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ORIGINAL RESEARCH

Utilization of Failure Mode and Effects Analysis (FMEA) Method in Increasing the Revenue of Emergency Department; a Prospective Cohort Study

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Abstract

Introduction: The balance between revenue and cost of an organization/system is essential to maintain its survival and quality of services. Emergency departments (ED) are one of the most important parts of health care delivery system. Financial discipline of EDs, by increasing the efficiency and profitability, can directly affect the quality of care and subsequently patient satisfaction. Accordingly, the present study attempts to investigate failure mode and effects analysis (FMEA) method in identifying the problems leading to the loss of ED revenue and offer solutions to help fix these problems. **Methods:** This prospective cohort study investigated the financial records of ED patients and evaluated the effective errors in reducing the revenue in ED of Imam Hossein hospital, Tehran, Iran, from October 2007 to November 2009. The whole department was divided into one main system and six subsystems, based on FMEA. The study was divided into two phases. In the first phase, the problems leading to the loss of revenue in each subsystem were identified and weighted into four groups using risk priority number (RPN), and the solutions for fixing them were planned. Then, in the second phase, discovered defects in the first phase were fixed according to their priority. Finally, the impact of each solution was compared before and after intervention using the repeated measure ANOVA test. **Results:** 100 financial records of ED patients were evaluated during the first phase of the study. The average of ED revenue in the six months of the first phase was 73.1±3.65 thousand US dollars/month. 12 types of errors were detected in the predefined subsystems. ED revenue rose from 73.1 to 153.1, 207.06, 240, and 320 thousand US dollars/month after solving first, second, third, and fourth priority problems, respectively (337.75% increase in two years) ($p<0.001$). 111.0% increase in the ED revenue after solving of first priority problems revealed that they were extremely indispensable in decreasing the revenue ($p<0.0001$). **Conclusion:** The findings of the present study revealed that FMEA could be considered as an efficient model for increasing the revenue of emergency department. According to this model, not recording the services by the nursing unit, and lack of specific identifying code for the patients moving from ED to any other department, were the two first priority problems in decreasing our ED revenue.

Key words: Organizational productivity; failure mode and effects analysis method; emergency services; financial management; cost saving

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Introduction:

Balance between revenue and cost of an organization/system is essential to maintain its survival and quality of services (1). Emergency departments (ED) with a large number of annual visits are one of the most important parts of health care delivery system (2-4). Financial discipline of ED can directly affect the quality of care and subsequently patient satisfaction by increasing efficiency and profitability of the department (5, 6). In this context, finding an efficient method for identifying defects and failures, which decrease the revenue and increase the cost, has a high priority. Failure mode and effects analysis (FMEA) is one of the methods for identification and analysis of failures and errors (7-12). Early and continuous application of this method in the process of designing, allows managers to depict failures and reach a reliable, secure and customer-friendly management model (12). The application of FMEA in healthcare systems was first investigated in the 1990s. It was mainly used to avoid errors in medical therapies and became so popular in the second half of this decade (12, 13). Accordingly, the present study attempts to investigate FMEA in identifying the problems leading to ED revenue loss and offer solutions to help fix these problems.

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Methods:

Study design and setting

This prospective cohort study investigated the financial records of ED patients and evaluated the effective errors in reducing revenue in ED of Imam Hossein Hospital (With an average of 4500 visits/month), Tehran, Iran, throughout an about 24-month period, from October 2007 to November 2009. A workgroup (consisting of the head of ED, head of the insurance office, head of the nursing office, and the study researchers), was established to find financial problems and offer solutions. Based on FMEA, the whole department was divided into one main system and 6 subsystems: reception unit, nursing unit, medical unit, secretarial unit, discharge unit, and insurance unit. In order to have a clear view on the defects of each subsystem, data was collected through three main methods. I) regular and focused meetings with the personnel working in the subsystem and compiling defect reports; II) regular meetings with the staff of the next subsystem to identify the problems in the preceding subset based on the analyzed files; and III) random selection and analysis of files by the authors, in the presence of the related personnel. According to the designed protocol, the researchers along with each subsystem's personnel investigated the files and then, gave them to the personnel in the next subsystem. They were asked to find the problems and give suggestions to remove them. The solutions for removing the defects were also clarified with the help of the expert panel in medical economy. In these solutions, the responsibility of each subsystem and the period required to obtain the results were assigned. In addition, a supervising unit was planned to evaluate all parts of the process.

