DEVELOPING A FRAMEWORK FOR ANALYZING DOOR TO BALLOON TIME PROCESSES BASED ON SELF-ORGANIZING MAP

Narges VAHEDI, Mohammad Mehdi SEPEHRI

Department of Industrial Engineering, Faculty of Engineering, Tarbiat Modarres University, Tehran, Iran

Received: 22.03.2015; Accepted: 29.05.2015

Abstract. Self-organizing networks is a kind of neural network with unsupervised that is very powerful in analyzing complex spaces. Door-to-balloon time is one of the most important criteria for quality evaluation of cardiac patients cure process. Considering that process faster doing of restoring the blood to vessel in patients of severe heart stroke is with reduction of mortality rate, so reduction in door-to-balloon time, the treatment process analysis, quality management and continuous improvement of it are very important. In this research the door-to-balloon time has been investigated by using self-organizing map.

In order to this, getting electrocardiogram (ECG), patient transportation to emergency department (ED) and catheterization laboratory are observed and sub processes are extracted by direct observation, interviewing emergency staff and experts of Tehran Heart Center Cathlab. Using door-to-balloon time of Tehran heart center during 2010 to 2012 it has been shown that 6.5% of patients who referred with acute coronary syndrome are diagnosed STEMI and are treated by angioplasty. The mean of door-to-balloon time of this center is obtained 137.8 minutes with standard deviation of 161.338. Self-organizing network for analyzing process and developing a framework is checked using different levels of process clustering and after identifying processes are presented in order to visualization and analyzing door-to-balloon time workflow. Moreover the method of self-organizing map can provide approximately from simultaneous effect of different therapy levels, obtained results feedback and effective levels identification. Analyzing door-to-balloon time processes based on self-organizing map instead of just paying attention to the average time of treatment and developing a framework for extracting some data about door-to-balloon time are such innovations of this research.

Keywords: Door-to-balloon time, STEMI patient, framework, self-organizing map

1-INTRODUCTION

Cardio vascular diseases (CVD) are the most prominent cause of adult’s mortality in most of countries around the world especially developed ones. According to world health organization (WHO) estimates about 17.3 million people die of CVD. Because of this CVD make burden on society in terms of economic and health; there are a lot of studies about these diseases (WHO, 2005).

During recent decades a lot of attention is given to reducing door-to-balloon time and a lot of studies have been done in order to discover effective factors on it and the result of that includes report, changing and correcting the functional strategies in performing performances by hospitals and medical team. Based on this, there are some guide lines for Physicians and Surgeons of this area that two institutions of America College of Cardiology and the Heart Association of America are pioneers in designing these guide lines. Considering the bottlenecks which are in the path of door-to-balloon time, service providers face increasing the ST segment elevation myocardial infarction or STEMI or the existence of limited resources for presenting better needed services to patients with acute myocardial infarction. Solutions for reducing the cost of operation and time
are optimizing the patient flow in this process, improving the time delays and adjustment and removing existing bottlenecks (Georgieskiy et al, 2007).

In this article a method of visualization and analysis of door-to-balloon time based on self-organizing map has been presented. More over offered method can provide approximately from simultaneous effect of different process levels that the main idea in this area is discovering process patterns.

One of the most important methods of identifying and treating heart artery occlusive disease is done in Heart catheterization laboratory or Cath lab. A set of medical procedures that are done in Cath lab are called catheterization. There are a lot of different surgeries such as angiography and angioplasty in this part.

BACKGROUND
Delay identification causes the increase of efficiency, patient treatment process improvement and lack of hospital, waste of resources in door-to-balloon time and finally will bring the reduction of medical team errors who are in Cath lab and the personnel of emergency. The time increase in every step of angioplasty treatment process is an event that causes the increase of time in door-to-balloon and as result causes the deviation of instructions. In another word each event that causes the path changing of angioplasty treatment and creates waiting for the patient, increases the time of treatment and causes the length of patient staying in hospital (Farwell et al, 2010).

