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Exploration of Group Technology Applications: Triage in the Emergency Department

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Abstract

Emergency Departments (EDs) provide a multitude of services and treatment options to variable and increasing demand. Therefore, EDs are usually crowded, leading to long waiting times and lower patient satisfaction that may have adverse effects on the entire hospital. Decision-making is a critical part of the triage process as it helps to improve the productivity as well as reduce waiting times for patients in need of immediate medical attention. Hospitals utilize triage algorithms in order to rapidly sort incoming patients and group them based on the severity of their injury or illness. Group Technology (GT) is a management philosophy that improves manufacturing systems' efficiency and productivity by classifying individual parts into part families. This paper is a part of an ongoing research that seeks to develop a framework for the definition and the identification of patient groups in EDs using GT; it aims to identify the important patient characteristics and system requirements that will be utilized by GT. Informed by the research presented in the paper, utilization of GT algorithms will result in a scientific basis for making an informed and logical decision for patient classification.

Keywords
Group Technology (GT); Emergency Department (ED); Triage; Emergency Severity Index (ESI)

1. Introduction
Emergency Departments (EDs) are essential element in healthcare facilities that provide medical treatments to patients with acute injuries or illnesses. In the U.S, EDs are considered a vital component of the nation's health care safety net [1], and are responsible for 45-65% of hospital admissions [2]. In most hospitals, EDs operate 24/7. In 2006, there were 119.2 million visits to EDs [3]. Patients arrive to EDs with various injuries or illnesses, with various health insurance plans, if any at all, and without a planned appointment. Some patients come with life-threatening status, needing immediate treatment, while others come with non-urgent status and are able to wait.

Complexity in health care settings, such as the ED is apparent not only in the patient and treatment protocol, but also due to the high level of automation and instrumentation, huge volumes of information, and the level of interdisciplinary coordination required [4]. Not only are many U.S. EDs are exceedingly crowded, but they are also characterized by increased performance pressures, which prompt researchers to study the complexities and inefficiency factors of the ED system and the ED-hospital interfaces [5].

Crowding could be the result of system factors such as complexity and inefficiency [5]. ED crowding is considered a global problem that adversely affects the quality of the health care provided [6-9]. Bernstein et al. [10] found that crowding is correlated to the increased risk of in-hospital mortality, longer waiting times (time-to-treatment) for some patients and with patients who leave the ED without being seen or against medical advice. Similarly, Hoot et al. [7] found that crowding commonly affects mortality, transport delays, treatment delays, ambulance diversion, patient elopement, and financial effect. Therefore, it can be concluded that crowding is correlated with two important dimensions of health care quality, patient safety and timeliness of care.

In a complex environment, the right information and resources must move through the ED system at the right time to the right patient. Therefore, many EDs utilize triage algorithms to assign a priority level for incoming patients. The purpose of this process is to place the patient in one of several queues; each queue has a maximum time for the patient to see the physician [11].

This paper is part of an ongoing study that aims to utilize Group Technology (GT) approach in ED triage. GT is a management philosophy that uses knowledge about groups to lead to efficient problem solving. GT is an approach that involves detection of the attributes by which the members of a population can be clustered into groups (families). In a manufacturing context, part families would be created based on routing or design information [12]. In healthcare systems, the patient families would be created based on patient characteristics (such as age, chief complaint, etc.) and system information (such as laboratory tests, CT scan, etc.).

The purpose of the research is to develop the framework for implementing GT in EDs. The framework development has two stages: 1) identifying and exploring patient and system attribute permutations through semi-structured interviews in clinical settings, keeping in mind the impact of the current healthcare policies that are used in practice, and 2) developing a Graphical User Interface (GUI) with the underlying GT algorithm so that the healthcare providers can use the resultant approach.

This paper presents the results of the semi-structured interviews with three experienced health care providers of the Hershey Medical Center in Hershey, PA.

2. Literature Review

Patients undergo a triage interview upon their arrival to the ED. Triage has been in place, formally or informally, since the first ED opened [2]. In the U.S., EDs started using triage as early as the 1960s [13]. The purpose of the triage interview is to place the patient in one of several queues, each with an associated maximum time until the patient sees a physician [11]. During this process, the quality and timeliness of information collected in the first interview with the patient must be maximized [14]. Thus, the qualification and the personal qualities of the triage nurse are very important for an effective triage [13].

