Determine the performance of selected critical care medical equipment in Teaching Hospital, Peradeniya, Sri Lanka

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Abstract
Background: Medical equipment are imported assets that directly influence the medical management in patient care. To ensure effective and safe health care, medical equipment must be maintained efficiently and effectively with expected performance. The way in which it is used and maintained may greatly affect the reliability and productivity of an equipment (H. Mahfoud, 2016).
Objective: The main aim of this study is to determine the performance of selected critical care medical equipment in Teaching Hospital, Peradeniya (THP) and to make recommendation to rectify deficiencies.
Method: Descriptive cross sectional study design was adopted in this study. Medical equipment which are used in critical care (Intensive care units and operation theatres) were selected based on Equipment management number (EMN) of which is introduced by Fennigkoh and Smith where numerical value is assigned to each medical equipment type in terms of its function, clinical application, required maintenance and history. Out of 510, 103 of equipment whose EMN was more than 12, were shortlisted for the study.

Equipment failure rate, the percentage of equipment failed as an average of total number of same equipment in a given period was selected as the performance indicator of medical equipment. Feasibility and availability of data were summoned to choose this indicator as performance measure.

Results: Following medical equipment showed equipment failure rate more than 20%,

- ICU ventilators
- Anesthetic machines
- Incubators
- ICU monitors
- Syringe pumps and infusion pumps

Conclusion: Equipment with failure rate more than 20% need more extensive and comprehensive preventive and corrective maintenance programme.
Recommendations: Inspection and preventive maintenance (IPM) programme and effective corrective maintenance programme is a mandatory requirement to harvest optimum performance levels. Training programme for end users, effective monitoring and evaluation mechanism and good asset management system are other recommendations.

Index Terms: Critical care medical equipment, Equipment failure rate, performance, Teaching Hospital- Peradeniya

I.INTRODUCTION

Any instrument, apparatus, article, or machine that requires calibration, maintenance, training for user and technicians, repair and decommissioning and these activities usually coordinated by the biomedical engineering department is called medical equipment. They are used diagnosis and treatment of any ailment or rehabilitation following disease or any kind of injury. This medical equipment can be used either alone or in combination with any other medical equipment or device. (1)

It has been found that in most of the instances, maintenance of an equipment over its life span costs more than the money spent for its procurement. (2) This could lead to increased cost of service ratio and may be due to poor performance. These equipment are used in variety of clinical applications including screening, prevention, diagnosis, monitoring from the treating patients to rehabilitation. Therefore, it is virtually impossible to manage patients without medical devices or equipment in present scenario.

There are two types of medical equipment maintenance system. Inspection and preventive maintenance (IPM) include and planned maintenance activities that ensure continuous smooth functioning of equipment and prevent equipment breakdown of failures. Corrective maintenance (CM) denotes that maintenance is done according to used arises (repair) and correct the function of the equipment.

As the technological advancement and cost continue to escalate, the maintenance cost and complexity of maintenance activities have also increased sharply during past decade. In European countries, it has been found that bed: equipment ration is about 15-20 pieces of medical devices for one bed and this approximately cost around 400,000 -800,000 $ for one bed. (3)

Medical equipment ranges from simple manual devices like sphygmomanometers to highly sophisticated advance automated equipment such as new advanced imagine radiological equipment (MRI) and automated laboratory equipment. These high-tech devices require extensive financial, physical and human resources when they need repair, calibrating and maintenance. Between these two extremes, there are other lots of medical devices in varying complexity like multipara-Monitors, syringe pumps, infusion pumps, x-ray machines and defibrillators. Irrespective of the complexity and technological advancement, all medical equipment should be inventoried in a proper manner unlike in some developing countries (WHO medical equipment management overview)

In Sri Lanka all the medical equipment and devices have been inventoried and this is a general rule comes under financial regulations. In the beginning of the planning process of the preventive maintenance program, the devices or equipment that need to be included into this program should be decided in a scientific manner in which could address the facilities available and other priorities of the system.

Other factors that have to be taken into consideration include, administrative time, preparation time, and documentation time. Estimation of direct maintenance cost may be difficult in the beginning but can be improved with experience and time.