THE DEFINITION OF TIME IN DOOR-TO-BALLOON
Door-to-balloon is a time that starts with patient entering to the hospital and when gets balloon it will finish. The ACC/AHA instructions offer that the time in door-to-balloon will be less than 90 minutes and whatever this time is less the patient gets the angioplasty treatment faster as result, the patient's length of stay will be reduced and finally the rate of mortality will be reduced. The effective factors in door-to-balloon time are divided into below four categories:

1- Patient demographic characteristics
2- Hospital facilities and health care system
3- Features of the medical team
4- The treatment process

Above factors are important because of some reasons:

- They will increase the ability of analyzing effective factors on time in door-to-balloon and increase the accuracy of obtained results which are done by quality assurance agencies.
- They provide the possibility of data analysis in research area considering hospital's conditions and facilities that are studied by researchers who checks door-to-balloon time in quantity point of view.
- For reducing the time of door-to-balloon we have to improve the smallest delays as well, to be able to save each step of time process. Whatever the mean in door-to-balloon decreases, the percentage of patients that their door-to-balloon time is less than 90 minutes will decrease (Pelletier, 2009).

---

1 It includes cases such as diagnosis of disease by emergency physicians in front of cardiologists call and arranging Cath lab team in normal day hours and night shift and also holidays.
Developing A Framework For Analyzing Door To Balloon Time Processes Based On Self- Organizing Map

THE IDENTIFICATION OF THE LEVELS OF TREATING METHOD IN DOOR-TO-BALLOON TIME

There are different factors that able us to analyze delays in door-to-balloon time. Some of these factors depend on the first place of medical call, so the tool and path which patient uses to be transferred into clinics can be the determining factor in attributed delay analysis to primary angioplasty. Moreover according to published reports recent years, the patients who enter hospital during quiet hours are exposed more delay in primary angioplasty. Figure 2-1 shows the general divisions for the time of acute myocardial infarction (Leor et al, 2011).

Figure 2-1. The general division of acute myocardial infarction.

Considering that whole door-to-balloon time are considered considering ACC/AHA recommendation maximum 90 minutes, Feng et al, 2009 consider below main seven levels for door-to-balloon time that we can see these levels in picture 2-2.

Figure 2-2. The different levels of time processing door-to-balloon.

It is noticeable that Belinda B. Hammond et al, 2009 and Farewell et al, 2010 also have studied similar divisions for this treating process. Considering ACC/AHA instructions and done researches base on them, we can mention below cases for explaining above process different levels:

The first phase of getting ECG: existed solutions recommend that ECG must be gotten during the first 10 minutes of patient entry to hospital.
**The second, third and fourth phases or making decisions and STEMI diagnosis:** in some hospitals emergency physicians that consult with cardiologists before activating Cath lab to be able to make decisions and diagnose.

**The fifth phase or activating Cath lab:** many Cath labs don’t have enough personnel in 24 hours so the time of preparation Cath lab has the direct relationship with STEMI detection hour. Wang et al, 2009 believe that door-to-balloon time is significantly long in 7 a.m. and 5 p.m. and also weekends and has a delay with average 23 minutes.

Considering these results, ACC/AHA believes that only 4.2% of patients who are transferred to health centers with angioplasty equipment can have door-to-balloon time 90 minutes maximum.

**The sixth and seventh phases or the process of surgery and getting balloon:** the thing that seems in this phase is related to needed equipment for surgery. If tools such as catheter, guide wire … are easily available, surely the big part of delays detection will be prevented. On the other hand this phase has a lot of dependency to on time presence of all Cath lab team people and if each one of them delays for operation, door-to-balloon time will delay.

**DOOR-TO-BALLOON TIME REDUCTION SOLUTIONS**
Bradly et al in a research identified 6 solutions as the most effective solutions in 2006:
- Activating Cath lab by emergency doctor (average reducing 8.2 minutes)
- The system of activating Cath lab and the presence of medical team just with one call (average reducing 15.4 minutes)
- The presence of Cath lab medical team in hospital in maximum 20 minutes from paging them by pager (average reducing 19.3 minutes)
- Always being ability of cardiologist (average reducing 14.6 minutes)
- Being available of medical personnel in medical emergencies and using data by Cath lab and real time information (average reducing 14.6 minutes)

**THE STANDARDS OF DOOR-TO-BALLOON TIME PROCESS**
Elizabeth Kelley et al 2010, extracted standards for different treating levels through, 6 sigma method for reducing the door-to-balloon time which are summarized in table 2-8.