The Emergency Severity Index (ESI) triage system sorts patients into five clinically distinct groups. These five levels are different in projected resource and operational needs [15]. The most acutely ill patient gets ESI level 1 (highest level) or 2. The ESI levels 3, 4, and 5 (lowest level) are assigned based on the number of needed resources [16]. For example, a patient with ESI level 1 or 2 could be taken immediately to the treatment area, while patients with ESI level 4 or 5 can wait [15]. During the triage process, the triage nurse checks the patient's vital signs, temperature, pulse, respiration rate, and blood pressure. Then he/she discusses the present illness, past medical history, and other pertinent information such as allergies and immunization status with the patient. The nurse then determines if the patient needs immediate treatment or he/she can wait based on the above information [17].

The prioritization of time-to-be-seen is essential to the patient and is related to his safety, especially, when ED crowding delays evaluation [18]. Recent research utilized the utility theory to prioritize the patients with the same acuity level in EDs [19]. In this study, the authors demonstrated the use of utility theory in patient prioritization with a hypothetical example. They explained the choice of utility theory due to the inherent uncertainty in ED settings, and that the utility theory accounts for uncertainty. Ashour and Okudan [19] also presented a solution to the problem of patient prioritization in EDs using utility theory. A major difference from prior work is that this study ranks patients with different acuity level, using patient age, gender, pain level, and the assigned ESI. For example, while vital signs (i.e., temperature, pulse, respiration rate and blood pressure) were considered for patient ranking in the Claudio and Okudan [17] study, patient age, gender and pain level information were neglected. Further, these variables are also excluded from the ESI algorithm.

In another work, Ashour and Okudan [20] developed an approach that aggregates patient's chief complaint, age, gender and pain level along with the vital signs to create a clear ranking among waiting ED patients. The goal is to help triage nurses make their decisions more efficiently and easily, taking into account their intuitive judgment and preferences, but also minimizing potential bias. The proposed decision algorithm starts by identifying the patient status as one would in the current ESI algorithm [15]. Then, if the patient requires any immediate intervention, he is considered to be in "Critical State". After this stage, the procedure progresses as follows: 1) Is the patient in need of immediate intervention? If the response is affirmative, he is a "Critical State" patient. If no, he goes to Step 2. 2) The

triage nurse asks the patient about his complaint, pain level, age, and gender, and takes his/her vital signs. 3) The complaint and the vital signs data are treated using the Fuzzy Analytic Hierarchy Process to yield what we referred to as "pre-treated" data. 4) The data from Steps 2 and 3 are processed by the overall utility function to give the utility value for each patient. 5) Patients with high utility values go to the treatment area first, and the others with the lower values can wait in the waiting room. They are treated in descending order of priority based on the overall utility values. In both studies, each patient gets a priority level or rank, but patients are not sorted into families. It is obvious that there is need for a realistic and scientific approach that identifies and assesses patient families (groups) who visit the ED systems and their relationships with system performance.

The main principle of GT is that a set of problems that share similar concepts, principles and tasks can be solved by a single solution that in turn saves time and effort [21]. In the past, GT has helped to improve manufacturing systems efficiency [22] and productivity [23].

Productivity of the manufacturing system could be improved through the following: 1) improving the quality of the workforce that contributes by 15%; 2) the greater availability of capital with 25% contribution; and 3) improving the production technology that contributes 60% [24]. GT has been involved in the production technology for years [24]. The GT approach involves detection of the attributes, by which the members of a population can be clustered into groups (families). In the manufacturing context, part families would be created based on routing or design information [24]. In healthcare systems, patient families would be created based on patient information, such as age, gender, chief complaint, etc. and system information, such as laboratory tests, CT scan, etc.

No study has yet utilized GT concepts in the healthcare domain. In order to understand how GT techniques impact ED system performance, this paper presents the first step of developing a framework of an integrative approach to identify patient groups (families) based on patient and system characteristics.

3. Methodology

Currently, the ED triage nurse receives patients with different illnesses and/or injuries, and then based on several factors (i.e., vital signs, complaints, and pain level, etc.), he/she assigns the ESI level. Then, the triage nurse decides which patient will be treated first. The most widely used algorithm is the five-level ESI that takes into account most vital signs in assessment of the acuity level (e.g., respiration rate, oxygen saturation and blood pressure, etc.). Only a tiny percentage of the patients get the highest acuity level, and thus receive immediate service, however; the rest of patients would have to wait.