The cost of service ratio can be used to determine the financial effectiveness of a maintenance program. This ratio is estimated dividing the total operational cost by the total initial cost. (4)

$$\text{Cost of service ratio} = \frac{\text{Total operational cost}}{\text{Total initial cost}} \times \%$$

In the USA this cost of service ration has been reported between 5% - 10% and this level of ratio can be achievable only with adequate supporting resources are available and with the sustainable proper improvement in the program. Further, cost of service ratio can be used as on indication to evaluate the performance improvement of a maintenance progress. (4)

1.1 *Performance monitoring*

Performance monitoring is essential and important activity in efficient and effective equipment management program. Since there are no benchmark or standards to compare performance of equipment bio medical engineering department has to monitor their own performance overtime to compare and to identify any discrepancies to take action. The other possibility is to compare with possible institutions, with their performance and can identify the gaps and deficiencies thereby may find opportunities for improvement. There are few performance indicators which are using worldwide, but they are difficult to calculate without having CMMS.

1.2 *Computerized maintenance management software (CMMS)*

In growing technological advancement, CMMS system has been introduced for managing medical equipment management program. This is very useful for institution with large number of medical equipment. This is computer software tool that is able to operate on a stand – alone computer. Basic CMMS system consist of following capabilities (WHO)

1. Inventory Management
   Storing of comprehensive history of an equipment and should be able to easily add or remove information as need arises.
2. Keep record of past service events and ability to retrieve or print them as need arises.
3. Ability to store IPM procedure, corrective maintenance activities and other important information.
4. Scheduling of IPM activities, Changing of IPM schedule and summarizing of IPM schedules.
5. Formation of individual IPM forms with a relevant procedure and computing of pending IPM completion dates/time.

6. Recording of IPM inspection procedure including tasks that completed with replaced parts.
7. Produce summary of report including following performance indicators,

- IPM completion rate
- IPM failure and required repair
- Ratio of IPM actual versus expected completion times
- Summary of Inventory
- List of repairs completed
- List of parts used over the required time period
- Down time
- Cost service ratio
- IPM yield

1.3 *IPM productivity*

$$\text{IPM productivity} = \frac{\text{Time taken to complete given IPM procedure}}{\text{Expected time to complete the same procedure}}$$

This indicator measures the productivity of IPM staff which one of the most important information in management of IPM program. Here, time taken to complete any procedure means the actual time that the technician takes to complete procedure excepting the preparation and set up times. The expected IPM time can be taken from the manufacture recommendations. Experience also can be taken as useful guide.

The highest priority equipment should have the highest rate of completion, over 95% and lower goals can be entertained by lower priority equipment. This indicator provides the most important information; status of productivity and effectiveness of the IPM staff, the ability of the bio medical department and the overall productivity of the IPM program. (5)

1.4 *Equipment location rate*

The proportion of devices planned to be inspected in the given period but not located before the finishing of the inspection term is called as equipment location rate. This indicator can be used to measure the accuracy of the inventory system or inventory database in CMMS. (5)

1.5 *IPM yield*

This is the percent of planned IPMs conducted where problems/complaints were reported on affected device / equipment operation or safety. Here cosmetic issue which do not hinders the performance or safety of equipment are not considered. This indicator gives information on equipment general reliability and it can be used to compare the reliability of two different equipment. Further, effectiveness of the maintenance program can be viewed by using IPM yield. (5)

1.6 *Completion rate of assigned IPM*

The general meaning of this is the percentage of completed IPM procedures during given period. At least 90% of completion rate is warranted to be labeled as good completion rate of assigned IPM. This rate could also be used to evaluate the completion rate of most prioritized equipment. (5)

Performance of medical equipment assessment is important aspect in medical administration because they are directly influence the medical management and therefore affect the human life. Since there are many number and type of medical equipment are available, prioritization of medical equipment is needed as inclusion criteria for the study.

1.7 *Objective*

The objectives of this study were identification and prioritization of medical equipment to be included to the performance assessment programme and to assess the performance of selected medical equipment using selected performance indicator. Further recommendations were made to improve medical equipment performance.

II. METHODOLOGY

Descriptive cross sectional study design was adopted in this study and was carried out in the intensive Care Units (ICUs) and Operation Theaters (OTs) of Teaching Hospital, Peradeniya, Sri Lanka. All critical care medical equipment whose EMN was more than 12 were included for the study. Data was collected by quantitative and qualitative means. Key informant interviews (KII) and focus group discussions (FGD) were conducted to gather information.

