

Maintenance management analysis on electrical equipment of a neonatal ICU in a hospital unit in Manaus, Amazonas

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Abstract— This article evaluates the maintenance management of electrical equipment of medical-hospital units in a Neonatal Intensive Care Unit (ICU), with the objective of analyzing the importance and performance of services in the area of medical equipment maintenance, during its implementation in a private hospital in the city of Manaus, Amazonas. In addition it seeks to plan the actions and the systematization, identifying the methodologies that will be applied, to suit the sector. In this context, to demonstrate, especially in the area of maintenance plan management, the importance of an engineering professional in the maintenance management of medical electrical equipments, relating engineering to health.

Keywords— *Electrical engineering, clinical engineering, management.*

I. INTRODUCTION

Electrical engineering uses numerous tools to describe technological processes through the use of energy. It is a science that deals with the studies, applications, research and development of devices or technology process production based on electromagnetism phenomena. Currently, a large number of subareas are also part of electrical engineering, such as control and automation, electronics, telecommunications and similars, seeking to diversify technological knowledge, given this breadth [4].

Thus, the relationship between exact sciences and health sciences is made in an area called clinical engineering, which adopts the techniques of engineering in the management of health equipment, in order to ensure traceability, practicality, quality, efficacy, safety and operation of these equipment, in order to promote patient safety [9].

The maintenance of medical-hospital equipment considers non-interruption of the operation, indicating the availability for immediate use of all Health Care Facility (HCF) appliances, facilities and supplies. HCF's greater responsibilities to its beneficiaries do not tolerate inaccuracies or downtime resulting in serious or even lethal circumstances [21].

When implementing maintenance management in medical equipment, is essential to take into account the importance of the service to be performed and especially the way to manage the execution of this service. It is not enough for a maintenance team to only fix one piece of equipment, it is necessary to understand the level of

importance of the equipment in clinical procedures or in support activities for such procedures [10].

In complex projects should be observed the implementation of equipment control practices, maintenance services, administration from cost prevention and concern with complexity to the equipment. In this context, the importance of the engineering professional in the maintenance management of these equipments is visible, especially regarding the management of the maintenance plans.

Clinical engineering is a branch that operates in health care facilities, enhancing activities based on engineering studies and management for health technologies, emerging as a discipline in the second half of the twentieth century, with Increasing of electronic and mechanical complexity in medical devices, have entered the health environment for preventive, therapeutic, diagnostic and restorative applications [22][14].

In 1989, the Ministério do Bem-Estar e da previdência Social estimated that from 20 to 40% of the equipment in Brazil was inoperative, due to lack of maintenance, and when it was performed, the main responsibility was on the manufacturers and representatives that have monopolized the knowledge about these devices [17].

In addition, the authors cite that other factors also drove the establishment of a niche market for this professional, such as: shortage of trained human resources for the job; lack of equipment documentation; bureaucracy on the importation of parts and equipment testing; lack of cooperation from equipment manufacturers or

representatives regarding the purchase of parts or technical documentation [11].

Somehow, this competence to deal with technical problems also extends to social issues, being necessary in professional practice. In fact, the attitude of thinking and acting needs to receive more attention, especially during vocational training, walking in the direction of forming what can be called a citizen engineer [4]. Therefore the clinical engineer is the specialist who uses the studied engineering methods in the management of health equipment seeking to promote patient safety [9].

The term “maintenance” has its origin in the military vocabulary, whose meaning was “to keep in combat units, the effective and the material at a constant level”. The area of medical-hospital equipment management is also aiming at meeting the various complexities that the hospital environment faces daily, such as technological necessity, legal requirements and the constraints on the economic budget [15].

Collegiate Board Resolution Number 2, of January 25, 2010 advises that health services should develop and implement a management plan for each technology used in the service, including all equipment [6].

Therefore, the objective of the study is to demonstrate the relevance of the engineering professional in the logistics and performance of services in the area of maintenance in advanced medical equipments at a hospital unit, presenting the current structure of the Neonatal ICU, the actions and systematization applied to provide proper operation to the needs of the sector.

