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Preventive Maintenance of Ventilators and Its Cost Consideration

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Abstract- *Background:* Maintenance is the core function of biomedical engineering and is essential for the optimum functioning of equipment. This study was undertaken to understand the current maintenance practices of ventilator and its cost implications from administrative point of view.

Methodology: 179 Ventilators supplied and installed by one vendor in different wards of the hospital were studied. It was a retrospective, descriptive study. Equipment related data was taken from various service reports. This data was used to calculate spares failure and their costs implication.

Results: A total of 692 maintenance visits were undertaken for 179 ventilators of 5 different modals over 27 months by 6 Bio- Medical Engineers (BME). The mean number of spare changed throughout the study was 2.73. The uptime was within satisfactory limits. The yearly repair to cost ratio was 3.50 %. The cost of spare changed was a factor of modal under consideration and the status of equipment concerning its coverage under maintenance contact.

Conclusion: The findings of the study should enable researchers in the future to formulate an effective equipment maintenance policy for the hospital.

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I. Introduction

The high-cost industry of modern health care is also equipment intensive. Modern clinical equipment's with skilled manpower, consumables and infrastructure, in addition to the important costing centre, are prerequisites for providing quality health services in any modern hospital.

Medical equipment is any article, instrument, apparatus or machine that is used in the prevention, diagnosis and treatment of illness or disease, or for detecting, measuring, restoring, correcting or modifying the structure or function of the body for some health purpose which requires calibration, maintenance, repairs, user training and decommissioning related activities.[1] Medical equipment, based upon its operational characteristics, have three categories: Electric, Electronic and Mechanical.[2] Equipment's could also be classified as Critical or Noncritical depending upon its criticality in rendering effective patient care.[3]

As per the study conducted in a Canadian hospital, for each hospital bed, 15-20 medical equipment are required with the capital cost of 200-4,00,000 $.[4] Hospital have to spend approximately 1% of its operational budget on maintenance of biomedical equipment's.[3] As per the estimates, 3% to 8% of the initial cost of the equipment should be earmarked for its repair and yearly maintenance. The rage will depend upon the complexity of the equipment. Based on depreciation, safety, reliability, clinical application, and budget, the lifespan of medical equipment is generally set between five and fifteen years. As the price of bio-medical equipment is determined by the global market, in developing countries, with weak currencies, the purchase of new equipment is a heavy financial burden.[4] Hence, it is imperative to ensure maximum utilization of the equipment with minimum downtime.

Proper maintenance of medical equipment ensures longer functional time for the medical equipment. It also ensures that patient safety is not compromised due to the use of critical equipment's, having unidentified defects (partial failure), such as Ventilator's, ECG machine, infusion pumps, etc.[5]

The most appropriate plan for equipment maintenance is a topic of debate for quite some time, but no consensus seems to be on the horizon.[5-14] Authors have classified two major type: Corrective/ breakdown and Planned Preventive Maintenance.[5]

Monitored equipment maintenance program for critical equipment's from the patient's safety point of view, or those who are maintenance sensitive should be developed and expected to be cost-effective.[15] The precondition for the effective equipment management program is the estimation of necessary consumables, calculations of Equipment Management number (EM) and operational costs, and planning at the end of every year.[4]

Ventilators which are used more rigorously will require intense maintenance program.[2,16,17] Choice amongst various maintenance models such as maintenance outsourcing, in house maintenance, on-call services, etc. has to be arrived after taking the costs

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into consideration. It is not economical to provide the level of service in-house.

The study was undertaken to find the cost consideration of the current maintenance practices for ventilators at the Institute and to design a cost-effective maintenance program for critical equipment such as ventilators.

II. Methodology

This study is a retrospective descriptive and observational study. The study was carried out in a 2500 bedded autonomous tertiary healthcare Institute over six months (December 2014 to May 2015). A total of 179 ventilators installed and serviced in the institute by a single vendor from January 2013 to March 2015 were included in the study.

Data collection: The data for the study was obtained from the service reports, and it was compiled to determine the parameters to measure the effectiveness of maintenance. For reliability, data cross-checking of 89 company reports was done.