2.1 *Identification and categorization*

A facility survey was conducted using check list to identify available critical care medical equipment by Principal investigator (PI). All available medical equipment was categorized according to following criteria. (WHO medical equipment management overview)

1. Diagnostic equipment
2. Monitoring equipment
3. Therapeutic equipment
4. Imaging equipment
5. Other

2.2 *Identification of equipment*

This study was mainly focused on performance of critical care medical equipment in ICUs and OTs which have more than 12 EMN. To meet this inclusion criteria principal investigator (PI) selected following equipment types for the study.

1. Ventilators
2. Multipara monitors
3. Normal monitors
4. Defibrillators
5. Dialysis machine
6. Portable X-ray
7. Scan – USS machine
8. Pulse oximeters
9. Heavy duty suckers
10. OR machine
11. CRRT machine
12. Infusion pumps
13. Syringe pumps
14. C – PAP machine
15. DVT pumps

16. Blood-gas Analyzers
17. Electrolyte Analyzers
18. Infant Incubators

2.3 Equipment prioritization for selection to the study

There are various methods to prioritize medical equipment to be used in various purposes. In this study, Fennigkoh and Smith model (3) where numerical value is assigned to each medical equipment type in terms of its function, clinical application, and required maintenance was used as prioritization criteria.

Equipment Management Number = Function + Application + Maintenance + History

2.3.1 Equipment function

Medical equipment has been given numerical values according to its type of function. Following table illustrates the point score.

Category	Function Description	Point score
Therapeutic	Life support	10
	Surgical and ICU care	9
	Physical therapy and treatment	8
Diagnostic	Surgical and ICU monitoring	7
	Additional physiological monitoring and diagnostic	6
Analytical	Analytical laboratory	5
	Laboratory accessories	4
	Computer relate	3
Miscellaneous	Patient related and other	2

(Source – WHO medical equipment management overview) Table 1

2.3.2 Physical risk associated with clinical application

(Potential patient or device risk during use)

Description of use risk	Point score
Potential patient death	05
Potential or operater injury	04

Inappropriate therapy or misdiagnosis	03
Equipment damage	02
No significant identified risk	01

(Source – WHO medical equipment management overview) Table 2

2.3.3 Maintenance requirements

Consider the level and frequency of maintenance required according to manufacture or by experience.

Maintenance required	Point score
Extensive (Routine calibrate and port replacement	05
Above average	04
Average performance verification	03
Before average	02
Minimal	01

(Source – WHO medical equipment management overview) Table 3

2.3.4 Equipment incident history

Service history can be considered when determining the EM number.

Equipment failure	Factor
Significant (>every 6/12)	+2
Moderate (one every 6-9 month)	+1
Average (one every 9-18 month)	0
Minimal	-1
Insignificant (Less than one in the past30/12)	-2

(Source – WHO medical equipment management overview) Table 4

Equipment management number for each equipment type was calculated by the PI with the viewpoint of the expert panel. Further they decided that all equipment types those who rated above EMN score of 12, as inclusion criteria to be included into the study. EM number below 12 was excluded from the study.

2.4 *Assessment of performance of medical equipment*

Though there are several performance indicators are available in the world, most of them cannot be calculated due to lack of available information in the existing system. Therefore, PE compelled to select an indicator which is easy to synthesize. Equipment failure rate: a performance indicator which mostly measure preventive and corrective maintenance of equipment, was selected as performance

measure. Equipment failure rate (EFR) is sensitive indicator which can be used to compare the performance of medical equipment in different settings and deferent brands.

Equipment Failure Rate (EFR)

Equipment failure rate denotes the percent of equipment failed as an average of total number of same equipment in a given period.

$$\text{Equipment Failure Rate (EFR)} = \frac{\text{No of equipment failed}}{\text{Total number of same equipment in a given period}} \times 100\%$$

Since equipment failure rate calculation requires reliable information, records in the bio medical engineering department were retrieved to gather information needed for the process. 510 number of medical equipment were subjected to the study. Out of this 510, only 103 medical equipment have been considered to measure performance.