Figure 1 shows the triage process with different tools. With the ESI, the process of identifying the groups of patients is done by the triage nurse. The differentiation between patients is a result of the nurse experience and knowledge. Studies have shown that there are discrepancies in triage decision between nurses in the same hospital and between different hospitals (e.g., [25]). Ashour and Okudan [20] developed an approach to prioritize patients who are waiting in ED. The approach is based on Fuzzy Analytic Hierarchy Process (FAHP) and Multi-attribute Utility Theory (MAUT). The model prioritizes the patients according to their characteristics, i.e., age, gender, pain level, chief complaint, and vital signs. The model does not take into consideration the processing requirements, such as, estimated treatment time, lab test, etc. Due to the dynamic nature of the triage process and the difficulty in differentiation, new methods are needed to help the triage nurse to be efficient (without increasing potential bias) in identifying patients groups or families. It is hypothesized that GT will improve patient flow, which will impact the performance of the system. The performance of the ED system can be measured by patient safety, quality of care, time-to-bed, resource utilization, etc. Minimizing patient waiting times will improve the quality of care and the safety in the ED environment.

GT has two steps: 1) developing a patient coding scheme, and 2) identifying patient families. First, we need to identify the most important and related patient and system characteristics in order to develop the patient coding scheme. This can be achieved through utilizing semi-structured interviews in clinical settings, keeping in mind the impact of the current healthcare policies that are used in practice. Section 3.1 presents the interview questions.

3.1 Clinical Interview

Clinical interviews that target health care providers practicing at Hershey Medical Center (HMC) in Hershey, Pennsylvania would provide the important patient and system attributes that serve as the basis for developing the coding scheme. A study to explore the data that are collected during triage in actual practice has been implemented

in New York State [26]. One limitation to this study is that it was conducted in New York State, thus, the results could not be generalized to the other geographic areas or demographic populations. Therefore, our main objective is to validate the generality of this study.