**Table 2-5.** Standard times for different steps in door-to-balloon time.

<table>
<thead>
<tr>
<th>The main step of process</th>
<th>Standard Time (min)</th>
<th>Detailed description of process</th>
<th>Standard Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emergency Department</td>
<td>15</td>
<td>Door to ECG</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BCG to Call</td>
<td>5</td>
</tr>
<tr>
<td>Call the Cath lab</td>
<td>10</td>
<td>Call to Decision</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Decision to CCL Notification</td>
<td>5</td>
</tr>
<tr>
<td>Patient transfer</td>
<td>25</td>
<td>Notification to Arrival</td>
<td>25</td>
</tr>
<tr>
<td>Coronary intervention</td>
<td>40</td>
<td>Arrival to Arterial Access</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Access to Completion of Diagnosis</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diagnosis to Intervention</td>
<td>15</td>
</tr>
</tbody>
</table>
Developing A Framework For Analyzing Door To Balloon Time Processes Based On Self-Organizing Map

With studying different articles that are mentioned in table 2-6, table 2-8 presents the most complete timing for standard door-to-balloon time and these values will be used in checking the data of Tehran Heart center.

CHECKING THE STATUS QUO

Tehran Heart center is a specialized hospital of cardiology and opened in February 11th 2002 with Tehran University of Medical Sciences management and educational-scientific supervision. This hospital after Rajaei heart center is considered as the second specialized cardiology hospital in Tehran. This center with 500 fixed beds that 250 beds are equipped to Cardiology monitoring device, is one of the most equipped centers of treating and diagnosis of heart and vessels in area. This center includes 4 sections of normal hospitalization, four sections of CCU, Emergency, ICU Cardiac two parts, two parts Post ICU, Cath lab, the recovery, the patients VIP, Research Division. Para clinical facilities of this center are Angiography, radiology, laboratory, physiotherapy. During past 10 years in this center more than 1133162 patients in outpatient appointments have been visited and 179312 patients were hospitalized and more than 41343 open heart surgeries are done. Also there have been more than 120561 cases of angiography and angioplasty and 259830 Eco.

INTRODUCTION OF PRIMARY ANGIOPLASTY TREATING PROCESSES IN TEHRAN HEART CENTER

For knowing the processes of Tehran heart center, in first phase processes and their relationships and also their relationships with other sections were determined by direct observation and interviewing Cath lab head nurse, triage nurse and doctor of fellowship. Performing process of primary angioplasty can be divided into 3 different sections, so that all patients that are exposed to primary angioplasty operation do these levels: before operation (Diagnostic care in emergency), during operation (in Cath lab), after operation (Transferring the patient to recovery and post-operative care). Below figure shows these levels:

![Diagram](image)

**Figure 3.1.a**. the primary angioplasty process in different sections of Tehran heart center.

Each patient after doing reception steps in triage if their STEMI is confirmed by triage nurse will be transferred to CCU till be visited again by fellowship assistant. In this phase patients’ ECG is checked again and his clinical signs are recorded and in case of need for improving patients situation relevant drugs are given to him. If after the permitted waiting period, patient’s STEMI is confirmed, it will be reported to on call professor. At the same time Cath lab nurse will be informed to prepare Cath lab for transferring patient. Cath lab must be prepared at the least possible time. In cases that Cath lab is prepared faster than patient, patient will be taken to Cath lab and his preparation will be done there.
Cath lab team includes fellowship, resident, nurse and on call professor who come Cath lab for operating. After accessing to the artery, heart is taken picture from different angels and in a definitive diagnosis, stent will be used. As it seems after balloon dilatation, the operation place will be closed and patient will be ready for exiting Cath lab and entering Recovery.

Figure 3.1.b. performing algorithm of primary angioplasty in Tehran heart center.
Developing A Framework For Analyzing Door To Balloon Time Processes Based On Self-Organizing Map

Figure 3.2. The treating patient process in emergency till patient transferring to Cath lab.
COLLECTION AND ANALYSIS OF INFORMATION

Relevant information to processes recognition and framework extracting of time investigating door-to-balloon are done by referring to the hospital and observing different steps of implementation of treatment.

In Tehran heart center for collecting data a form is used that this database includes 220 patients with acute myocardial infarction. The number of data collection variables is 74. This form is designed for recording the information of patient with acute myocardial infarction time and includes 3 sections of clinical signs of patient at the time of referring, used strategy for patient treating and prescribed drugs. In first section some information such as the onset of chest pain,
Developing A Framework For Analyzing Door To Balloon Time Processes Based On Self-Organizing Map

when in contact with emergency / referring to emergency departments, the Transferring to the hospital, the time of Getting ECG, receiving first medical examination, the average time to Transferring the patient to hospital admission after treatment of systolic and diastolic pressure, heart rate and other causes of angina pectoris are recorded. Considering demographic characteristics only age and patient gender are recorded in this collection. For analyzing the time of processes and obtaining the average door-to-balloon time we need duration of getting the patient's ECG, the first medical examination, transferred to special care and operation of emergency angioplasty that these variables are extracted among 74 mentioned variables.

