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Annals of Biological Research, 2012, 3 (5):2248-2254
(http://scholarsresearchlibrary.com/archive.html)

Annals of Biological Research
Scholars Research Library
ISSN 0976-1233
CODEN (USA): ABRNBW

Comparative Study of Procurement, Distribution, Maintenance, and Control of Medical Equipment in General Teaching Hospitals Affiliated with Tehran University of Medical Sciences

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ABSTRACT

The purpose of the present research is a comparative study of the performance of general teaching hospitals in Tehran using the measures of procurement, distribution, control, and maintenance. Six hospitals were selected as population: Imam Khomeini, Cancer Institute, Bahrami, Shariati, Farabi, and Valiasr. First, procurement, distribution, control, and maintenance were examined using t-test and the results indicated that all the criteria except maintenance are in good conditions. Then, significant differences between the demographic characteristics of the managers (age, gender, education, and working experience) were established using chi-square test. Finally, the hospitals were ranked with respect to the studied criteria usingGAHP, TOPSIS, and ELECTRE, and using themoving average method, the results were merged and Imam Khomeini Hospital was selected as the best in terms of performance. Shariati and Bahrami hospitals jointly shared the second position.

Keywords: medical equipment, procurement, distribution, control, maintenance.

INTRODUCTION

Hospital is the most important medical and therapeutic institution since it provides medical and hygiene services with defined scope of responsibility [1]. Hospital is an integral part of a social and medical organization, the function of which is to provide for the population complete health care, both curative and preventive; the hospital is also a center for the training of health workers and bio-social research (World Health Organization). Hospital is much more complex than other manufacturing organizations, for it undertakes medical and health responsibilities that deal with the lives of people, and it must also account for health economics which is different from economic production in important respects [1].

On the one hand, the importance of medical equipment, effective management of such equipment, and advances of this technology in prevention, diagnosis, and treatment of diseases is evident. Without medical equipment, diagnosis and treatment will be done at very basic, insufficient levels. On the other hand, for years extortionate costs have been paid for procurement and maintenance of hospital equipment in the health and medical centers of Iran and the equipment has been largely supplied by foreign countries. This certainly has had negative consequences for the country and necessitates attention, care, maintenance, and proper use of hospital equipment.

Moreover, incorrect use of medical equipment leads to detrimental consequences for the safety and health of the patient, and malfunctioning equipment due to inappropriate maintenance can affect the health of patients and the performance of hospitals. Considering the lack of research in this area, the researcher, who has been working in medical centers and has witnessed the misuse of medical equipment, decided to examine the processes of procurement, distribution, control, and maintenance of medical equipment in general training hospitals affiliated with Tehran University of Medical Sciences, using databases and assistance of experts.

In an effort to rationalize health spending and curb health care inflation, many countries require health planners to evaluate community needs and institute a Certificate of need review programmed, particularly for heavy medical technology. Although Certificate of need programmers were intended to control health care spending by limiting service expansion, many studies indicate that they have not lived up to expectations [2,3].

Problem Statement

The management of a hospital has a grave responsibility, for they are faced with critical conditions which are directly related to the health or, in other words, lives of people (Asefzadeh, 1990). Having enough high-quality medical equipment and experienced personnel for using the devices ensures the success of hospital managers in providing the best medical care and quick diagnostic services to outpatients and inpatients. Medical equipment must correspond to the actual needs of the hospital and its patients. It must also be commensurate to the qualified human resources and must be purchased from creditable sources with appropriate price, and subsequently there must be planning for effective maintenance of medical equipment. The manager of the hospital, the personnel in charge of the equipment, and the department authorities must be familiar with how to choose and purchase armamentaria and to pay attention to the plan for proper distribution, maintenance, and use of the equipment [4].

Unawareness regarding the structure and function of each medical device increases the chance of its misuse and damage to the equipment, which in some cases can injure the patients as well. If the users of these devices have a clear understanding of how to use them, it is possible to avoid malfunctioning due to breakdown of the equipment. Moreover, consultation and coordination of the logistics unit with biomedical engineers and technicians for procuring medical items with less expenditure and more efficiency enhances the effective management of medical equipment.

The main reason for carrying out the present research is that so far there has been no comprehensive, meticulous research on how to properly procure, distribute, maintain, and use medical equipment in the medical centers affiliated with Tehran University of Medical Sciences. Therefore, an understanding of the activity of these centers is essential in promoting the quality of services and increasing the efficiency of the armamentaria available in the hospitals of this large organization.