II. MATERIALS AND METHODS

This study has a descriptive character according to the analysis of the maintenance management of electrical equipments in a medical-hospital unit. The scenario of this research was inside of a Neonatal ICU of a large private hospital of the city of Manaus, Amazonas, which was followed by the analysis of the adequacy of the management processes of hospital equipment of the neonatal intensive care unit (NICU), by clinical engineering of that hospital. The data used are the pieces of information from march to august 2019, which was based on the next conditions:

- a) Verification of the updating of the technology park;
- b) The analysis of the introduction of daily patrol;
- c) The execution of the preventive maintenance plan for the medical equipments;
- d) Control analysis of corrective maintenance performed in equipment belonging to the sector, through documentary means;

e) Cost analysis of the effectiveness of maintenance management from the medical equipments.

2.1 Equipment Inventory

The inventory presented data about the medical equipments such as: model, serial number, manufacturer, sector location, assets, annual maintenance plan. The methodology was developed to establish improvement criteria, according to the indicators extracted from the elaborated tables, such as: minimum amount of unresolved corrective maintenance, maximum execution of planned preventive maintenance, reduction of the misuse rate and operational failure.

This ICU has 12 beds and a storage room for extra equipment such as a transport incubator and phototherapy equipment from the manufacturer Fanem. In the total of 12 beds there are 62 equipment, each bed has:

- 1) Mechanical fan from manufacturer Maquet;
- 2) Multiparameter monitor from manufacturer Dixtal;
- 3) Neonatal incubator from manufacturer Fanem;
- 4) Infusion pump from manufacturer Lifemed;
- 5) Cardioverter from manufacturer Philips;

The inventory has occurred in two days, generated a document for the registration of each equipment. From these data obtained, plus the information of each equipment, a registration was made in a Microsoft Excel spreadsheet.

2.2 Daily Patrol

The daily patrols, lasting approximately one hour, was responsible for the surveys performed in all sectors of the hospital, as a way to prevent problems associated with medical equipment, identifying them during this process. The main purpose of the patrols was to test the mechanical fans, multiparametric monitors, infusion pumps, among others.

During the activity there was also a work of awareness about the use of the equipment, because most of the occurrences founded came from the misuse of the operator. These actions are registered in a specific document (Fig.2), with the activities carried out in that sector, and the responsible technician signs the document, as a guarantee. For each problem founded during the inspection process, the corrective maintenance was performed, identifying it like a service order (SO) reporting the occurrence, the cause of the defect and, the solution.

INTERNAL DOCUMENT: SECTOR PATROL		CODE:
RESPONSIBLE CONTROL AREA: CLINICAL ENGINEERING		
Revision Date: Review: Issue date:		
HOSPITAL/SECTOR:		Service Order:
EXECUTING TECHNICIAN:		EXECUTION DATE:
EQUIPAMENT	OPERATING CHECKS	Observation
Cardiovesor / Desfibrilador	1. Check the power cable	
	2. Check the battery	
	3. Check the accessories	
	4. Verify physical integrity of enclosure	
	5. Trigger Test	
	6. Physical integrity of blades	
Multiparameter Monitor	1. Check equipment startup.	
	2. Verify physical integrity of equipment and accessories (keyboard, cabinet, buttons and sensors).	
	3. Perform a function test of the parameters used in the monitor.	
	4. Check Battery	
Fan	1. Physical integrity of displays	
	2. Physical integrity and power, cable conductivity	
	3. Physical Integrity of Membrane Keyboard Buttons	
	4. Physical integrity of gas hoses	
	5. Gas Pressure Gauge	
	6. Check the battery	

Fig.1: Sector patrol document

2.3 Preventive Maintenance Plan

An annual preventive maintenance plan was prepared covering all ICU hospital equipment (Fig.2). This maintenance plan defines the periodicity of these actions and the professional responsible.

