Effective Maintenance Of "Non-Medical Equipment" At Selected Base Hospital In Sri Lanka

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***Abstract*- Background:** This project was carried out to implement strategies for effective maintenance of a prioritized "non-medical equipment" at selected Base Hospital in Sri Lanka.

Aim: To prioritize a "non-medical equipment" and to develop and implement strategies for effective maintenance of the selected equipment.

Methods: Non-medical items of importance were selected using frequency of breakdown and impact on patient care. Both qualitative and quantitative techniques were used to study the process and practices. Based on pre-intervention findings, the post intervention phase was undertaken using the same instruments to assess the effectiveness of the improvements.

Results: There was an undue delay due to several factors and strategies was developed to address the deficiencies in effective maintenance of air conditioners (AC). Post intervention results revealed improved level of satisfaction; increased process knowledge and awareness; increased traceability and reduced the mean AC downtime from 5.21 (SD±0.832) to 2.33 days (SD± 0.5) after intervention; this was significant at 5% level.

Conclusion: Standard Operating Procedure and maintenance activities has improved AC downtime; reduced repeated breakdown of the ACs, thereby significantly increasing the level of satisfaction among all the stakeholders in this process in Sri Lanka.

***Index Terms*-** air conditioners, Standard Operating Procedure, maintenance, downtime.

I. Introduction

Over the course of time, the hospital maintenance management has continuously grown with regard to its great importance and is now considered throughout the world as a vital and widespread phenomenon (1,5) It is no longer viewed merely as a necessary evil (2), but in fact a source of profit (3). Poor maintenance leads to more frequent breakdowns (4). Maintenance is an essential basic work carried out to maintain the original anticipated useful life of a fixed asset, the conservation of property and equipment in order to preserve reliability, efficiency and cost effectiveness (5). This has led to the development of the Standard Operating Procedures (SOP) (6).

Over time, the importance of managing hospital maintenance continues to grow, and it is now considered important and widespread worldwide (1, 5) and is no longer considered a significant evil but a very good source of profit (3). Poor service often leads to breakdowns (4). Maintenance is an important key function of maintaining the initial expected useful life of fixed assets, maintaining core assets and equipment to protect reliability, efficiency and profitability (5). This led to the development of standard operating procedures (SOP) at Base Hospital Homagama (6).

Well established Healthcare Maintenance Units headed by a Maintenance Engineer, deliver excellent patient care and outcomes in most of the western world (7). The unavailability of establish maintenance systems such as, SOP and job order format/logbooks, has been identified as a major obstacle for delivering of timely maintenance management; it has adversely affected the smooth delivery, quality and safety of the service provided and increased overall operating cost, downtime etc. (16). This creates more and more maintenance issues which lead to deterioration of patient's care (8).

SOPs are vital components in any quality management system and provide information to carry out a job effectively; they assign procedures for the preparation, approval, distribution, amendment and storage (9). The Ministry of Health has achieved health indicators, which are on par with western countries and is looking forward to improving quality and safety in patient care. Improvement of maintenance and management has been identified as one of the main pillars towards health care quality and safety (10).

Very little research has been carried out in Sri Lanka to assess equipment maintenance8management (8). Strategies to identify and address the issues have not yet been formulated by the Quality Secretariat, Ministry of Health. In 2007, Dharmaratne has described that the nonexistence of a maintenance system had resulted in great inconvenience to patients, frequent breakdowns and an increase in the down time required.

Therefore, it is vital that steps are taken swiftly to identify any gaps in the process, rectify the drawbacks in the current system and provide better patients care, which will eventually give rise to short and long-term benefits to the organization. This process was mostly affected the clinical areas of focus in the hospital such as the Operation Theatre (OT), Intensive Care Unit (ICU) and Labour Room (LR). Provision of proper maintenance is crucial for smooth running of the Base Hospital Homagama (BHH), as it caters to over hundred thousand patients monthly (16). The cost incurred for recurrent maintenance management is about Rs: 5.4 million per year (11). Initial focus group discussions with stakeholders revealed that frequent breakdowns in ACs and unnecessary delays, was a reason for poor performance and

dissatisfaction amongst staff and patients especially in the clinical areas such as the OT, ICU and LR. Introducing and developing strategies for effective maintenance of split air conditioners in the OT, ICU and LR can make the system more cost effective, efficient, safe and reliable at BHH.