III. RESULTS

3.1 *Calculation of Equipment management number (EMN)*

Equipment type	Equipment function	Clinical application	Maintenance required	Failure history	EMN
Ventilator	10	5	5	0	20
US scanner	7	3	3	0	13
Infant incubator	10	5	5	0	20
ICU monitor	7	3	2	0	12
Infusion pump	8	3	3	0	14
Syringe pump	8	3	3	0	14
CVD pump	8	3	3	0	14
C-PAP	10	5	5	0	20
Blood Gass Analyzer	6	3	3	+1	13
Defibrillator	9	5	4	0	18
Pulseoxymeter	9	3	3	0	15

Equipment type	Equipment function	Clinical application	Maintenance required	Failure history	EMN
Sucker	2	2	2	-1	5
Infant warmer	10	5	3	0	18

RO machine	10	5	4	0	19
Hemodialysis	10	5	5	0	20
CRRT	10	5	5	0	20
Portable x-ray	7	3	3	0	13
Ophthalmoscope	6	3	2	0	11
Sphygmomanometer	6	3	1	-1	9

Table 5

Ventilators, C-pap machines, infant incubators, hemodialysis machines and CRRT machines got the highest (20) EMN.

3.2 *Equipment failure rates of selected medical equipment*

Equipment	No of failures	Equipment failure rate
Monitors	14	20%
Defibrillator	3	16%
DVT pumps	2	14.2%
Syringe pumps	42	34.5%
Infusion pump	16	27.7%
CVP pumps	3	15%
Pulse oxy meter	1	16%
ICU ventilator	4	28.5%
Anesthetic machine	2	20%
Incubators	4	29.6%

Table 6

Infant incubators, ICU ventilators, syringe pumps and infusion pumps record the highest equipment failure rate.

IV. DISCUSSION

Medical equipment is imported asset that directly influence the medical management in patient care. To ensure effective and safe health care, medical equipment must be maintained efficiently and effectively. The way in which it is used and maintained may greatly affect the reliability and performance of an equipment. Further, Government spends substantial proportion of health expenditure on acquisition of medical equipment. Therefore, assessment of their performance is vital for provision of quality standard health care delivery. Though there is great concern over the medical equipment and their performance, in depth studies on this area is scares in worldwide (6).

4.1 *Identification of critical care medical equipment in ICUs.*

In this survey, there are 510 critical care medical equipment have been identified according to inclusion criteria. Medical equipment those EMN was less than 12 were excluded from the study.

In this assessment out of 510, only 103 medical equipment have been subjected to performance assessment program. Many studies suggested that for efficient and effective medical equipment maintenance program is warranted to acquire better performance of medical equipment, thereby provides high degree of patient care (7,8)

It was found 74 equipment which were not working condition at the time of survey. In key informant interviews conducted with Bio-medical department personal revealed that those failures were due to mainly unavailability of spare parts, consumable spares such as probes in monitors and equipment failure due to lack of proper preventive maintenance activities.

The results showed that the overall failed equipment percent was 12.7% which is relatively high number of failures. Out of this 74 failed equipment, 68 equipment (81%) have not been subjected to the IPM program. This figure is alarming and gives rich information by which the importance of a preventive maintenance program can be justified.

The failed equipment ratio of this study seems to be relatively high, and this finding may be supported by various factors. The equipment which was listed in the existing inventory system may be included some obsolete items too. Delaying of condemnation process may contribute to remain failure equipment in the inventory.
During the assessment of performance, factors like brand of the equipment, age, availability of IPM, availability of user training and number of available equipment were not considered. These factors may contribute to misshape the ultimate result.

V. LIMITATIONS

The main limiting factor was unavailability of information due to poor record keeping by users and bio medical engineering department. Therefore, PI had to select only few equipment types for performance evaluation.

The scarcity of research on performance of medical equipment in Sri Lanka, makes it difficult to compare the findings of this study with other similar studies. The generalizability of findings to the Sri Lankan context is limited because of the fact that the external validity is low.

The focus of a medical equipment performance assessment program is reliability (6). In this research project reliability cannot be addressed effectively because it needs periodical calibration and performance checking with the manufacture's recommendations (9). This endeavor needs reasonable time period and well-equipped biomedical engineering department with adequate human resources.

VI. CONCLUSION

Despite the limitations describe above, this study provides better understanding on the performance of medical equipment in the Teaching Hospital, Peradeniya. The overall performance of critical care medical equipment in Teaching Hospital, Peradeniya is not satisfactory. Equipment with failure rate more than 20% need more extensive and comprehensive preventive and corrective maintenance programme. There is no correlation between EMN and EFR.

VII, RECOMMENDATIONS

Inspection and preventive maintenance (IPM) programme and effective corrective maintenance programme is a mandatory requirement to harvest optimum performance levels. Introduction of training programme for end users, effective monitoring and evaluation mechanism for equipment management and good asset management system are other recommendations.

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