Control of medical equipment

The medical equipment control plan allows the hospital as well as the maintenance and biomedical engineering unit to organize the management concepts and techniques for controlling complex medical devices that contribute to health and treatment of patients. This plan provides a structure for clinical use of hospital's equipment. Today's advances in medical care are based on technological progress and the medical personnel may require basic technical knowledge along with acquiring medical knowledge and experience in their specialized field. Building on their knowledge and experience while receiving technical information, they will learn how to effectively choose, maintain, and use medical equipment.

In managing medical technologies and equipment, technical support of the operators of medical devices can reduce costs and assist in optimal allocation of resources for the actual needs of the hospital. The quality control of medical equipment ensures that the hospital is providing the best care for patients. The hospital must conduct valid regular tests (safety test, performance test, and adjustment and calibration of the devices). These tasks may be done separately by hospital departments, but the results will be more favorable if the maintenance and biomedical engineering unit is designated with the responsibility.

Advanced safety standards and procedures are used in the control plan of medical equipment (specifically in electrical systems and armamentaria), and this issue is followed up by a committee that is held every month. The components of this plan are as follows:

1. Policies
2. Processes
3. Interdepartmental and external relationships
4. Coordination of engineering operations

In order for the control plan to be effective, it must be created within the organizational structure of the hospital, and it must then be supported by different departments of the hospital. The maintenance and biomedical engineering department is in charge of this plan.

Purchase and procurement of medical equipment

The logistics unit of the hospital is responsible for purchasing, and for the medical equipment to correspond to the actual needs of the hospital, there must be proper connection and coordination between the logistics unit and the maintenance and biomedical engineering department.

Ergonomic design is designing products or services based on the physical and emotional needs of the consumers which are often disregarded. In this method, designers must try to create products that would endow the consumer with efficiency, facility, and joy. Ignoring anthropometric criteria in designing medical equipment can lead to serious problems for the users. As a result of this negligence a device is produced with many errors. In designing a medical device, the design team progresses with the design and interesting ideas are provided by the medical personnel [4].

Sufficient and high-quality purchasing from valid sources within the designated time and with appropriate price is an important issue. Nowadays, patients are treated by hi-techmedical devices(electronic and mechanical) and biomedical engineering department is responsible for using, maintaining, and control ling patient care systems. Thus, this department must be careful in choosing and purchasing the devices. The process and plan for purchasing medical equipment involves three major components:

1. Determining the actual needs for medical equipment
2. Evaluating the place for installing the devices
3. Examining the available medical equipment inside and outside the country.

Planned maintenance

Planning and itemization for the maintenance of medical equipment not only increase the due ability of the devices, but also reduce repair costs and increase the effectiveness and efficiency of the equipment. “Planned maintenance” includes preventive maintenance, scheduled service visit, and regular process of repair (Webster, 1979). The most important factors that push us toward planned maintenance are:

1. Increasing replacement costs of medical equipment
2. Increasing complexity of medical devices, where the volume of maintenance engineering is not sufficient
3. The only way for effective maintenance is to do it regularly and systematically
4. Poor maintenance of medical equipment wastes money and energy.

The planned maintenance system must be clear and comprehensible in which there are adept, experienced personnel with total satisfaction. What makes the planned maintenance successful is belief in the system and presence of personnel who are ready to strive and fight for progress therein.

A successful maintenance plan starts from the designing of the hospital at which point the biomedical engineer calculated the number of devices and the space necessary for installing them taking into account their properties, and provides his or her suggestions to the structural engineer. Further, the success of a maintenance plan entails proper relationships between maintenance and engineering units for radiology, anesthetic machine, and dialysis machine that requirelong-term, constant maintenance. Availability of a reliable local service center must be taken into consideration as the first purchase criterion and the maintenance and biomedical engineering department must determine the initial costs of purchasing medical equipment and estimate their operating costs.

MATERIALS AND METHODS

The present research is applied in terms of its purpose and descriptive-survey in terms of data collection. The population of the research consists of 30 managers of general training hospitals affiliated with Tehran University of Medical Sciences in which there is (or is planned to be) a medical equipment committee and the sessions of this committee are held occasionally and when necessary. These hospitals include Shariati, Imam Khomeini, Cancer Institute, Valiasr, Bahrami, and Farabi. Library method (books, articles, archives, the Internet, etc.)and field method (questionnaire) were used for data collection. The questionnaire included 20 items: procurement (9 items), distribution (2 items), maintenance (3 items), and control and monitoring (4 items).The content validity of the questionnaire was examined. First, a few professors of management were asked for advice and the questionnaires were modified accordingly. Then, 25 questionnaires were distributed among the population and all the shortcomings and ambiguities were resolved. In the end, the final questionnaires were distributed among the entire population of the research. Cronbach's alpha was used for verifying the reliability of the questionnaire. The result was 0.82 which suggests the high reliability of the measurement instrument.