Implementation of a proper maintenance system will benefit the administration significantly as reducing the overall down time boosts productivity and satisfies the end user (8). Therefore, hospital maintenance management should be given top priority in day-to-day activities (12).

Absent, insufficient, or ineffective maintenance and management have been identified as a major obstacle for smooth and uninterrupted patient care delivery in most of the developing countries (2). An enormous amount of money, time and resources have been wasted due to unavailability of establish maintenance and management systems in healthcare facilities; this includes hospital AC maintenance (13). BHH has faced many issues due to ineffective non-medical maintenance and management and some audit enquiries. Therefore, an effective management process for the maintenance of non-medical equipment would help to overcome this issue was identified thorough project questions. Which was what is the priority non-medical equipment item, what is the current maintenance practice regarding this non-medical equipment and What interventions should be introduced to improve the maintenance practices of this equipment in BHH.

II. METHOD

This was hospital based interventional research project conducted in three phases, using a qualitative and quantitative method conducted using in-depth interviews and document reviews. This project was conducted in Base Hospital Homagama in Western province Sri Lanka during May 2018 to January 2019. Project was conducted in three phases. During the Phase 1, identified the priority non-medical equipment for effective maintenance in BHH, assess the current equipment maintenance processes and practices of this prioritized item and identified the gaps in equipment maintenance processes. After identification of gaps, in phase 2 was develop and implement strategies for effective maintenance of the prioritized a "non-medical equipment" and assess the effectiveness of the interventions in phase 3.

Qualitative data gathered though Key informant interviews (KII) and focused grouped discussions (FGD) were noted down and recorded with the participants' consent. Statements were synthetized according to common words and coded into thematic areas. Each thematic area was then converted into information. Quantitative data gathered through questionnaire and desk reviews was analyzed using Statistical Package for Social Sciences 23.

III. RESULTS AND DISCUSSION

The total sample size of those involve in the AC maintenance process was 51. Of them 27, 15 and 9 were attached to Operation Theater, Labour Room and Intensive Care Unit respectively. The nursing officers were questioned on knowledge pertaining to AC maintenance.in their units. All 51 answered "NO" to this question; hence a training programme was arranged for them to acquire knowledge on AC mechanism and maintenance. In addition, in phase 1 bellow mention gaps were identified separately by, FGD and KIIs.

By FGD it was revealed, poor attention to maintenance processes and frequent breakdowns gives rise undue delay in getting them repaired once broken due to multiple reasons such as, non-availability of service agreement, non-availability of separate maintenance logbooks, schedules and unavailability of trained staff. Further KII revealed, non-availability of directive and assigned responsibility for regular maintenance operations as a major barrier. In addition, non-availability of instructions for uniform process and practices in AC maintenance, overall poor knowledge on maintenance, delays in payment approval process and poor documentation process and supervision were identified as the gaps in the process. Based on the KII and FGD, the existing AC corrective maintenance process has been described as below. When an AC breaks down the on-call nurse-in-charge of the unit informs the Medical Superintendent in writing using a common complaint book; he/she is not kept informed regarding the processes that follow. Once Medical Superintendent approves the request, it will be forwarded to the relevant officer and accountant for necessary arrangements. In the majority of cases the nurse-in-charge of the unit has to submit the written request several times or contact and remind the relevant officer as the lack of a feedback mechanism leaves them unaware of when their request will be attended to. These conversations often result in arguments and overall dissatisfaction.

The non-availability of a maintenance agreement makes it difficult for the Subject Officer to acquire the services of maintenance personnel who normally address the issue at their convenience. These unscheduled visits result in further delays as they are not allowed into the theater or labour rooms as they are occupied at the time. This means that they have to repeat the visit for the same job; this results in difficulties in sourcing maintenance personnel the next time. This situation is made worse due to undue delays in the payment process. This leads to a vicious cycle making everyone tired, unhappy and unsatisfied. The staff in these units have to therefore make do with pedestal fans; this makes it difficult to maintain the ambient temperature at the correct level risking the lives of patients who require continuous care. At this point, it was observed there was no preventive maintenance mechanisms exist for AC maintenance. Identifying the gaps in phase 1, strategies were developed with the staff and management. The nurse-in-charge of each unit has agreed to perform overall supervision of the new process and the maintenance unit agreed to intervene and help with the AC maintenance process. With the implementation of developed strategies, it was observed a significant reduction in breakdowns, a significant improvement in the AC maintenance process, a significant reduction in downtime, a significant improvement of process knowledge, awareness and satisfaction among staff, a significant improvement of quality and traceability of the process. All of them agreed on, both the SOP and maintenance agreements as the most important tools for effective maintenance of selected equipment.

