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HOW TO EVACUATE AN EMERGENCY DEPARTMENT DURING PANDEMICS: A COVID-19 AGENT-BASED MODEL

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ABSTRACT

Evacuation of patients during a pandemic is a complicated process. Some patients may be infectious, some may be considered Persons Under Investigation (PUI) with pending test results, some staff might be wearing Personal Protective Equipment (PPE) which restricts movement, all the while, additional infection control protocols might be in place to prevent further transmission. Modeling and simulation can help emergency planners by providing an estimation of intermediate and final evacuation times for different groups of patients. These results can provide insights for emergency evacuation planning or inform strategic decisions such as the location of PUI areas. In this study, we developed an agent-based model to simulate the evacuation of the emergency department at the Johns Hopkins Hospital during the COVID-19 pandemic. The results show a larger nursing team can reduce the average and maximum probable evacuation times by 12 and 19 minutes, respectively.

1 MOTIVATION

Every year, many hospitals are forced to evacuate their patients due to natural disasters or man-made incident. Between 2000 to 2017, there were 154 reported hospital evacuations in the United States, of which 71% were due to natural disasters, 16% man-made threats, and 13% incidents such as fires and chemical fumes (Roberts et al. 2019). Hospital evacuation is challenging due to the unique mobility characteristics and needs of different patients. This complexity deepens when there is an existing state of emergency such as an infectious disease outbreak. In such scenarios, often preventive measures are considered to limit interaction between patients and staff. These measures and the addition of PPEs may delay patient flow during an evacuation. With the ongoing global COVID-19 pandemic, which has impacted healthcare services for months and is expected to continue to do so for the near future, a rising concern is safe evacuation of hospitals where COVID-19 patients are hospitalized.

In this study, using agent-based-modeling (ABM), the evacuation of the adult emergency department (ED) at the Johns Hopkins Hospital is simulated considering the presence of COVID-19 patients. An especial evacuation priority is assumed to be in place to separate COVID-19 patients, according to which, first priority goes to non-COVID patients. As all non-COVID patients are evacuated, the evacuation of COVID patients can start. Furthermore, the nursing team dedicated to the COVID-19 patients does not interact with other patients and medical teams in other parts of the ED.

2 METHODOLOGY

There are two types of agents: patients and staff. Patients have different class codes as they behave differently during the evacuation, and staff help patients move. We develop a patient classification system for non-ICU patients based on the mobility characteristics and needs from the literature. Accordingly, patients are classified into five groups: (1) visually impaired, (2) hearing impaired, (3) mobility impaired, (4) mentally impaired, and (5) non-disabled. Mobility impaired patients are further classified into five sub-groups of wheelchair users, motorized wheelchair users, stamina impaired (including crutch and walker users), high acuity bed-bound, and low acuity bed-bound patients. Non-disabled patients are divided into two groups: elderly or children, and adults. The Floyd-Warshall algorithm and Karamouzas's predictive collision avoidance model (recalibrated for evacuation behavior) are used for path planning and navigation. Certain social behaviors, such as grouping, herding, rescuing, and information sharing, are also implemented.

The scenario is a fire emergency outside of the ED that leads to a complete evacuation of the adult ED at 12PM. Based on patient service area utilization data, 80 patients, including 16 high-acuity bed-bound COVID-19 patients, 25 low-acuity bed-bound and ambulatory COVID-19 patients, and 39 non-COVID patients, are located in different units of the ED. To evaluate the effect of the size of the nursing teams on the evacuation, two sub-scenarios are considered: in Scenario A, a nurse-to-patient-ratio of 1:5 is used, which is the current practice in the ED, giving 20 nurses over the entire ED. In Scenario B, the proposed nurse-to-patient ratios by the National Nurses United Organization is considered, i.e., 1:4 for psychiatry, 1:3 for ER and triage, 1:2 for acute care units, and 1:1 for the trauma units; increasing the total to 37 nurses.

3 RESULTS

Figure 1 shows the results in form of heat maps for 500 simulations per scenario.

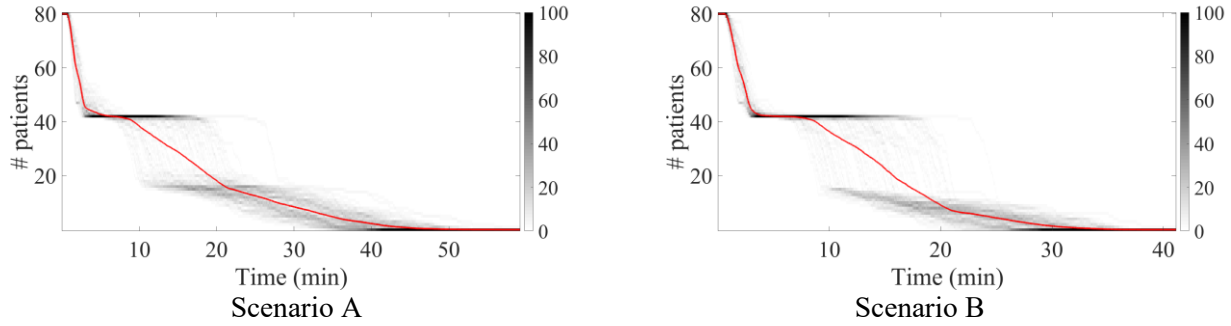

Figure 1: Heat maps of the evacuation curve (for 500 simulations per scenario).

In any imminent or ongoing disruptive event, especially a fire emergency, time is a major constraint as for the safety of the patients the evacuation has to be over by a certain time. Scenario A shows that the hospital officials will need 33 to 60 minutes (an average of 42 minutes) to completely evacuate the patients to safety. Scenario B shows that having the larger nursing team can reduce the average and maximum probable total evacuation times to 30 and 41 minutes, respectively. This implies that the decision-makers would have up to 20 minutes extra time to evaluate the situation and consider alternative solutions, and nevertheless take all patients to safety in about an hour. The model can also be used to evaluate whether the current emergency plan meets certain safety policies, e.g. regarding acceptable evacuation times under different scenarios.

REFERENCES

Roberts M. F., F. Archer, and C. Spencer. 2019. "Reviewing Disasters: Hospital Evacuations in the United States from 2000 to 2017". *Prehospital and Disaster Medicine* 34(1):s21-22.