Hospital																	
Engenharia Clínica																	
PLANEJAMENTO DE MANUTENÇÃO PREVENTIVA DE EQUIPAMENTOS MÉDICO-HOSPITALARES																	
UTI NEONATAL																	
ITEM	EQUIPAMENTO	MODELO	FABRICANTE	PATRIMÔNIO	NÚMERO DE SÉRIE	JAN	FEV	MAR	ABR	MAI	JUN	JUL	AGO	SET	OUT	NOV	DEZ
1	ASPIRADOR	DIAPUMP 089	FANEM	010553	GAM051210												
2	BERÇO AQUECIDO	AMPLA 2085	FANEM	020949	GAL043397												
3	BIUTRON SKY	5006	FANEM	004603	MAL041820												
4	BOMBA DE INFUSÃO	LF SMART	LIFEMED	000906	LFT1411005 1												
5	CARDIOVERSOR	HEARTSTART MRX	PHILIPS	006007	U50058945 8												
6	INCUBADORA	VISION 2286	FANEM	004639	CO0379												
7	INCUBADORA DE TRANSPORTE	IT158T5	FANEM	020351	CF8424												
8	MONITOR MULTIPARAMÉTRICO	DX2023	DIXTAL	005006	111503819												
9	VENTILADOR MECÂNICO	SERVO-I	MAQUET	006110	52263												
	CALIBRAÇÃO																
	MANUTENÇÃO PREVENTIVA																
				Engenharia Clínica			Responsável da UTIN			Gerência de Enfermagem							

Fig.2: Annual preventive maintenance schedule

The period of preventive maintenance was defined according to the need of the hospital, and because it has a large amount of equipment and demand, in addition to the high complexity of maintenance, more time is required than stated in the schedule, between 1 and 2 months. However, standards have been established for performing preventive maintenance that meets all equipment in the Neonatal ICU sector (Fig.3).

	INTERNAL DOCUMENT: CHEKLIST OF GENERAL PREVENTIVE MAINTENANCE RESPONSIBLE CONTROL AREA: CLINICAL ENGINEERING	Code:		
Revision Date: Review: Issue date:				
Unit:	Sector:			
Inspected equipment:				
Model:	Manufacturer:			
Serial Number:	Patrimony:			
Procedure Execution:				
Date:	Start Hour:	Finish Hour:		
General verifications:				
Instructions	OK			Observations
	Yes	No	N/A	
PHYSICAL INTEGRITY AND EXTERNAL PAINTING				
PHYSICAL INTEGRITY OF DISPLAYS				
PHYSICAL INTEGRITY OF (INTERFACE HUMAN MACHINE) IHM				
ON / OFF BUTTON PHYSICAL INTEGRITY				
POWER CABLE CONTINUITY TEST				
INTERNAL CLEANING OF ALL EQUIPMENT				
TIGHTEN OF INTERNAL WIRING CONNECTIONS				
WELDING CHECK ON PCI'S				
CHECK FUNCTIONALITY OF ACCESSORIES				
CLEANING OF ACCESSORIES				
CLEANING ELECTRONIC CONTACTS				
CHECK INDOOR LEAK				
PERFORMING EQUIPMENT SELF-CALIBRATION				
PERFORM EQUIPMENT SELF TEST				
FUNCTION TEST				
OPERATING EQUIPMENT				
_____	_____			
Responsible Technician	Responsible Sector			

Fig.3: Preventive Maintenance Checklist

For the type of management, checklists are needed and mandatory, so that there is monitoring and clarity in the evaluation of the activities performed.

2.4 Service Order

The service order records equipment data, reported failure, service to be performed by the technician, the date of entry and exit, and whether parts or components need to be replaced. Equipment that is under warranty, under

contract or in need of maintenance and needs to leave the hospital is also recorded, indicating: the equipment in question, defect presented and dates of departure and return.

A flowchart was used to standardize SO openings and how the employees should proceed with the equipment maintenance (Fig.4).