Group Analytic Hierarchy Process (GAHP)
The AHP method is one of the multi-criteria decision making techniques that are used to choose one alternative from a series of choices based on certain criteria. This method provides a framework for cooperation and group contribution in decision making or problem solving [5]. In other words, AHP is an effective tool for structuring and modeling of multi-criteria problems that has been widely used in different management issues [6].

Technique for Order Preference by Similarity to Ideal Solution (TOPSIS)
This technique is one of the compensatory models for multi-criteria decision making that was introduced by Hwang and Yoon in 1981. In this method, malternatives are evaluated using n criteria [4]. The agreement in using TOPSIS for decision making is that the optimal alternative is the closest to the ideal solution and the farthest from the negative ideal solution [7].

Elimination et choice Translating reality (ELECTRE)
This model was introduced in the late 1980's and received much attention as one of the best methods of multi-criteria decision making. This concept is based on "outranking relationships"; that is, this method does not necessarily result in ranking of alternatives, and it may eliminate some of the alternatives [8].

RESULTS

Kolmogorov-Smirnov test
This test was applied to examine the normal distribution of factor scores and the results are presented in table 1.

Table 1 – The results of Kolmogorov-Smirnov test

Variables	Procurement	Distribution	Maintenance	Control
Sig	0.033	0.041	0.029	0.017

The results in table 1 show that the obtained significance values for all the variables are less than the predetermined significance level (0.05). Thus, the normality of factor scores is rejected and non-parametric statistics will be used for data analysis.

T-test
This test was applied to examine the performance of the studied hospitals.

Table 2 – The results of t-test

Variables	$Z_{0.05}$	Z	Result
Procurement	1.645	2.013	Procurement is in a good condition.
Distribution	1.645	2.247	Distribution is in a good condition.
Control	1.645	1.659	Control is in a good condition.
Maintenance	1.645	1.414	Maintenance is in a bad condition.

As can be seen in table 2, the Z-value obtained for the variables of procurement, distribution, and control is more than average. Therefore, it can be concluded that the hospitals are at a desirable level in terms of procurement, distribution, and control of medical equipment.

Chi-square test
The chi-square test was used to compare the demographic characteristics of the personnel of the studied hospitals, and the results are presented in table 3.

Table 3 – The results of chi-square test

Demographic variables	F-statistic	Significance level	Result
Age	2.726	0.000	Significant difference
Gender	4.447	0.000	Significant difference
Education	1.696	0.000	Significant difference
Working Experience	2.204	0.000	Significant difference

As can be seen in table 3, the significance values obtained for different variables are less than the predetermined significance level (0.05). Thus, there is a significant difference between the demographic characteristics of the personnel of the studied hospitals.

4. Ranking the hospitals based on performance

Creating pairwise comparison matrix
Using this technique the performance of the studied hospitals is ranked based on procurement, distribution, maintenance, and control.

Table 4 – The pairwise comparison matrix for the criteria

Matrix	Procurement	Distribution	Maintenance	Control
Procurement	1	2	0.4673	3.6591
Distribution	0.5	1	0.3815	5.1261
Maintenance	2.139	2.6207	1	3.6467
Control	0.2732	0.1951	0.2742	1

The inconsistency rate of the integrated matrix for criteria is 0.0838 and since this value is less than 0.1, it indicates good consistency in comparisons. The weight of each criterion is presented in table 5.

Table 5 – The final ranking of the criteria

Matrix	Procurement	Distribution	Maintenance	Control	Mean	Rank
Procurement	0.26	0.34	0.22	0.27	0.27	2
Distribution	0.13	0.17	0.18	0.38	0.22	3
Maintenance	0.55	0.45	0.47	0.27	0.43	1
Control	0.07	0.03	0.13	0.07	0.08	4

As provided in table 5, maintenance of medical equipment, with a weight of 0.43, is selected as the most important criterion, and procurement and distribution assume the next ranks with 0.27 and 0.22 respectively. Finally, the decision matrix is obtained from the weights of each hospital (alternative) for each of the criteria (according to the mixed pairwise comparison matrix), where the elements of a column are the weights with regard to the criterion for that column. The decision matrix is presented in table 6. In fact, decision matrix is an m×n matrix where the element r_{ij} denotes the value of alternative i (A_i) with respect to criterion j (X_j) (Hwang and Yoon, 1981).