Study Details

The study was performed in two phases:

First phase: In this phase, the defects in the subsystems were detected and prioritized according to FMEA. This phase was carried out during the first six months of the study (October 2007 to April 2008). Each defect was weighed based on its impact on the final product of the system. This weight was called risk priority number (RPN) and calculated through the following formula:

RPN= severity × diagnosis probability × detection degree

Severity coefficient was defined as the impact of the parameter on revenue. According to the probable impact of each defect on the revenue, a coefficient between 1 and 3 was assigned. These assignments were based on: (1) no financial loss even if the defect is continuous, (2) possibility of financial loss because of the present defect and (3) definite financial loss with the continual presence of the defect.

Diagnosis probability coefficient was defined so that the score was 1, if the defect was diagnosed through one method of data collection (mentioned above), 2 if it was diagnosed through two of them, and if all three methods diagnosed the defect, the score was 3.

Detection degree coefficient was defined using the frequency of the defects, so that if incidence of defect was 1 to 10 times per month, the assigned score was 1; 2 was assigned to 11 to 20 times, and if the number exceeded 20 time per month the score would be 3.

Then, defects with RPN> 15 were put into the first priority category; RPN between 6 and 15 into the second priority; RPN 4 to 6 in the third priority; and RPN< 4 into the fourth priority problems.

Second phase: In this phase, discovered defects in the first phase were fixed according to their priority during April 2008 to September 2009. Finally, the impact of each solution was evaluated before and after the interventions.

Statistical analysis

The collected data were put into SPSS 21.0 statistical software and after ensuring that all parameters were normal, the impact of each solution was rated using repeated measures ANOVA test before and after interventions. $p<0.05$ was considered as the level of significance.

Results:

100 financial records of ED patients were evaluated during the first phase of the study. A close evaluation of the revenue of the ED revealed that the average revenue was 73.1±3.65 thousand US dollars per month in the six months of the first phase.

Findings of first phase

12 types of errors were detected in the six predefined subsystems as:

1) Accepting patients with expired insurance credit by the reception unit.
2) Not recording the services by the nursing unit.
3) Lack of coordination between nursing reports and the doctor's prescriptions.
4) Not recording medical procedures by physicians.
5) Incomplete recording of procedures by physicians.
6) Ambiguous outpatient physicians' prescriptions on insurance files.
7) Physicians' prescriptions with no or illegible dates on insurance files.
8) Partial documentation of services by secretarial unit;
9) Lack of final control on patients' files by secretarial unit.
10) Late sending of the patients' files to the discharge unit.
11) Lack of specific identifying code for the patients' files moving from the ED to any other department.
12) Late sending of the patients' files to the agents of the insurance companies.

Table 1: Frequency and priority of errors present in each subsystem ⇧

Subsystem	Error	RPN[1]	Frequency
Reception	Accepting patients with expired insurance credit	6	7 (7%)
Nursing	Not recording the services	27	23 (23%)
	Lack of coordination between the nursing reports and the doctor's prescriptions	4	10 (10%)
Medical	Not recording the medical procedures	12	12 (12%)
	Incomplete recording of procedures	4	8 (8%)
	Ambiguous outpatient prescriptions on insurance files	4	9 (9%)
	Prescriptions without or with illegible dates on insurance files	6	8 (8%)
Secretarial	Partial documentation of services	6	6 (6%)
	Lack of final control on patients' files	4	4 (4%)
	Late sending of the files to the discharge unit	2	4 (4%)
Discharge	Lack of specific identifying code for the patients files moving from the ED to any other department	27	100 (100%)
Insurance	Late sending of the patients' file to the agents of the insurance companies	2	6 (6%)