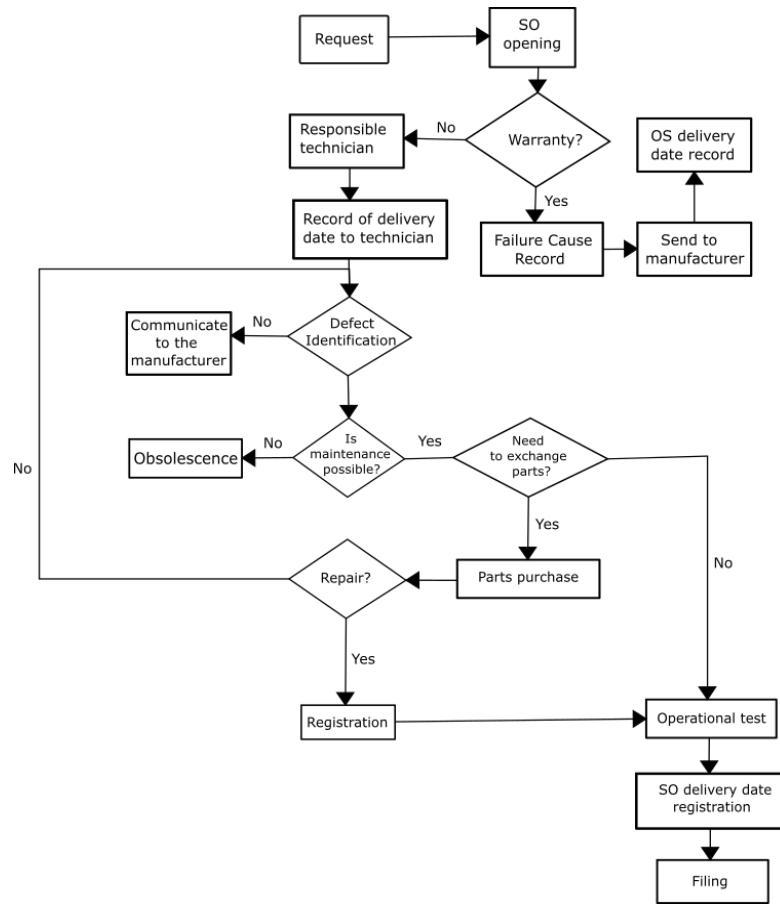


Fig.4: Maintenance flowchart

III. RESULTS AND DISCUSSION

It was evident the need to build control practices and equipment maintenance planning in the sector observed, aiming at the standardization of quality and greater safety, leading the hospital to migrate to an effective management process, complying with the regulations of the Brazilian regulatory agencies. All elaborated documentation was based as suggested by the document on hospital medical equipment maintenance and management [10].

Thus, compliance with the maintenance of equipment is expected, as well as schedules, described through the hospital's internal system, with support of a spreadsheet for monitoring, as scheduled. The dates were set in agreement with the nursing staff and medical coordinator of the sector involved, ensuring equipment reliability and optimization, reduced outsourced workforce costs, corrective maintenance and calibration.

Corrective maintenance is simpler to be understood, being applied by the simple act of fixing what is broken, inoperative, unproductive. Meanwhile, preventive maintenance has the purpose of avoid the failure occurrence [23][19].

3.1 Equipment Maintenance History

All events associated with equipment life, from installation to obsolescence disposal, were documented in an organized way and this observation fed the system, forming a history, where reports are generated of each equipment in the sector, describing which services were performed, when performed, and who performed them.

These data were tabulated via Excel, where all events occurred was recorded in the form of SO: corrective, preventive maintenance, replacement of parts, updates, and others, must be filled the largest number of fields with the identification of the register in order to provide speed in equipment demand, including: sector, equipment, assets, and serial number.

Clinical engineering performance monitoring was established through data obtained from OS (corrective and preventive maintenance, patrols and equipment installation), managed through the generated spreadsheets (Fig.5).

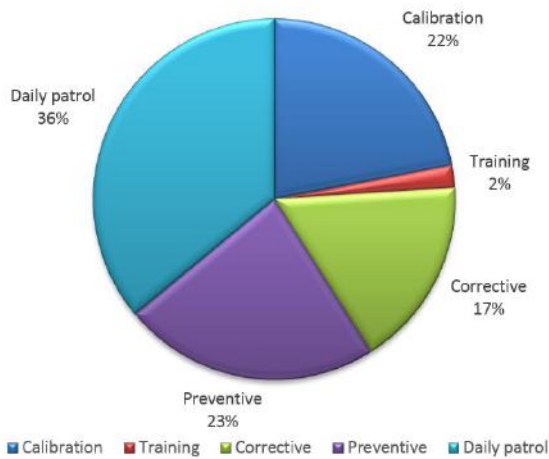


Fig.5: Documented service orders

All maintenance histories are available quickly and affordably, enabling improved management of the operating procedures in terms of accessibility, control and functionality. Therefore, the work order is a propitious tool to manage and control maintenance interventions, because it contains information related to the equipment indicating the description of causes and occurrences in order to help the employee to feed the management indicators. This document is usually adapted to the health facility [5].

