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Computer-simulated assessment of methods of transporting severely injured individuals in disaster—Case study of an airport accident

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ARTICLE INFO

Article history:
Received 7 April 2005
Received in revised form 24 July 2005
Accepted 12 August 2005

Keywords:
Emergency medical care
Computer simulation
Priority order of transport
FIFO
Subgroup sorting
Triage

ABSTRACT

A system utilizing computer simulations was developed in order to compare (1) situations wherein critically wounded individuals are, at first, ranked and classified into subgroups based on criticalness of the wounds, and then be evaluated and re-ordered within the subgroups before transported to hospitals, with (2) those situations in which the conventional method of transport was employed. The objective of the study is to infer whether there is a further possibility for enhancing the possibility of the wounded individual's survival rate at the time of arrival at the hospital. The variables that are required to be entered include the number of patient subgroups, the number of patients in each of the subgroups, the total number of patients to be transported, the time required to assess the severity of each patient, the speed of the ambulance, the interval between the ambulances' arrivals and departures, and the distance between the site at which the transportation begins and the destination or the hospital. Utilizing the same system, a virtual simulation of a large-scale disaster at airport was used as sample data. As a result, it was confirmed that the survival rate would improve under certain conditions, if the values for some of the variables, such as geographic conditions, were altered and then calculated.

1. Introduction and objectives

It is generally expected that the transportation of patients based on the level of severity, which leads to early launching of proper operation/treatment, will bring about better prognosis. Because of the fact that occurrences of disasters are relatively infrequent, computer simulations prove to be one of the effective methods for analyzing such events. Among the studies applying computer simulations for disaster situations include, for instance, a study, involving workflow model, conducted by Ohboshi et al. [1]. The objective of the program utilized in this study is to see whether devising how patients are transported, such as through optimizing the transporting sequence of patients based on severity, would result in better prognosis. In this virtual model, the survival rate or life-saving rate was treated as a dependant variable for the time it takes to arrive at the hospital, and calculations to estimate the rate at the time of arrival at the hospital were made based on an approximation curve. Usually, a group of severely wounded patients is assessed and divided into different subgroups through the process called triage. In this study, however, a computer simulation system was developed, so as to shorten the time it takes for more critically wounded patients, in need of more

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0169-2607/$ – see front matter
doi:10.1016/j.cmpb.2005.11.014

urgent care, to arrive at the hospital through more precise prioritization. This system allows for adjustments of various parameters, as well as analyses of the impact such changes in conditions may have on the optimization of the sequence or order of patients' transport. For instance, the variables include the time it takes to assess the severity of the condition of each patient, the speed of the ambulance, the interval between the arrival and departure of the ambulance(s), the number of available hospitals, and the geographic condition surrounding the destination/hospital. The system also allows for quantitative analyses to see whether there is a possibility for improving the average survival rate or life-saving rate of the entire patient group, based on the survival curve. In addition, using this system, some sample data were tested for simulations. The results are presented and discussed herein.

2. Design considerations

2.1. First In First Out (FIFO) and subgroup sorting (SGS) methods

In the conventional method of patient transport, those patients determined by triage to be the top priority are the first ones to be transported. This is similar to the method of data array processing, also known as first in and first out. In this paper, the conventional transport method is referred to as the FIFO method. On the other hand, re-sequencing of the order of patient transport, as considered here, is equivalent to sorting of data arrays. That is, first, the survival rate of each patient was calculated; and the data were sorted, and the patient with the lowest survival rate goes first. The method of assigning transport priority based on the severity of each patient, as used in this study, is referred to as the subgroup sorting method, since, in real situations, the triage officer would divide the patients into smaller subgroups, and then prioritize them (Fig. 1).

2.2. Setting the time it takes for the patient to reach the hospital (pre-hospital time)

In this model, the efficacy of transporting severely wounded patient changes with the passage of time. There are uncertainties in disasters. For example, the time it takes to go through the outbreak of a disaster, successful rescues of the wounded patients, and the start of transporting activities are generally uncertain. These are influenced by such factors as the size, location, and time of the disaster, in addition to fire extinguishing and life-saving activities that take place at the site. It is also possible that rescue activities may proceed simultaneously with medical first aid. In this study, the pre-hospital time is defined as the time stretching the start of severity assessment at the first aid station in the site of disaster and the arrival of the patient at the hospital. In other words, the pre-hospital time is the sum total of the time it takes to assess the severity of each patient, the time that passes before being on the ambulance, and the time that is spent in the ambulance, all the way to the arrival at the hospital. The time spent in the ambulance until the arrival at the hospital is calculated by dividing the distance between the site of disaster and the hospital by the speed at which the ambulance heads for the destination, that is, the hospital. If the wait time after severity judgment until the start of transport on ambulance for the patient in the nth place in line is denoted by $\mathrm{Tw}(n)$, $\mathrm{Tw}(n)$ is obtained by multiplying $(n-1)$ by the interval between two ambulance departures. Therefore, the pre-hospital time, $\mathrm{Tp}(n)$ (unit in minute), for the severely injured patient transported in the nth place is given by Eq. (1), as shown below. The time required to assess the severity of each patient before re-arrangement or sorting is denoted by "the time for evaluation".

$$\mathrm{Tp}(n) = \text{the time for evaluation} + \mathrm{Tw}(n) + \text{time spent on ambulance} \quad (1)$$

2.3. Time course of life-saving rate and other indicators

The life-saving rate was set as an indicator to assess the efficacy of transport for severely wounded individuals. The life-saving rate upon arrival at a hospital of a severely injured patient who is transported in the nth place, $\mathrm{Lsr}(n)$, is a function of $\mathrm{Tp}(n)$. $\mathrm{Lsr}(n)$ takes values between 0 and 1 inclusively. It was postulated that the life-saving rate right before the breakout

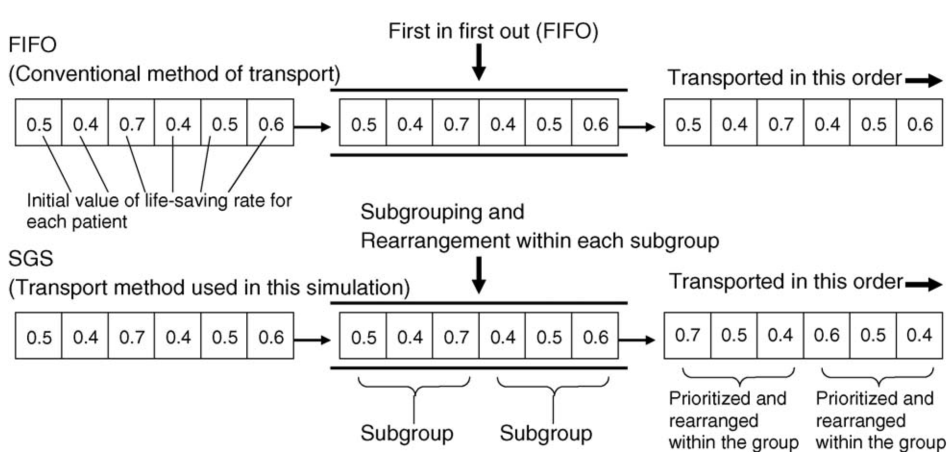

Fig. 1 – Optimization of the order of patient transport by re-arrangement compared to conventional methods (SGS—subgroup sorting method).