Table 6 – The decision matrix for prioritizing the models

Decision Matrix	Procurement	Distribution	Maintenance	Control
Imam Khomeini	0.044	0.148	0.388	0.201
Shariati	0.119	0.256	0.039	0.336
Cancer Institute	0.179	0.074	0.140	0.089
Valiasr	0.074	0.037	0.065	0.043
Bahrami	0.228	0.383	0.258	0.124
Farabi	0.356	0.102	0.110	0.207

Ranking based on GAHP, TOPSIS, and ELECTRE
The obtained weight of each criteria and the related decision matrix become the basis for multi-criteria decision making techniques. In the present research, the hospitals are prioritized using GAHP, TOPSIS, and ELECTRE. The results of applying the mentioned techniques are presented in table 7.

Table 7 – Ranking of hospitals based on MCDM techniques

Alternatives	MCDM Techniques		
	GAHP	TOPSIS	ELECTRE
Imam Khomeini	1	1	1
Shariati	4	2	2.5
Cancer Institute	5	6	6
Valiasr	6	5	4.5
Bahrami	2	4	2.5
Farabi	3	3	4.5

Moving average method
Considering the fact that at some cases the results of GAHP, TOPSIS, and ELECTRE are inconsistent, integrated techniques are used in order to reach a general agreement regarding the prioritization of the hospitals.

The average rank method
In this method, the alternatives are prioritized based on the mean ranks obtained from different decision making techniques (Momeni, 2008).

Table 8 – Ranking the hospitals with three different methods

Alternatives	MCDM Techniques			Average Rank
	GAHP	TOPSIS	ELECTRE	
Imam Khomeini	1	1	1	1
Shariati	4	2	2.5	2.667
Cancer Institute	5	6	6	5.667
Valiasr	6	5	4.5	4.667
Bahrami	2	4	2.5	2.667
Farabi	3	3	4.5	3.5

Considering the mean ranks (in the left hand panel of table 8), the preference of the hospitals will be as follows:

Imam Khomeini > Bahrami = Shariati > Farabi > Valiasr > Cancer Institute

The result indicates that Imam Khomeini Hospital has the best performance among the studied hospitals and that Shariati and Farabi have jointly assumed the second position.

DISCUSSION AND CONCLUSION

The present research was carried out to examine the performance of general training hospitals affiliated with Tehran University of Medical Sciences, i.e. Imam Khomeini, Shariati, Cancer Institute, Valiasr, Bahrami, and Farabi. First, using Kolmogorov-Smirnov the non-normality of the distribution of the data was established and as a result non-parametric statistics (chi-square test) was applied for data analysis.

The results of average test showed that procurement, distribution and control of medical equipment were in a desirable condition and only the criterion of maintenance was not favorable. Then, chi-square test was applied to examine any significant differences between the demographic characteristics of the population (including age, gender, education, and working experience) and the results suggested the existence of significant differences in all the characteristics. Finally, the hospitals were ranked according to procurement, distribution, maintenance, and control using GAHP, TOPSOS, and ELECTRE [9].

The results from the three techniques were different. Thus, the average ranking of the hospitals was calculated by means of moving average method and in the end Imam Khomeini Hospital was selected as the best hospital in terms of performance, with Shariati and Farabi hospitals jointly assuming the second position. Considering the results, the following suggestions can be made:

1. It is recommended that all the hospitals of the country establish a medical equipment committee so that the issues related to medical equipment will follow a scientific and systematic course.
2. The can be a specialized committee for identifying the priority of needs and purchase of medical equipment so that the procurement corresponds to the actual needs of the hospital and commensurate to the existing human resources. This committee prevents the accumulation of new medical equipment in the storehouses of the hospital and eliminates indulgence in procurement of these devices. This committee must have clear, precise instructions and the representatives of different departments must be selected as its members.
3. A control schedule of medical equipment must be created as one of the most important elements of planned preventive maintenance. The instructional manual of the producers or the service guidebook of the device can be used to create the timetable.
4. The life of medical equipment is definite and it is necessary to plan for replacement and to create the required budget.
5. Implementing the control plan of medical equipment in the hospital and creating a system that incorporates quality control and periodic tests such as safety test, performance test, and calibration can help in reducing the costs of the hospital.

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