operating principles of non-ionizing imaging systems.

4.2 Implications for Patient Safety and Clinical Workflow

Stable performance of radiological equipment directly supports patient safety and clinical workflow efficiency. In digital X-ray systems, proper functioning of collimators, detectors, and control units ensures consistent image quality while minimizing unnecessary radiation exposure.

For ultrasonography systems, reliable transducer and processing units enable uninterrupted non-ionizing diagnostic procedures. The absence of equipment failure reduces the risk of repeated examinations and workflow delays, thereby improving patient comfort and diagnostic efficiency.

These findings address the research problem by demonstrating that preventive maintenance plays a crucial role in maintaining patient safety and service continuity. In digital X-ray systems, reliable equipment performance reduces the risk of repeat examinations and unnecessary radiation exposure. In ultrasonography systems, stable transducer functionality supports uninterrupted non-ionizing diagnostic procedures, contributing to efficient clinical workflow.

4.3 Operational Efficiency and Cost Implications

The absence of downtime throughout the study period suggests that preventive maintenance contributed to uninterrupted clinical services and avoided potential revenue loss associated with equipment failure. Preventive maintenance also minimizes the need for corrective repairs, which are typically more costly and time-consuming.

These findings support previous studies highlighting preventive maintenance as a cost-effective strategy for managing radiological equipment in secondary healthcare facilities (Rahmiyati et al., 2019).

4.4 Relevance for Secondary Healthcare Facilities

This study provides practical evidence that structured preventive maintenance programs can be effectively implemented in secondary hospitals with limited technical resources. The results emphasize that consistency, documentation, and adherence to manufacturer guidelines are key determinants of successful equipment maintenance.

The two-month observation period was sufficient to evaluate routine preventive maintenance activities and short-term equipment operational stability. However, this duration may not fully capture long-term performance variations or infrequent failure events. Therefore, future studies are recommended to conduct preventive maintenance evaluations over longer observation periods to obtain more comprehensive results.

5. Conclusion

This study demonstrates that systematic preventive maintenance plays an important role in maintaining the operational reliability of digital X-ray and ultrasonography equipment at Ibnu Sina Hospital. Routine inspections and scheduled maintenance activities were effective in ensuring stable equipment performance and preventing operational downtime during the observation period.

Although the two-month observation period was sufficient for evaluating short-term maintenance effectiveness, longer evaluation periods are recommended for future studies to provide more comprehensive insights into long-term equipment performance and maintenance outcomes.

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Author Contributions

DR conducted the data analysis and wrote the original manuscript as well as the revised manuscript. NW wrote the original manuscript and contributed to the revised manuscript. NH conducted the data analysis, supervised the study, and wrote both the original and revised manuscripts.

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