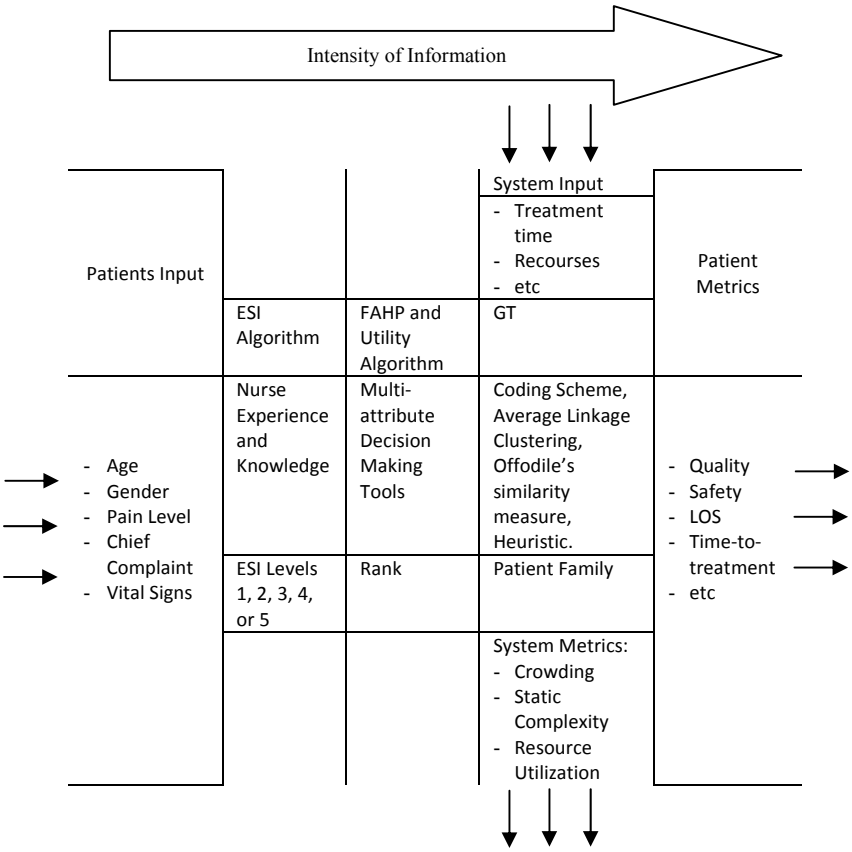

Figure 1: Triage Process with Different Tools

The coding scheme is similar to the traditional GT part classification and coding but incorporates the part (patient) information along with the system information. The aim of the classification coding scheme is to separate the incoming patients to ED into: 1) distinct groups based on the patient attributes, i.e. gender, age, vital signs, etc., and 2) distinct groups based on the system information, i.e., lab tests, physicians, nurses, etc. The coding system will be similar to the existing coding systems for GT. In our case, the code would be monocode or tree structure, which means that the code characters (digits) are arranged to follow the order of the information for the patient. For example, when the patient first comes to the ED, the health care provider must recognize if the patient is conscious, or disabled, then vital signs are taken. Accordingly, the code would first start with a digit that represents the status of the patient's consciousness, then another digit to identify disability, then digits that represent vital signs and so on. This would help the healthcare providers to follow the patient's information systematically. Hypothetically, the proposed coding scheme would have the following digits shown in Figure 2.

For example, if a patient has arrived to the ED with the following attributes: conscious, not disabled, normal mental status, 19 years old, female, 5 out of 10 pain level, temperature = 37^{o} C, systolic bp = 120 mmHg, diastolic bp = 81 mmHg, HR = 70 beats/min, respiration rate = 20 breaths/min, SaO2 = 95%, expected treatment time = 25 min, and the discharge state would be to home, then the coding number would be as in Table 1. These codes will be used to identify patient groups. Identifying patients groups is not in the scope of this paper.

Appendix A presents the set of interview questions that were used to extract the important patient's and system's information that impacts patient triage and classification.

A	B	C	D	E	F	G	H	I
Conscious-ness	Disability	Mental Status	Age	Gender	Pain Level	Vital Signs	Expected Treatment Time	Discharge
0 – unconscious 1 – conscious	0 – disabled 1 – normal	0 – impaired 1 - normal	0 - 0 - 1yr 1 - >1- 18yr 2 - > 18 - 65yr 3 – > 65yr	0 – female 1 – male	0 – 10 scale (0 – no pain, 10 – severe pain)	1 – low 3 – relatively low 5 – medium 7 – relatively high 9 - high	0 – 0 min- 60 min 1 – 61 min – 120 min 2 – > 120 min	0 – home 1 – hospital

Figure 2: Coding Scheme

Table 1: Patient Coding Example

Patient Info.												Treatment Info.	
A	B	C	D	E	F	G						H	I
						Temp.	Sys. BP.	Dia. BP.	HR	RR	SaO2		
0	1	1	2	0	5	1	2	2	1	1	1	0	0

3.2 User Interface

Figure 3 shows the overall procedure of triage process when the GT technique is utilized. A graphical user interface should be developed to facilitate the use of this procedure in ED. Figure 4 shows a tentative interface that was introduced to the health care providers during the clinical interviews.

The interface would have a section to search for returned patients, a section to add new patients, a section to enter patient and system information, and another section to show current patient groups. And by using this interface, health care provider would be able to discharge the patients who already finished the treatment or have been admitted to the hospital or transferred to another place.