The estimated market value of the spare parts was collected with the help of a private company working in the field of providing biomedical engineering solutions to the hospitals. These under mentioned parameters were identified (by Review on literature to reach a conclusion) [21]

1. The ratio of the total cost of service to total equipment acquisition cost is sometimes called the Cost of Service Ratio [4] (COSR) = (Total cost of service/Total equipment acquisition cost) * 100
2. Total Clinical Engineering cost/device serviced = Total cost for all Clinical Engineering activities / Total number of devices receiving service

Unstructured interviews with the BME responsible for maintaining these equipment in the Institute as well as with other engineers from the industry were used to further understand the reasons of breakdowns and to understand the financial implications of these maintenance programs from their prospective. Bio-medical Engineers guide with their expert opinion several times.

Statistics used: Data processing and analysis was done by using Microsoft Excel and SPSS Version 20.0. Cross tabulations were done to determine the significance of each of the visits from the point of the nature and frequency of breakdown.

III. Observations

A total of 692 maintenance visits were undertaken for 179 ventilators over a period of 27 months by six Bio-Medical engineers (BMEs). These 179 ventilators installed over 14 months, were of 5 different models. The date of installation of nineteen ventilators could not be determined. Out of total 692 service visits, 11.64 % were for Preventive Maintenance, and 88.36% were for Breakdown Maintenance. Despite low rates of preventive maintenance, downtime per equipment was well within the acceptable limit of 5%.

Age of the equipment

The age of the equipment's ranged from 0.5 years to 15 years, with a mean of 4.77 years.

Number of spares changes 488 spares were changed in 418 visits and 2.73 spares were replaced per equipment during the study period of 27 months.

Repair to cost ratio

Estimated total cost, after considering the conversion rates of foreign currency into Indian Rupees for the year of procurement was found to be Rs.11,09,47,523 per ventilator. The approximate price of all spare parts was taken from the open market, which was further verified from a biomedical consultation company.

Repair to cost ratio was calculated using the formula given below.

$$= \frac{\text{Cost of the repair} * 100}{\text{Price of the equipment at the time of purchase}}$$

The total expenditure incurred to replace spares was Rs. 80,35,800/- during the study period of 27 months and the total expenditure incurred to replace Spare per year was Rs. 35,71,467.

$$= \frac{(35,71,467 + 3,00,000) \times 100}{11,09,47523} = \mathbf{3.50\%}$$

The salary of the BME is also considered (Rs.3,00,000). Thus, the total cost of repair will be Rs 35,71,467 per year (3.5%).

The above findings indicate that the actual expenditure being incurred on equipment maintenance over a decade is 35% of the equipment cost which is way less than the current amount being spent on the same over a decade which is approximately equal to the cost of equipment.

Maintenance contract

On calculating the cost of spare changed per visit, it was found to be Rs 12867, Rs 4252, and Rs 13081 respectively for equipment under warranty, under CMC and for the equipment neither under warranty nor under CMC. When ANOVA was applied, it was found that both these factors are statistically significantly related. (Table 3)

Table 1: Relation of Expenditure on spare changes and Maintenance Status.

Maintenance status	Total no. of visits	Values of spare changed (Rs.)	Mean value of spares changed
Under warranty	272	3512850	12867.58
CMC	110	467800	4252.727
No warranty or CMC	310	4055150	13081.13
Total	692	8035800	11612.43

Ventilator model

The monetary value of the spare parts changed was statistically significantly related to the model. (Table-2) This observation implies that the model selection is critical during procurement, as some models are sturdier and require less maintenance in comparison with the other models.

Table 2: Expenditure on Maintenance visit and Model of Ventilators.

Model	No. of visits	Total Cost of spare parts replaced (Rs.)	Spare parts replacement cost per visit (Rs.)
A	385	56,71,100	14730.1
B	34	8,95,600	26341.2
C	87	5,53,400	6360.9
D	70	4,23,000	6042.9
E	116	4,92,700	4247.4
Total	692	80,35,800	11612.43