DATA PREPARATION

Among data features, relevant features to processes time and prehospital delay are selected and all are converted to minute. First the relevant features to the patient entry time to each phase of process is prepared as the beginning time of process and then the distance between both two steps is calculated based on minute and the length of doing each one was clarified.

REMOVING OUTLIERS AND BALANCING DATA

After building all considered characteristics for processes segmentation, the diagram of distribution processes against each other are observed in figure 4-1.

![Figure 4-1](image)

Figure 4-1. The matrix of distribution diagram of processes against each other.

Using above picture 6 of data that were more distant than others are checked. Most of features in these data had more value $3\sigma$ than mean so they were removed from collection.
CHECKING DATA DISTRIBUTION

Table 4.1. Shows the descriptive statistics relevant to all these variables.

<table>
<thead>
<tr>
<th>Time of stay in the center (day)</th>
<th>Time of Cath lab (min)</th>
<th>Time of getting first medical Contact (min)</th>
<th>Time of getting ECG (min)</th>
<th>Patient pre-hospital delay (min)</th>
<th>Time of transfer to the center (min.)</th>
<th>Chest pain duration (minutes)</th>
<th>Patient age (years)</th>
<th>Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.37</td>
<td>79.94</td>
<td>18.34</td>
<td>40.04</td>
<td>460.67</td>
<td>49.9</td>
<td>75.5</td>
<td>57.79</td>
<td>Average</td>
</tr>
<tr>
<td>4</td>
<td>40</td>
<td>13</td>
<td>39</td>
<td>357</td>
<td>45</td>
<td>0</td>
<td>56</td>
<td>Middle</td>
</tr>
<tr>
<td>25.289</td>
<td>2092.423</td>
<td>421.227</td>
<td>1570.06</td>
<td>12294.53</td>
<td>962.5</td>
<td>03.31968.03</td>
<td>147.963</td>
<td>Mode</td>
</tr>
<tr>
<td>46</td>
<td>990</td>
<td>110</td>
<td>286</td>
<td>1400</td>
<td>237</td>
<td>780</td>
<td>61</td>
<td>Domain</td>
</tr>
</tbody>
</table>

FRAMEWORK DESIGN

In the first phase, the number of clusters considering identified boarders is in matrix U and different features values are in output map. The first and second variables are age and gender of patients. The third one is the kind of cardiac disease and forth to seventh are related to the time of their treating in different levels of treating method.

In second phase, patients STEMI that are treated by primary angioplasty data that are extracted among all data and considering patients’ age and gender the time of processes in the map of first to seventh variables are analyzed. Matrix U and matrix of similar clustering of different stages of the treatment process are shown in figure 4-7.

Figure 4.6. The self-organizing plan of patients with acute coronary syndrome.
Developing A Framework For Analyzing Door To Balloon Time Processes Based On Self-Organizing Map

Figure 4.7. Matrix U and the values of all features in nodes in clustering without processes supervision.

Considering figure 4-7 if we consider below order for variables’ title:
V1: patient age, V2: patient gender, V3: Duration of transmission the patient to the center (min.), V4: prehospital delay, V5: the duration of getting ECG (min.), V6: the duration of first diagnostic examination (min), V7: the duration of Cath lab (min).

Then we can deduct below scenarios from above maps:
Men are suffering from acute myocardial infarction more than women and their Cath lab time also is more.
Older people’s ECG taking, first diagnostic examination and the time of Cath lab need less time.
Whatever the time of getting ECG increases, the time of first diagnostic examination will increase as well.
Prehospital delay is more in men than women.

Considering done researches, we can divide the factors that cause delay in getting ECG to factors such as Personnel, capacity, space, triage processes, open beds in the emergency department, the patient’s symptoms, a lack of ambulances, emergency communication tools, the lack of beds, false diagnosis, the process of admission, the patient’s lack of alertness, disorder in ECG machine … .

The factors that cause delay in Cath lab preparation and diagnosis cramps are Sector capacity, the patients with suspicious symptoms, personnel, delays in the ECG, the delay in getting the report of ECG, ECG machine shortages, improper preparation of Cath lab, clinical symptoms, emergency nurse patient triage, decision-making and identify the professor, read the report by Master, a change in the patient’s condition, emergency communication tools … .