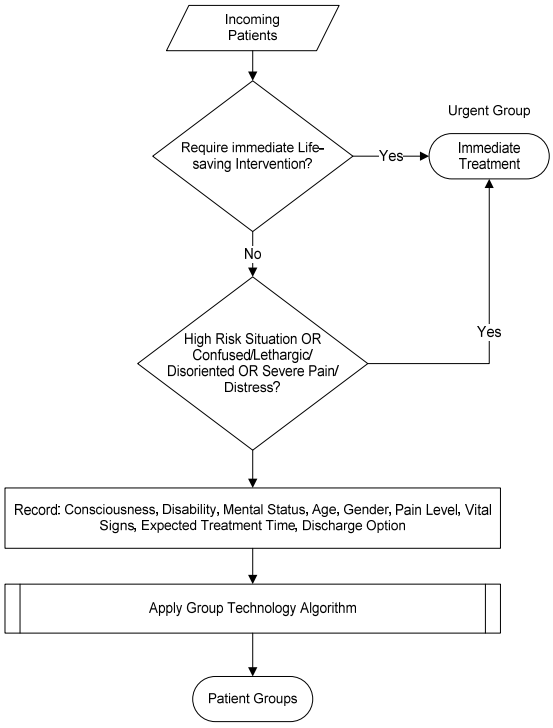

Figure 3: The Big Picture of the Triage Process

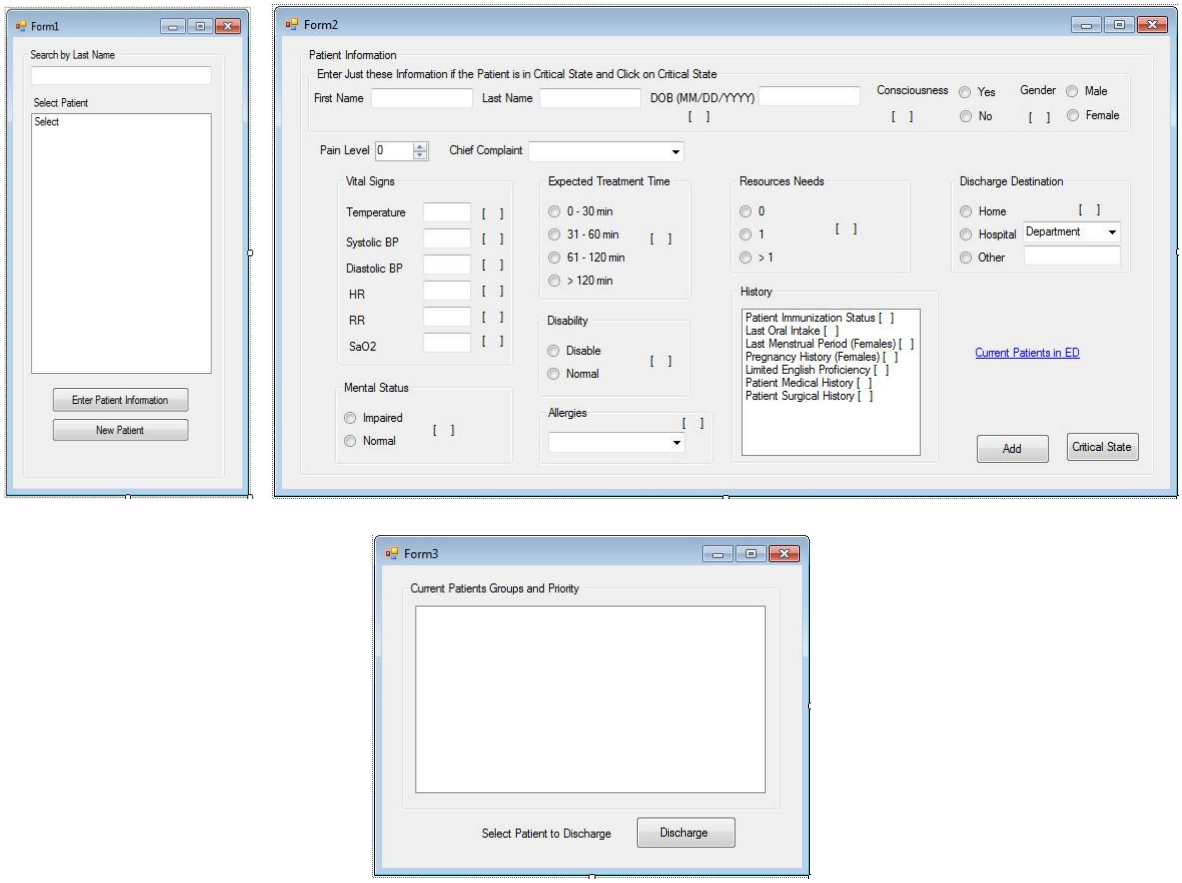

Figure 4: Group Technology Triage based Graphical User Interface

4. Results and Discussion

A semi-structured interview has been conducted with three healthcare providers who have experience in emergency medicine. The providers consist of: 1) one Clinical Head Nurse (Experience ~ 8 years) and 2) two Emergency Medicine Physicians (Experience ~ 18 and 19 years). The Institutional Review Board approval for these interviews was obtained.

The interview questions are attached in the Appendix A. The questions are divided into six groups: 1) Interface; 2) patient-flow; 3) ED crowding; 4) performance measures; 5) clinical information systems; and 6) simulation. The interview questions were developed based on the literature review. For the interface questions, a GUI, Figure 4, was used that consists of a list of data that are usually used during triage process. Each item has a bracket beside it that is used by the subject to rate each item using a 0-5 scale to indicate how related each item is to the triage process. The range is from 0, "no-relation", to 5, "highly related". The rest of the interview includes open-ended questions administered to the interview subjects. This offers the subject the opportunity to add more data than the interview questions themselves. Since we have interviewed just three people, the analysis would be to validate the results found in Castner's [26] study.