In phase 3 following the establishment of AC maintenance process with adherence to the SOP, when an AC breakdowns, on call nurse-in-charge informs the maintenance unit over the phone. This has reduced several steps in comparison to the procedure that

was previously followed. Thereafter trained AC staff will attend and immediately and will fix the problem. As per the SOP, maintenance staff should attend to any maintenance request made by the unit in charge at any given time. They are also required to help in the training minor staff when requested. If it is beyond their capacity, the nurse-in-charge will inform the AC maintenance company. Once informed they are obliged to attend to the problem within 24 hours as stipulated in the service agreement.

After attending the training workshops the minor staff have attended to the preventive maintenance measures by cleaning the filters and outside condenser coils and inspecting the drainage tray bi-weekly as per the regular cleaning log scheduled in the SOP. Any faults they find are then immediately reported to the on call nurse-in-charge. Additionally, a monthly preventive maintenance is carried out by the contractor as per the "SOP preventive maintenance schedule". Each and every AC is numbered from 1-17 and given separate logbook for easy retrieval and responsibility for it has been assigned to the unit's nurse-in-charge in accordance with the SOP.

Pre and post assessment results comparison were listed as bellow,

A five-point Likert Scale was used, and total marks were given 1 to 5. Categories in five-point scale were reduce to two by grouping; ≤ 3 = Unsatisfied/Yes/ useless/ rarely together and ≥ 4 = Satisfied /No/useful/ very frequently together following the expert's opinion.

Observed differences are significant at 5% level with the exception of contacting. Traceability has improved significantly (Table 1). Separate request books for each AC were allocated in Phase 2 (100) to overcome the issues related with traceability of the request.

The majority (92.2%) of staff believed SOP was a tool for effective maintenance of AC in post intervention and changes after the intervention for all the variables are statistically significant at $p<0.05$ (Table 2). Satisfaction level improved from 0% to 94.1%, which is statistically significant at $p<0.05$ (Table 2).

Average downtime in pre-intervention group was 5.21 days, which has reduced to 2.33 days following the intervention (Table 3). Reduction in downtime is statistically significant at 5% level. In addition, number of breakdowns also had reduced from 24 times to 9 in post-intervention (Table 3).

Pre intervention four breakdowns out of 24 were addressed within 24 hours by the team; post interventions four of nine breakdowns were addressed within the same time frame (Table 4).

The percentage of breakdowns completed within 24 hours had improved from 16.7% to 44.4% from pre to post-intervention (Table 4). Chi square test of homogeneity was done to check the change in this percentage after the intervention. However, this was not statistically significant at 95% level.

Table 1. Differences in responses in pre and post intervention for selected variables.

Selected variables	Pre-intervention	Post-intervention	Statistics *Wilcoxon sign rank test*
	N %	N %	
Repeat request for Same Job			
Yes	49 (96.1)	06 (11.8)	
No	02 (3.9)	45 (88.2)	**p= 0.001**
Times of repeat request* to same job			
0 to 2 times	18 (35.3)	51 (100)	**p=0.001**
3 to 5 times	33 (64.7)	00 (0.0)	
Traceability of request			
Intractable	47 (92.2)	02 (03.9)	**p=0.001**
Traceable	04 (07.8)	49 (96.0)	
Contacting of Maintenance Unit quickly and easily			
Poor	38 (74.5)	28 (54.9)	**p=0.101**
Good	13 (25.5)	23 (45.1)	
Total	**51 (100)**	**51 (100)**	

*NB: * 0 = 1st request, 1st= repeat request, 2=2nd repeat request etc.*

Comparison of number of AC breakdown pre and post intervention was carried out as using online web based software (https://www.medcalc.org/calc/comparison_of_proportions.php), and test of proportions was done as follows.