The factors that cause delay in door-to-balloon time are ECG misdiagnosis, delays in triage patients, the incidence of myocardial infarction in the sector, delay in obtaining the electrocardiogram, equipment and … .

Considering above cases we can offer below framework for processes time investigating and analysis of different phases.
Next considering offered framework and reviewing research background we can offer the following corrective solutions considering extracted scenarios.

<table>
<thead>
<tr>
<th>Hospital solution</th>
<th>Explain</th>
<th>Needed tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>Getting prehospital ECG</td>
<td>using prehospital ECG by emergency services and activating Cath lab in the path of patient transfer according to the result of ECG</td>
<td>ECG taking instruction, Activating Cath lab instruction</td>
</tr>
<tr>
<td>Patient priority and fast performing of ECG in emergency</td>
<td>Direct transferring to Cath lab by emergency services in using prehospital ECG</td>
<td>Cooperation and team people spirit</td>
</tr>
<tr>
<td>Activating Cath lab by doctor</td>
<td>The request of activating Cath lab and its team by emergency physicians</td>
<td>Cath lab activation instruction</td>
</tr>
<tr>
<td>Activating Cath lab only one time Calling team</td>
<td>Creation of single read for activating Cath lab team</td>
<td>Personnel workshop</td>
</tr>
<tr>
<td>The fast presence of Cath lab team in hospital</td>
<td>Fixing conditions that according to that group members will be ready for patient reception in 20 or 30 min.</td>
<td>Timing work flow during the day and correct timing of weekly plan of staff, Needed standards definition for personnel and using equipment during quiet hours</td>
</tr>
<tr>
<td>Macro management obligations</td>
<td>Organizational support through macro management for doing organizational developments that their goal is optimizing the duration of using balloon as soon as patient entry to hospital</td>
<td>Management development plan</td>
</tr>
<tr>
<td>Personnel commitment and group work</td>
<td>Focus on methods depending on group work that presents continuous care from the ambulance arriving till balloon dilatation</td>
<td>Training and guiding about continues quality improvement</td>
</tr>
</tbody>
</table>
CONCLUSION

One of the most important achievements of this research is men potential for having more than 90 minutes door-to-balloon. From the other factors Old age, prolonged prehospital delay, the length of the patient’s ECG and length of the first medical examination can be mentioned that whatever these times are more the time of balloon dilatation and as result door-to-balloon time will increase as well. Therefor in facing patients who have one of mentioned conditions, predicting the length of treatment and the patient’s length of stay considering study variables of this research can help medical team and Cath lab personnel in correct making decision for managing sector capacity.

Whatever time interval of predicting door-to-balloon time is wider and the number of available variables for predicting more we can do more constructive actions in order to their reduction. More over below diagram can be considered as relationship among solutions and effective factors on door-to-balloon time:

![Diagram](image)

**Figure 5.1.** The relationship among solutions and effective factors on door-to-balloon time.

Using self-organizing map in order to investigating door-to-balloon time of study hospital can be considered as the most important innovation. Although in subject literature of processes in angioplasty treating has been researches desire but using data mining methods especially clustering and SOM techniques are not paid attention.

Although offered suggestions for improving in terms of economic are affordable, but management or obtained improvement will be ready to spend necessary expense for better efficiency of its management. As result for performing this research results it is needed to place expenses criteria in offered solutions and then implement research results in catheterization and emergency department.
The most important problems that we faced in this research are:

Time-consuming to identify current processes in door-to-balloon of Tehran heart center and its comparison with executive algorithm adopted in the emergency department and catheterization

Time consuming to collect each process time data

Not familiar with specialized expression in health area and cardiac diseases especially acute coronary syndrome

The limitation of data for modeling recorded information by center emergency

SUGGESTIONS FOR FUTURE RESEARCHES

The most important suggestions in here are:

Using other function scales like expenses criteria for processes evaluation

Simulating and identification of available processes for the physicians, nurses, equipment, tools and materials in treating method and evaluating available solutions addition to checking patient in door-to-balloon

Investigating the reduction solutions priority based on weighting effective factors on door-to-balloon time

Investigating systematic and non-systematic problems and the way of their effectiveness on length of door-to-balloon time

ACKNOWLEDGMENT

We appreciate Tehran hear center personnel in achieving relevant results in this research especially Dr. Aghajani because of his useful information.

REFERENCES


Developing A Framework For Analyzing Door To Balloon Time Processes Based On Self- Organizing Map


[10] 921


[25] 992

Developing A Framework For Analyzing Door To Balloon Time Processes Based On Self-Organizing Map