Table 2 represents the responses to the interface questionnaire. According to the average, the followings were the most important variables during triage process (with an average greater or equal 2.5): 1) consciousness; 2) vital signs except temperature; 3) mental status; 4) chief complaint; 5) age; 6) pain level; 7) resource needs; 8) medical and surgical history. The rest of the items received a very low rating. It should be mentioned that some of the factors got responses with large variability, for example, allergies; the nurse considered it as an important factor but the physicians did not consider it as an important factor to the triage process. On the other hand, Castner [26] has considered it as an important factor.

Table 2: Ratings of Variables Used in Triage

Item	Clinical Head Nurse	Physician 1	Physician 2	Average
Age	3	5	2	3.33
Consciousness	5	5	5	5.00
Gender	2	1	0	1.00
Pain Level	3	2	3	2.67
Chief Complaint	4	4	4	4.00
Vital Signs: Temperature	3	3	1	2.33
Systolic BP	5	4	5	4.67
Diastolic BP	3	3	4	3.33
HR	5	4	5	4.67
RR	4	3	5	4.00
SaO2	5	4	5	4.67
Mental Status	5	4	5	4.67
Expected Treatment Time	2	0	2	1.33
Disability	2	0	0	0.67
Allergies	4	2	0	2.00
Resource Needs	3	1	4	2.67
Patient Immunization Status	1	1	0	0.67
Last Oral Intake	1	1	2	1.33
Last Menstrual Period (Females)	1	2	1	1.33
Pregnancy History (Females)	1	2	1	1.33
Limited English Proficiency	1	1	1	1.33
Patient Medical History	3	2	4	3.00
Patient Surgical History	3	2	4	3.00

* BP: Blood Pressure; HR: Heart Rate; RR: Respiration Rate; SaO2: Oxygen Saturation

Moreover, Castner's study [26] has shown that vital signs, pain score, medical history, surgical history, last menstrual period, limited English proficiency, immunization status, pregnancy history, and last oral intake are important variables to triage. In our case, last menstrual period, limited English proficiency, immunization status, pregnancy history, and last oral intake got very low scores but still one of the rated items (got score greater than zero); thus they are still related to the triage process. It should be mentioned that the differences in rating might be because in Castner's study, they used a different survey tool (questionnaire). These surveys were distributed to registered professional nurses, while in our case, a semi-structured interview was preferred and our interviewees included physicians as well as a nurse.

Physician 1 suggested that we could combine consciousness with mental status; this will reduce the number of the variables. We believe that the expected treatment time would affect the patient grouping and the literature support this belief (e.g., [27]). The registered nurse and physician 2 agreed with us, while physician 1's opinion was that this item would not affect the triage process. The reason is that health care providers would think that the triage should always reflect the patient urgency only and not anything else; which is true if you are looking at the micro level (patient) and are not considering the macro level (system). The nurse and physician 2 suggested that patient with compromised immunity system and patient with communicable disease can be added to the items (factors) to group the patients accordingly. For example, patients with cancer should not be at the same place with other patients who have communicable diseases.

The ESI algorithm would group the patients with regard to their age as the following: 0 - < 3months; 3 months – < 3 years; 3 years – 8 years; and > 8 years. All the participants have suggested changing these ranges, there were differences about the definition of infants and children, and adults and elders; we decided to divide age range as follows: 0 – 1 year (infants); >1 – 18 years (children); >18 - 65 years (adults); and > 65 years (elders).

The rest of the questions are related to patient-flow and performance measures. A simulation model will be built to test the impact of using the GT on the ED performance measures. Thus, this information would be the input for the simulation model (not the scope of this paper). It should be mentioned that HMC is using different patient-flow paths than the regular EDs; each path takes different types of patients who are grouped or selected, explicitly, based on the urgency and, implicitly, based on treatment time and disposition destination. Also, according to the participants, the performance of this ED was improved since they implemented the new flow strategy. Therefore, GT is expected to improve some of EDs performance measures in a systematic and structured way, taking into consideration patient safety (and urgency).