Total sample size
= Number of AC X Number of days observed
= 17 X 90
= 1530 AC days

These numbers (1530) of AC days were observed during pre and post intervention periods. During the pre-intervention proportion of AC defective days were calculated using following formula.

$$\text{AC defective days} = \frac{\text{Total number of defective AC days during the period observed}}{\text{Total number of AC days observed}}$$

$$\text{Pre-intervention} = \frac{125}{1530} = 8.2$$

$$\text{Post-intervention} = \frac{36}{1530} = 2.4$$

AC defective days pre and post analysis was respectively = **8.2: 2.4** This is statistically significant at 5 % level (Chi-Square =51.26, df = 1, p<0.0001).

An excellent maintenance management combined with learned and proficient maintenance staff can avoid safety and health issues and environmental harm, yielding longer life to assets with less breakdowns, lower working costs and higher personal satisfaction for users (Matthews, 2017). The lack of appropriate maintenance facilities and prolong downtime of non-medical equipment was the driving force behind this research project. Owing to its high impact and frequency of breakdown, AC maintenance was selected for the project intervention at BHH.

The project was conducted in three phases. To achieve the project objectives quantitative and qualitative techniques were used to assess the maintenance process and practices. Hamilton *et al*. (2018) emphasized that using qualitative techniques with quantitative methods enriched the evaluations, strengthened the scientific integrity and aided in the utilization of implementation science (14). The final implementation project initiatives were developed after assessing the existing mechanism using in KIIs and FGDs with all stakeholders and with reference to literature.

The initial phase was spent studying the current maintenance process and practices and developing the conceptual framework. It was used as a tool for understanding the existing gaps. Frequent breakdowns and undue delays were identified as the major issues by the majority5 of the participants during FGDs and KIIs. The development of effective strategies to address the issues was suggested. According to the participants, non-availability of service agreements, separate maintenance logbooks, maintenance schedules, unavailability a uniform process, poor documentation and supervision; unavailability of trained staff and overall poor knowledge of maintenance complicated these issues as did the non-availability of directives and assigned responsibility for regular maintenance operations.

Table 2. Differences in responses for selected maintenance practices on pre and post intervention.

Selected Variables	**Pre-intervention**		**Post-intervention**		**Statistics**
	N	**%**	**N**	**%**	***Wilcoxon sign rank test***
Attendance to see the faulty equipment without delay					
Rarely	50	(98.0)	03	(05.9)	**p=0.001**
Very Frequently	01	(2.00)	48	(94.1)	
Proportion of time complete the work on timely manner					
Rarely	50	(98.0)	08	(15.7)	**p=0.001**
Very Frequently	01	(02.0)	43	(84.3)	
Current maintenance strategy helps to provide health care to patients on time					
Disagree	51	(100)	4	(07.8)	**p=0.001**
Agreed	00	(0.00)	47	(92.2)	
Current maintenance strategies help optimize the failure rates					
Disagree	51	(100)	07	(13.7)	**p=0.001**
Agreed	00	(0.00)	44	(86.3)	
Usefulness of SOP towards effective maintenance of AC					
Useless	43	(84.3)	04	(07.8)	**p=0.001**
Useful	08	(15.7)	47	(92.2)	
Overall satisfaction level towards current maintenance process					
Unsatisfied	51	(100)	03	(05.9)	**p=0.001**
Satisfied	00	(0.00)	48	(94.1)	
Total	**51 (100)**		**51(100)**		

Intervention was implemented in the form of a SOP to make all relevant stakeholders adhere to existing rules, regulations and procedures with regard to the maintenance management; guidelines, that have been issued periodically as department circulars, guidelines, hospital minutes etc., have been reviewed, revised and simplified. All relevant staff have been trained with emphasis on the importance of following the SOP and why they should adhere to the directions given. Through this SOP stringent adherence to maintenance of log sheets, staff training and an AC service maintenance agreement were signed to facilitate effective maintenance. Further, workshops were arranged with the help of external resource personnel to provide hands on experience on how to use this SOP.

