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A simulation analysis of the impact of FAHP–MAUT triage algorithm on the Emergency Department performance measures

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ABSTRACT

Emergency Department (ED) crowding is a major problem in the U.S. like in many other countries worldwide. This problem is adversely affecting the safety of the patients who rely on receiving a timely treatment in EDs. As a part of solving this problem, a triage process is utilized. Triage is a pre-hospital process by which patients are sorted according to the severity of their illnesses or injuries. Improvements to this process would affect the patient flow positively, and in turn would enhance patient satisfaction and quality of care. In a previous study, we developed a triage algorithm that uses Fuzzy Analytic Hierarchy Process (FAHP) and Multi-Attribute Utility Theory (MAUT) to rank the patients according to their characteristics: chief complaint, age, gender, pain level, and vital signs. The main purpose of this study is to compare two triage systems using Discrete Event Simulation (DES); one system uses the typical Emergency Severity Index (ESI), and the other uses the FAHP and MAUT algorithm. Overall, there was no strong statistical evidence that either system would do better than the other for all the performance measures when the average is taken across all ESI levels. On the other hand, the collected simulated data by each ESI level showed that the FAHP–MAUT algorithm tends to balance the time-to-bed (TTB) and length of stay (LOS) for ESI levels 2–5. In terms of the percentage of tardy patients, FAHP–MAUT system significantly outperforms the ESI system for ESI levels 4 and 5; 34% vs. 61% and 25% vs. 70%, respectively. Both systems were performing about equally for ESI level 1 and level 3 patients; 25% vs. 26% and 64% vs. 67%, respectively. While ESI system slightly outperforms FAHP–MAUT system for ESI level 2 patients, 56% vs. 66%. Based on these results, we recommend using FAHP–MAUT not only because it performs better in terms of minimizing the number of patients with longer than the allotted upper limits of wait times, but also it reduces potential bias and errors in decision making in clinical settings; and thus, it can be used as the basis of an expert system to advise triage nurses.

1. Introduction

Emergency Department (ED) is a healthcare facility that provides medical treatments for patients with usually acute injuries or illnesses who come to the department without prior appointment, by either themselves or by ambulance. ED setting is unique in that patients arrive to ED without planned appointments, with various injuries or illnesses, with various health insurance plans or even without insurance. Some of these patients come with life-threatening status, and thus need immediate treatment, while others come with non-urgent status and can wait. In US, EDs are considered as vital components of the nation's health care safety net (Richardson & Hwang, 2001), which are responsible for 45–65% of hospital admissions (Mahapatra et al., 2003).

EDs in most hospitals operate 24/7. In 2006, there were 119.2 million visits to EDs (Pitts, Niska, Xu, & Burt, 2008). Fig. 1 shows the trends in ED visits, number of hospitals, and the number of EDs in the US. (Kellermann, 2006). As observed in the figure, during the period from 1994 to 2004, although ED visits have increased by 26%, the number of EDs has decreased by 9%, and the number of beds in the hospitals has been reduced by 198,000 beds (Kellermann, 2006).

Emergency rooms are extremely complex. Complexity in health care settings, such as Operating Room (OR), Intensive Care Unit (ICU), and Emergency Room (ER), is obvious not only in the patient and treatment protocols, but also due to the high level of automation and instrumentation, huge volume of information, and interdisciplinary coordination that is necessary (Christian et al., 2006). Many U.S. EDs are exceedingly busy or crowded; thus, they are characterized with increased service pressures, which prompt researchers to study the complexity and inefficiency factors of the ED system and the ED-hospital interfaces (France & Levin, 2006).

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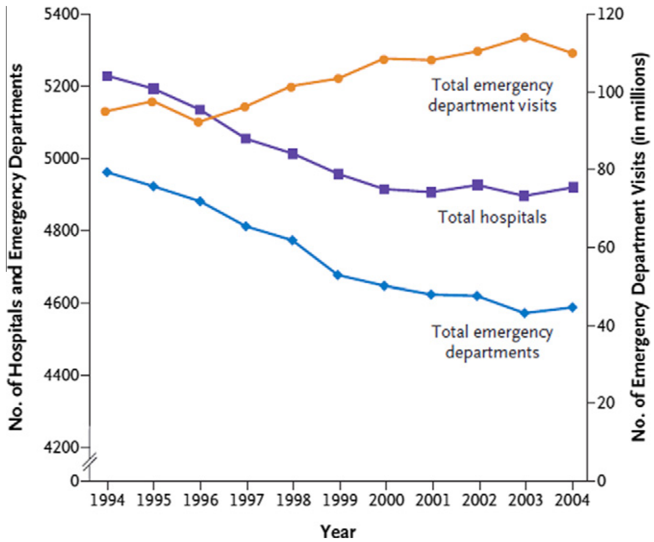

Fig. 1. Trends in Emergency Department Visits, Number of Hospitals, and Number of Emergency Departments in the United States, 1994–2004 (Adopted from Kellermann, 2006).

Every minute in the ED can make a big difference for patients. EDs usually implement a triage algorithm to assign a priority level for the coming patients. Triage is a pre-hospital process by which the triage nurse sorts the patients according to the severity of their illness or injury. The purpose of the triage interview is to place the patient in one of several queues, each having an associated maximum time until the patient sees a physician (Guterman, Mankovich, & Hiller, 1993).