5. Conclusions

The uncertainty involved in the triage process makes it a decision-making problem. Currently, this process depends highly on the nurse's knowledge, experience, and intuition and on the subjectivity of patient's attributes, such as, pain level. Some studies have incorporated patient's characteristics in this process such as, FAHP and MAUT algorithm that incorporated chief complaint, age, gender, pain level, and vital signs in order to triage patients.

Although, FAHP and MAUT would help decision makers improve their consistency, reliability, and repeatability, this model did not incorporate system characteristics, such as, treatment times, resource type, etc. in the model. This paper shows that both patient and system characteristics can be considered in sorting patients. This preliminary step in developing a framework for implementing GT in EDs motivates the use of other patient information that is not included in the ESI, such as infectious issues and different age classifications. The framework development is conceptualized in two stages: 1) identifying and exploring patient and system attribute permutations through semi-structured interviews in clinical settings, keeping in mind the impact of the current healthcare policies that are used in practice, and 2) developing a graphical user interface so that the healthcare providers can use the resulted approach. This paper presented our preliminary findings on the attributes; future research will focus on implementing the information found in this study to further explore the use of GT in EDs.

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Appendix A

These questions were asked to the health care providers after describing the GT and how the system will be used in real settings, Figures 3 and 4 will be used to illustrate the approach.

Interview Code (4 letters/2 numbers)_____ **Job Title**_____
Date_____ **Years of Experience**_____
Time_____ **Institution**_____
Length of the Interview 20 minutes **Recording Notes**_____

Interview Questions

Interface

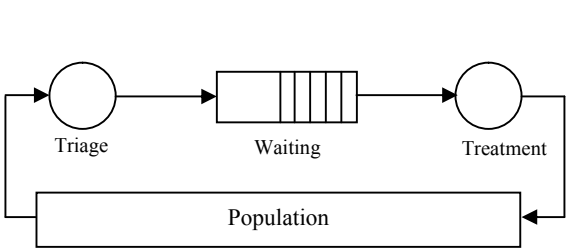
For the first set of questions, we will be referencing an interface of our proposed patient flow assistance tool.

1) For each of the items located on the interface please rate from 0 to 5 how likely each attribute is to affect patient triage where 0 is not at all likely and 5 is highly likely.
2) What patient information **not included** on this interface would be an important consideration during patient triage?
3) What system information **not located** on this interface would be an important consideration during patient triage?

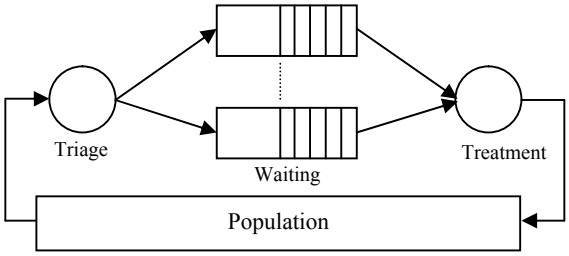
Note: Don't forget to ask about the age groups!

Patient-Flow

4) Please choose the patient flow structure of that best describes your Emergency Department (ED).



a) Single Queue



b) Multi-Queue

5) What determines the patient streaming? Do you have different paths for:

☐ Different ESI Levels (e.g. Fast Track)

☐ Disposition Destination (Home, Hospital, or other)

6) Currently, in this ED, are patients grouped and treated based on their severity (urgency or priority)?
   a. If so, what criteria are used to group patients?
   b. In your opinion, what other criteria should be included in patient grouping?
   c. Are there different patient priority queues for the different areas?

ED Crowding

7) When the ED is crowded, what are the solutions used to handle crowding?
   a. What if there is crowding in one patient service area, but not in others (i.e. flexibility)?

Performance Measures

8) What performance metrics that are currently used in the ED are the most important (i.e., Length of Stay (LOS), Time-to-Bed (TTB), Patient Safety, Patient Satisfaction, Resource Utilization, Quality of Care, etc.)?
   a. Does the importance of these metrics vary based on patient severity? If so, how?

Clinical Information Systems

9) To what degree does the ED clinical information system communicate with the main hospital clinical information system?
   a. What are the benefits to this level of information sharing? Drawbacks?

Simulation

10) On average, how many physicians, nurses, and support staff is on hand in the ED?
   a. About how many patients can each physician manage at a time? Nurse?
11) What information, if any, regarding patient time is collected in the ED clinical information system? For example; arrival time, triage time, time of first treatment, discharge time, etc.