340 service orders (SO) were opened and 346 closed, among them: 78 calibrations, 58 corrective, 78 preventive maintenance, 126 daily patrols, 6 training (Fig.6). For the relationship between the corrective maintenance closed by the corrective maintenance open, indicating using eq.1.

$$\frac{\text{Service Orders Closed}}{\text{Service Orders Opened}} \times 100 \quad (1)$$

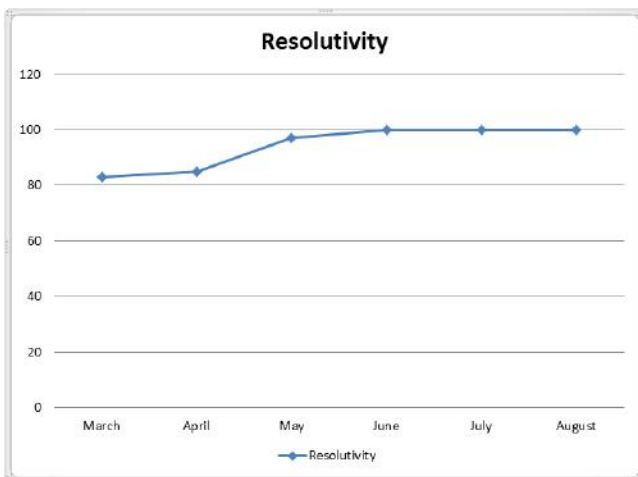


Fig.6: Resolutivity of clinical engineering

This result generated positive responses, causing the resolution in these months to reach and remain above 90%, where it was achieved in the third month of activity, thus leaving no internal issues of this period and previous periods. During the implementation of the maintenance

management of equipment of medical-hospital units, employees began to perform the first service and equipment evaluation, and a goal for corrective maintenance was set (Fig.5), aiming to minimize these demands.

For the effective accomplishment of this process, we have the indicators, parameters of a process that aim to measure quality and quantity in health institutions. These are used to assist in the management and investigation of facts related to hospital medical equipment, to extract the data to make the decision based on critical analysis and action plans, clearing problems, maximize gains and minimize costs of a strategic nature for excellent management [3][13].

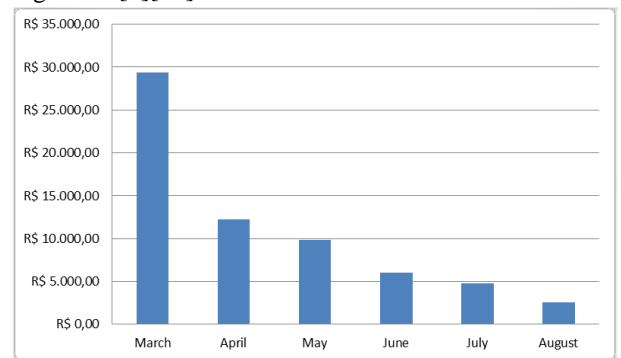


Fig.5: Total cost of corrective maintenance in 6 months of implementation of the management process.

IV. CONCLUSION

A methodology was developed to establish improvements according to the analysis of indicators extracted from the elaborated tables, such as: keeping the minimum of corrective maintenance, performing the maximum of preventive maintenance and predicted calibrations, reducing the misuse and operational failure rate and perform the planned training.

Thus, it is concluded that the activities related to management contribute to ensure the best use of medical equipment, having as its main objective the quality of services provided to the institution.

However, we continue to develop actions that serve as parameters for further studies and future adjustments, such as the implementation of management software not only in the Neonatal ICU, but also in all hospital sectors for better quality management, better care, facilitating the control and demonstrating the indicators.

Therefore, it is evident that the hospital management with quality of services provided to the patient, will be better provide the absorption of the data with this work done by the Clinical Engineering in the Neonatal ICU, achieving continuous improvement of the technology park

quality, in order to reach satisfactory proportions, for patient safety and the institution's strategic interest.

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