1. Risk priority number

Table 2: Suggested solutions offered to fix errors based on their priority ⇧

Priority	Error	Suggested solutions
First	1- Not recording the services by nursing unit 2- Lack of specific identifying code for the patients moving from the ED to any other department	1- Close control over the input and output services through the ED's store house 2-Holding the head of the shift responsible 3-Simplification of computer registration in the agenda 4-Assigning a separate section (code) for emergency services in the accounting software
Second	1- Not recording the medical procedures 2- Prescriptions with no or illegible dates on the insurance file 3- Incomplete recording of procedures 4- Accepting patients with expired insurance credit	1- Explaining the direct effects of ED revenue on the personnel's income 2- Rebuking the faulty personnel and reducing their pensions in case there is a problem with the expiration of the insurance or the files sent 3- Similar rebuking or encouragement policies for the department's secretaries 4- Returning the illegible or invalid prescriptions on insurance files to the faculty members for fixing 5- Nursing system is directly responsible for recording the procedures followed by doctors while recording the services 6- Residents' pensions are directly affected by their performance
Third	1- Late sending of the files to the discharge unit 2- Late sending of the files to the agents of the insurance companies	1- Giving the responsibility of sending files of each shift to the secretary of the same shift 2- Coordination between the accounting office and the insurance systems
Fourth	1- Lack of coordination between the nursing reports and the doctors' prescriptions 2- Partial documentation of services by secretarial unit 3- Ambiguous outpatient prescriptions on insurance files 4- Lack of final control on patients' files	1- Random revision of nursing reports with the attendance of the head of the shift and resident 2- Returning prescriptions on insurance files with ambiguous seals to the faculty members for fixing the problems before sending to the insurance unit 3- Controlling the used services of residents by faculty members 4- Controlling the recording of services used by residents while recording the nursing report 5- Promotional and instructional classes for the secretaries for a final control before sending the files to the insurance unit