The interventions mentioned above made a significant improvement to the process knowledge, awareness, traceability and satisfaction among staff. Downtime has reduced significantly, after adhering to the "SOP for effective maintenance of split ACs in OT, ICU and LR" (Table 3). This was because the unit's nurse-in-charge was given responsibility for prompt action when there was a breakdown and contractor/maintenance unit had to attend to the job as per the SOP, which cannot be violated by either party. Likewise, the contactor is bound address any breakdowns or complaints as per the service agreement.

Comparison of number of AC breakdown pre- and post-intervention was analyzed using online web-based software. AC defective days pre- and post-intervention were 8.2: 2.4 (125: 36 AC defective days) respectively. This is statistically significant at $p < 0.001$. Downtime has decreased after effective interventions in almost all studies conducted in different parts of the world (8). Because of the use of the SOP, preventive maintenance and written instructions have improved the reliability of equipment in relation to downtime. Furthermore, operationalization of SOP ensured responsibility and legal coverage.

Repeat request for same job has been significantly reduced after the intervention, as maintenance requests made by the nurse-in-charge at any given time needed to be attended immediately (Table 1). Likewise, traceability has significantly improved after allocating separate request books for each AC (Table 1) as per the SOP and these log sheets can be used as excellent source of data for monitoring. However, contacting of maintenance unit quickly and easily was not statistically significant. This may be due to unavailability of intercom communication facilities at the maintenance unit. Staff found it convenient to work with the maintenance unit after the interventions due to increased teamwork, better understanding of responsibilities assigned to each individual and increased morale following the workshops

Table 3. Reduction in downtime.

Pre-intervention		Post-Intervention		P-Value
n	Mean ± SD days	n	Mean ± SD days	0.049
24	5.21±0.832	9	2.33 ± 0.5	

NB: t= 2.048, n= Number of breakdowns

Table 4. Breakdowns completed within 24 hours before and after intervention.

Pre-intervention		Post-Intervention		P-Value
n	%	n	%	0.097
4	16.7	4	44.4	

NB: n= Total number of breakdowns pre-intervention = 24 and post-intervention=9

Attendance to examine the faulty equipment promptly and completing the work in a timely manner has improved due to adhering to SOP and the use of a maintenance service agreement (Table 2). After the interventions, most stakeholders believed that having a written document/SOP improves this process.

Although the percentage of breakdowns completed within 24 hours had improved from 16.7% to 44.4% (Table 4), this intervention was not statistically significant at 5% level. This may have been due to the contractor being not allowed to proceed due to a busy theater or labour room or non-availability of spare-parts at that time (15).

The interventions have given rise to significant improvement of process knowledge, awareness, accessibility, and satisfaction among all stakeholders. The overall satisfaction level towards current maintenance process has improved significantly due to overall process improvement (Table.2).

Therefore, the methodology strategies used in the research project has been shown to be successful in the effective maintenance of ACs, which were the prioritized a “non-medical equipment” at BHH.

The project was confined to selected units of BHH, due to time and resource constraints. Further, the limited time duration between pre and post assessment, the interventional time duration may not be adequate to assess the sustainability and impact of this research project.

IV. CONCLUSION

In conclusion, by developing a SOP and ensuring its use for maintenance activities namely, introduction of maintenance log sheets, signing of AC service maintenance agreement and training has improved the AC downtime and percentage of breakdowns completed within 24 hours and reduced the repeated breakdown of ACs.

Involvement of all the stakeholders in project formulation and implementation has improved their levels of satisfaction with regards to process knowledge, awareness, and traceability.

Project evaluation as measured by the process and outcome indicators have shown that the strategies implemented for the effective maintenance of ACs which were the prioritized “non-medical equipment” at BHH were successful.

Based on the outcome of the project, the following recommendations have been developed for future implementation. The methods and processes used in this project were successful in resource poor setting. Therefore, this methodology could be potentially implemented in other resource poor hospital settings, to improve organizational performance. Additionally, re-evaluation must be undertaken after six months and based on the finding’s necessary adjustments to process and practices must be introduced. The SOP must be reviewed and updated as need to keep up with changes in technology. New training programmes must be conducted in line with the staff turnover for the sustainability of the project. To improve effective communication and expedite response time, an intercom telephone facility will be provided to the maintenance unit of BHH.

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