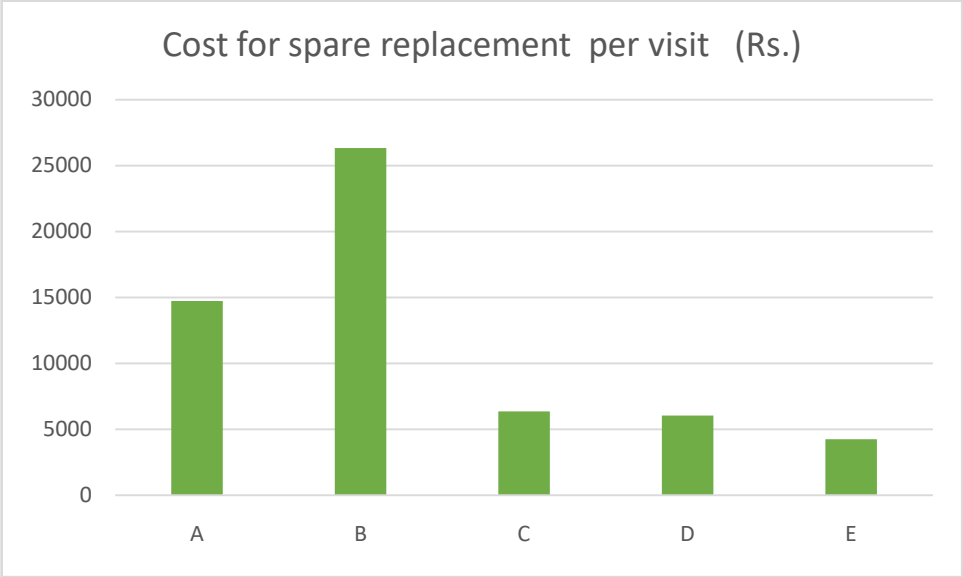

Figure 1: Relative cost of spare cost per maintenance visit

On an average, the expenditure on the spares during each visit was Rs.11612.4. However, the maximum was for Model- B, which was Rs. 26,341.2 and minimum was for the Model-E (Rs. 4247.4)

IV. Relationship of Maintenance Cost per visit with Maintenance Contract and Model of Ventilator

The value of the spare parts changed was compared using ANOVA with the model of the ventilators and the maintenance status of the ventilator (covered under warranty, under AMC, out of warranty). (Table -3)

Table 3: Relationship of cost of spare parts with Maintenance status and Model of Ventilator.

		Sum of Squares	Mean Square	Sig.
Total cost of spares change/ visit	Between Groups	22295899826.936	4459179965.387	.008
	Within Groups	413164243716.110	1395825147.690	
	Total	435460143543.046		
Model of the ventilator	Between Groups	39.380	7.876	.009
	Within Groups	739.295	2.498	
	Total	778.675		
Maintenance Status (Under Warranty, Under CMC Not under warranty)	Between Groups	35.774	7.155	.000
	Within Groups	231.750	.783	
	Total	267.523		

Both of these factors, were found to be of statistical significance and need to be kept in mind while making procurement related decisions.

V. Discussion

Despite the low rates of preventive maintenance, downtime per equipment was well within the acceptable limit of 5%. It was made possible by posting 2 BMEs exclusively for the hospital under study.

The selecting of the modal and proper monitoring of the maintenance by the vendor is essential in the background of cost of equipment's being influenced by the international market.

VI. Conclusion

In this study, an attempt was made by the authors to get a bird's eye view of the expenditure being incurred on the maintenance of critical equipment's such as ventilators.

The low rate of preventive maintenance is an indicator of the fact that in the present scenario where the cost of equipment's and spares is determined by the global market and the salary of Bio-medical engineers are very less. The local vendors are not changing the spares as per the manufacturer recommendations. But are allowing the spare part to failure. By posting dedicated manpower for the institution, they are assuring that the complaints are instantly attained. However, the latent failure cases are likely to remain undetected and jeopardizing patient's safety. The authors have concluded that the selection of the model of the ventilator imperative during the procurement of equipment. This observation is important as some models are sturdier and require less maintenance in comparison to other. Further, it is imperative for the organization to prepare a list of spares which require frequent replacement to ensure that such spares are readily available at a competitive cost. Thus, helping the organization develop a low-cost maintenance program. The lifespan of the equipment needs to be taken into consideration before entering into a maintenance contract as at times, procurement of new one is a more feasible option than incurring high running costs on the same. Further, various cost centers in the maintenance of such equipment's need to be identified so as to enable one to draw more factual conclusions and design a cost-effective and efficient equipment maintenance program.

Limitation of the study: The retrospective nature of the study and the partially filled service reports were limitation to the study.

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