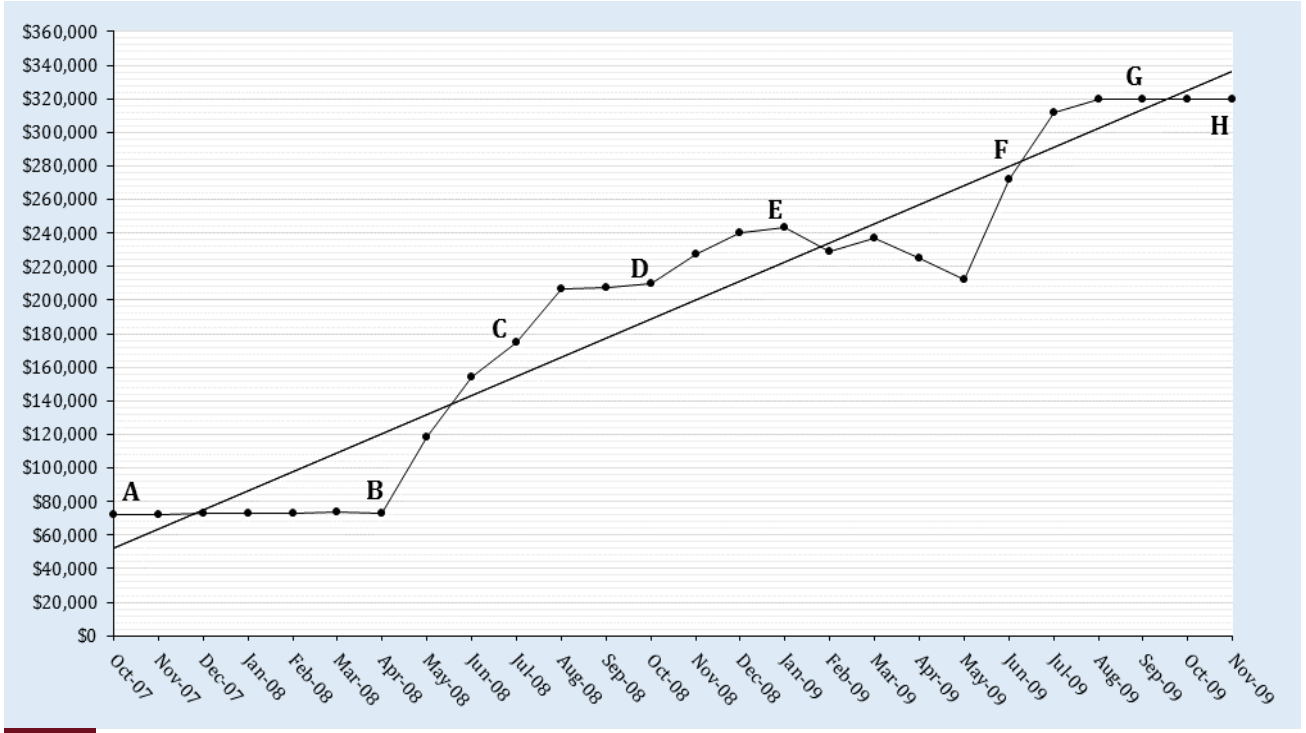

Figure 1: Trend of revenue changes during the study period. A-B: first phase, B-G: second phase (B-C: solving of first priority problems, C-D: solving of second priority problems, D-E: solving of third priority problems, E-F: study temporarily stopped, F-G: solving of fourth priority problems) G-H: two months observation. ⇧

Table 1 demonstrates the frequency and priority of errors in each subsystem. The third subsystem (medical unit) with its four errors has the highest rate of errors.

Findings of second phase

The solutions offered to fix the above-mentioned errors are demonstrated in table 2. The period needed to solve the problems was three months for each priority (sum: 12 months).

First priority problems

Not recording the services by nursing unit and lack of specific identifying code for the patients moving from ED to any other department, were the two first priority problems. Implementing the solutions offered in table 2 raised the ED revenue to 153.1 thousand US dollars per month at the end of July 2008. Repeated measure ANOVA showed a significant increase of revenue (111.0%) during April to July 2008 (df= 1, 7; F= 456.5, p<0.0001).

Second priority problems

Not recording the medical procedures by physicians, physicians' prescriptions with no or illegible dates on insurance files, incomplete recording of procedures by physicians, and accepting patients with expired insurance credit by the reception unit were the four second priority problems. Interventions made according to table 2 induced a great increase in the revenue. At the end of October 2008, the ED revenue rose to be 207.06 thousand US dollars per month. This 35.4% raise was significant as well (df= 1, 7; F= 199.6, p <0.0001).

Third priority problems

Late sending of the patients' files to the discharge unit and late sending of the patients' file to the agents of the insurance companies were the two third priority problems. By solving these problems, the ED revenue experienced a 15.9% increase and reached 240 thousand US dollars per month. This showed a significant difference compared to October 2008 (df= 1, 7; F= 83.2, p<0.0001).

Fourth priority problems

Lack of coordination between the nursing reports and doctors' prescriptions, partial documentation of services by secretarial unit, ambiguous outpatient physicians' prescriptions on insurance files, and lack of final control on patients' files by secretarial unit were fourth priority problems. By enacting the solutions, the revenue experienced a 33.3% increase and reached 320 thousands US dollar per month at the end of September 2009 (df= 1, 7; F= 112.5, p<0.0001).

