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 based on FMEA into one main system and six subsystems. The study was divided in two phases. In the first phase, the problems leading to the loss in the revenue in each subsystem were identified and weighted to four groups using risk priority number (RPN), and the solutions for fixing them were planned. Then, at 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 interventions using the repeated measure ANOVA test. Results: At last, 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 thousands US dollar/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 thousands US dollar/month after solving of 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 reveals 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 nursing unit and lack of specific identifying code for the patients’ files, moving from ED to any other department, were the two priority problems in decreasing our ED revenue.

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

Introduction:

The 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 numbers of annual visits are one of the most important parts of health care delivery system (2-4). Financial discipline of EDs, by increasing the efficiency and profitability of department, can directly affect the quality of care and subsequently patients’ satisfaction (5, 6). In this context, the need for an efficient method for identifying defects and failures, decreasing the revenue and increasing 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 the loss of ED revenue and offers solutions to help fix these problems.

Methods:

Study design and setting

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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 teaching hospital (With average number of 4500 visits/month), Tehran, Iran, during about 24 months 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. The whole department was divided based on FMEA into one main system and 6 subsystems of 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 staffs of 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 any suggestion 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 time period required to obtain the results were assigned. Also a supervising unit was planned to evaluate all part of process.

**Study Details**

The study was performed in two phases as follow:

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

\[
RPN = \text{Severity} \times \text{Diagnosis probability} \times \text{Detection degree}
\]

**Severity coefficient** was defined as the impact of parameter on revenue. According to the probable impact of each defect on the revenue, a coefficient was assigned between 1 and 3. These assignments were based on these: (1) no financial loss even if the defect is continuous, (2) the possibility of financial loss in spite of the present defect and (3) definite financial loss with the continual presence of the defect. **Diagnosis probability coefficient** was defined so that if the defect were diagnosed through one method of data collection (mentioned above), the score was 1, if it were diagnosed through two of them, the score was 2, 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, assigned score 1; 11 to 20 assigned 2 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; RPN between 6 and 15 into the second priority; RPN 4 to 6 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 compared before and after interventions.

**Statistical analysis**

The collected data were put into SPSS 21.0 statistical software and after ensuring the normality of the parameters, the impact of each solution was compared using repeated measures ANOVA test before and after interventions. P<0.05 was supposed to be the level of significance.

**Results:**

Finally, 100 financial records of ED patients were evaluated during the first phase of the study. A close evaluation on the revenue of the ED revealed that the average of the revenue was 73.1±3.65 thousands US dollar 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 follow; 1: accepting the patients with expired insurance credit by reception unit, 2: not recording the services by 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 without or with 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, and 12: late sending of the patients’ files to the agents of the insurance companies. **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 were offered to fix above mentioned errors are demonstrated in **table 2**. The time period needed to solve the problems were three months for each priority (sum: 12 months).
Table 1: Frequency and priority of errors present in each subsystem