In this paper, we present our investigation of the impact of using the Fuzzy Analytic Hierarchy Process (FAHP) and Multi-Attribute Utility Theory (MAUT) triage algorithm, and compare the ED performance measures under the conditions of using the aforementioned algorithm and the widely used Emergency Severity Index (ESI) algorithm. As explained later in the paper, although widely used, the ESI algorithm heavily relies on the judgment of the triage nurse, whereas the FAHP–MAUT triage algorithm makes use of quantitative triage knowledge in arriving at patient prioritization, and thus, if FAHP–MAUT algorithm is found to perform as good or better in realistic conditions, it will be conceivable to develop an expert system to aid nurse decision making. With these thoughts, we compare the algorithms based on system performance measures, i.e., time-to-bed (TTB), length of stay (LOS), throughput, time in ER, and percentage of tardy patients.

The paper is organized as follows: Section 2 describes the findings of key papers from the pertinent literature. Section 3 presents the problem and the methodology that was followed to draw our conclusions. Section 4 shows the experimental design and the results. Section 5 summarizes the findings.

2. Literature review

One of the most commonly used triage systems in the US, the five-level Emergency Severity Index (ESI), sorts the patients into five clinically distinct groups. These five levels are different with respect to resource and operational needs (Gilboy, Tanabe, Travers, Rosenau, & Eitel, 2005). The most acutely ill patient gets ESI level 1 (the highest acuity level), or 2. The ESI levels 3, 4, and 5 (the lower acuity levels) are assigned based on the number of needed resources (Gilboy et al., 2005). The algorithm flow chart is provided in Fig. 2. For example, a patient with ESI level 1 or 2 could be taken immediately to the treatment area, while patients with ESI levels 3, 4, or 5 can wait (Gilboy et al., 2005). During triage process, the nurse records the patient's vital signs as well as all the information about his/her current illness, past medical history, and any other needed information such as allergies and immunization status. Then, the nurse decides whether the patient needs immediate evaluation and treatment or he/she can wait (Claudio & Okudan, 2010).

Several attempts have been made to improve the ED care services, such as minimizing waiting time intervals and improving patient satisfaction (Spaite et al., 2002). Others have focused on developing a reliable decision support system in order to improve the patient waiting times and service quality problems (Mahapatra et al., 2003), and developing expert systems to aid the triage nurse in assigning patient's category (Padmanabhan et al., 2006), etc. The challenge in triage for nurses is to prioritize and rank non-urgent patients in order to recognize who is most in need of care (Claudio & Okudan, 2010). Some hospitals in the US use a three-level triage, which sorts the patients based on the question: "How long can this patient wait to be seen?" (Mahapatra et al., 2003). On the other hand, the five-level triage instrument has been developed and validated, which is based on not only on "Who should be seen first?" but also: "What will this patient need?" (Tanabe, Gimbel, Yarnold, Kyriacou, & Adams, 2004). Despite the fact that this system sorts the patients and prioritize them based on severity of the illness and/or injury (Tanabe et al., 2004), the patients' waiting period or the order of treating them, especially for the patients with the same acuity level, is rarely investigated (Claudio & Okudan, 2010). Tanabe et al. (2005) stated that the physician and nurses face a serious limitation of the ESI version 3; that is, they could not determine how acutely ill these level 2 patients in the waiting room are, when they deal with the scenario of "there are six level 2 patients in the waiting room". Moreover, two levels of the ESI level 2 patients have been identified in the clinical experience; those who can safely wait for physician evaluation for at least 10 minutes without clinical deterioration, and those who cannot wait (Tanabe et al., 2005).

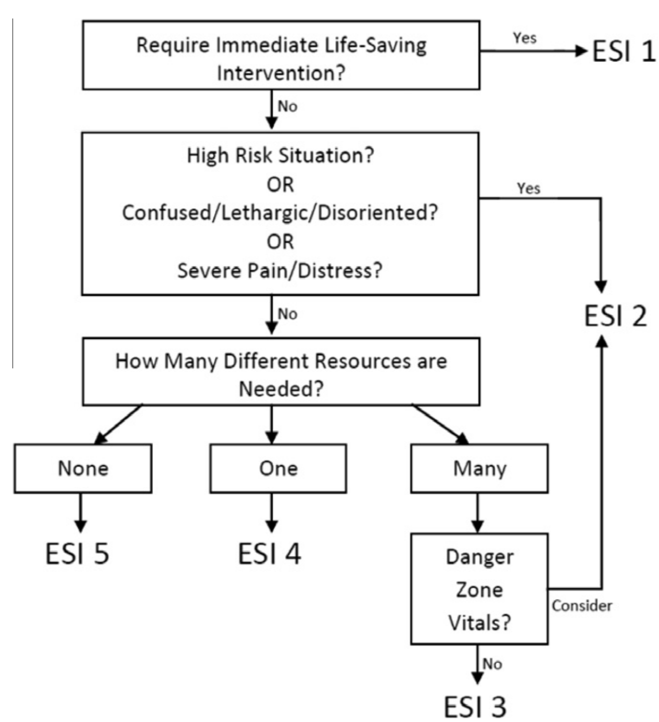

Fig. 2. ESI Triage Algorithm, version 4 (Modified from Gilboy et al., 2005).