In summary, ED revenue rose from 73.1 thousand US dollars per month to 153.1 after first priority problems solving, 207.06 after second priority, 240 after third priority, and 320 at the end of the study [(320-73.1/73.1) ×100=337.75%](P<0.001). Maximum increase in revenue occurred after solving first (111.0%), second (35.4%), fourth (33.3%), and third (15.9%) priority problems, respectively. Figure 1 reveals the trend of revenue changes during the second phase of study

period. As figure 1 shows, between the points E and F, the ED revenue reduces and in the mid May 2009, it reaches 211.76 thousand US dollars per month (1, 7;F= 72.6, p<0.0001). This could be explained by a temporarily delay in the study due to closing the trauma department and reduction in the number of the admitted patients. Also, in late November 2009, the revenue did not differ greatly compared to late September 2009 (df= 1, 7; F= 0.11, p=0.74). In these two months of observation, the revenue of the ED was 317.64 thousand US dollars/month (p>0.05).

Discussion:

Findings of the present study revealed that proper management in the financial system and its subsystems is potentially able to change a fruitless entity into a profitable one. Identifying and solving errors in the financial system of the ED in this study increased the revenue by 337.75% in two years. Implementing the solutions rose ED revenue from 73.1 thousand US dollars per month to 153.1 after first priority problems solving, 207.06 after second priority, 240 after third priority, and 320 at the end of the study. 111.0% increase in the ED revenue after solving of first priority problems revealed that the above-mentioned problems were extremely indispensable in decreasing the revenue. Decreasing the admitted patients and closing the trauma department led to pausing the study after solving third priority problems. This could be the reason for the surprising rise in revenue after solving fourth priority problems. Application of FMEA in this study revealed the fact that this system is not only applicable in industrial contexts, but also useful in medical finance and increases the profitability of these systems. The study also demonstrated that FMEA model is an efficient method in recognizing the errors in medical systems. For instance, Sheble et al. using this model, found approximately 100 errors in prescription of antibiotics, and monitored them. They stated that although this method has a high efficiency, healthcare systems should not rely merely on it in order to guarantee their patients' immunity (14). Robinson et al. demonstrated that application of this model decreased prescription of wrong drugs by 9% in chemotherapy patients and increased enforcement of standard procedures by 54%. They believed that computerized registration of the medicine is one of the most important measures that could be taken to elevate the efficiency in the system (15). Kim et al. showed that FMEA model decreased therapeutic errors in children under chemotherapy. They had similar findings and suggested that computerized registration had a positive effect on decreasing errors (16). Wetterneck et al. investigated the efficiency of this model in prescription of intravenous medications and concluded that FMEA is extremely efficient in identifying potential problems (17). Several other available studies demonstrate the efficiency of FMEA in decreasing the error rate in medicine and healthcare systems (8, 18, 19). The authors of the present study failed to find any studies on the efficiency of this model in increasing the revenue or decreasing the loss in healthcare organizations. However, a comparison between the findings of this study and other studies concerning the efficiency of FMEA model and revealed the huge compatibility between them. Similar studies have also demonstrated that application of FMEA optimizes the services offered to patients and increase the efficiency.

Limitation

It could be thought that the difference in the number of the patients increased the revenue in the ED. However, it should be noted that the number of patients did not differ significantly in the study period. On the other hand, there is a 10% increase in tariffs of the healthcare services according to the law enforced by the Iranian Ministry of Health. Because the increase found in this study is far more than the 10% imposed by the government, the authors believe that the reason of increase is the measure taken by authors. Lack of control group was another limitation of the present study. It is recommended that, in future studies, FMEA be used to fix problems in other departments to ensure its reliability and validity.

Conclusion:

The findings of the present study revealed that FMEA could be considered as an efficient model for increasing the revenue in the ED. According to this model, not recording the services by nursing unit and lack of specific identifying code for the patients' files, moving from ED to any other department, were the two first priority problems in decreasing our ED revenue.

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Conflict of interest:

The authors declare that there are no conflicts of interest.

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Authors' contribution:

All authors contribute in drafting/revising the manuscript, study concept or design, analysis or interpretation of data.

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