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

1. Risk priority number

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

<table>
<thead>
<tr>
<th>Priority</th>
<th>Error</th>
<th>Suggested solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td>1- Not recording the services by nursing unit</td>
<td>1- Close control over the input and output services through the ED's store house</td>
</tr>
<tr>
<td></td>
<td>2- Lack of specific identifying code for the patients moving from the ED to any other department</td>
<td>2- Keeping the head of the shift responsible</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3- Simplification of computer registration in the agenda</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4- Assigning a separate section (code) for emergency services in the accounting software</td>
</tr>
<tr>
<td>Second</td>
<td>1- Not recording the medical procedures</td>
<td>1- Explaining the direct effects of ED revenue on the personnel's income</td>
</tr>
<tr>
<td></td>
<td>2- Prescriptions without or with illegible dates on insurance file</td>
<td>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</td>
</tr>
<tr>
<td></td>
<td>3- Incomplete recording of procedures</td>
<td>3- Similar rebuking or encouragement policies for the department's secretaries</td>
</tr>
<tr>
<td></td>
<td>4- Accepting patients with expired insurance credit</td>
<td>4- Returning the illegible or invalid prescriptions on insurance files to the faculty members for fixing</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5- Nursing system is directly responsible for recording the procedures followed by doctors while recording the services</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6- Residents' pensions are directly affected by their performance</td>
</tr>
<tr>
<td>Third</td>
<td>1- Late sending of the files to the discharge unit</td>
<td>1- Giving the responsibility of sending files of each shift to the secretary of the same shift</td>
</tr>
<tr>
<td></td>
<td>2- Late sending of the file to the agents of the insurance companies</td>
<td>2- Coordination between the accounting office and the insurance systems</td>
</tr>
<tr>
<td>Fourth</td>
<td>1- Lack of coordination between the nursing reports and the doctors' prescriptions</td>
<td>1- Random revision of nursing reports with the direct attendance of the head of the shift and resident</td>
</tr>
<tr>
<td></td>
<td>2- Partial documentation of services by secretarial unit</td>
<td>2- Returning prescriptions on insurance files with ambiguous seals to the faculty members for fixing the problems before sending to the insurance unit</td>
</tr>
<tr>
<td></td>
<td>3- Ambiguous outpatient prescriptions on insurance files</td>
<td>3- Controlling the used services of residents by faculty members</td>
</tr>
<tr>
<td></td>
<td>4- Lack of final control on patients' files</td>
<td>4- Controlling the recording of services used by residents while recording the nursing report</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5- Promotional and instructional classes for the secretaries for a final control before sending the files to the insurance unit</td>
</tr>
</tbody>
</table>

1. Risk priority number
- **First priority problems**
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. Implementing the solutions offered in table 2 raised the ED revenue to 153.1 thousands US dollar 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 without or with illegible dates on insurance files, incomplete recording of procedures by physicians, and accepting patients with expired insurance credit by 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 thousands US dollar per month. This 35.4% raise was statistically 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 thousands US dollar per month. This showed a significant difference compared to October 2008 (df= 1, 7; F= 83.2, p<0.0001).

- **Fourth priority problems**
The 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 the four 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 thousands US dollar per month to 153.1 after solving of first priority problems, 207.06 second priority, 240 third priority and finally 320 at the end of study. 111.0% increase in the ED revenue after solving of first priority problems reveals that the above-mentioned problems were extremely indispensable in decreasing the revenue. Decreasing the admitted patients and closing the trauma department lead to pausing the study after solving third priority problems. It could be the reason of surprising rise in revenue after solving of 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 used this model and found approximately 100 errors in prescription of antibiotics and monitored them. They stated that although this method has a high efficiency, healthcare systems ought not to 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 the errors (16). Wetternick 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 study on the efficiency of this model in increasing the revenue or decreasing reduction in the number of the admitted patients. Also, in the late November 2009, the revenue did not differ greatly compared to the 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 dollar/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. Identification and solving of 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 thousands US dollar/month to 153.1 after solving of the first priority problems, 207.06 second priority problems, 240 third priority problems and finally 320 at the end of study. 111.0% increase in the ED revenue after solving of first priority problems reveals that the above-mentioned problems were extremely indispensable in decreasing the revenue. Decreasing the admitted patients and closing the trauma department lead to pausing the study after solving third priority problems. It could be the reason of surprising rise in revenue after solving of fourth priority problems. Application of FMEA in this study reveals 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 used this model and found approximately 100 errors in prescription of antibiotics and monitored them. They stated that although this method has a high efficiency, healthcare systems ought not to 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 the errors (16). Wetternick 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 study 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 revealed that there is a huge compatibility between them, since this model increased and stabilized the revenue in the ED. Similar studies have also demonstrated that application of FMEA optimizes the services offered to patients and increase the efficiency.

**Limitation**

It could possibly 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.

**References:**