Algorithm Development for Duke Emergency Pre-hospital Capacity Management

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Background. Emergency Department (ED) overcrowding is a growing national problem affecting quality and access of healthcare. Overcrowding can cause the ED to divert incoming emergency medical services (EMS), a decision which is often reactive and made subjectively, without pre-determined guidelines or sufficient coordination with nearby EDs. Diversion status also compromises patient safety and quality of care (long wait times, high left without being seen rates), diminishes provider well-being and performance, and increases downstream transfers to other hospital EDs, further detracting from efficiency and patient care. Prehospital traffic control using real-time ED census data could be an effective approach to ensuring incoming patients are transported to the most appropriate destination to receive timely care, while reducing ED diversions overall and supporting informed diversion when necessary. Implementing an algorithmic tool for capacity management could improve patient care and coordination between nearby EDs.

Motivation. The purpose of this project is to implement a capacity management tool to support prehospital transport destination decisions with the goal of reducing diversions in Duke's Durham-based EDs, Duke University Hospital (DUH) and Duke Regional Hospital (DRH). Based on historical data, DUH ED went on diversion 295 times during the period between Feb 2019 and June 2021. Past algorithms for ED capacity management utilized probabilistic models tailored to ED-specific or regional-specific operational variables to anticipate overcrowding in real time. Here, we build our own support tool for prehospital capacity management, incorporating our previously developed artificial intelligence (AI) support tools, such as the ED Triage tool. In collaboration with EMS and ED stakeholders and based on real-time ED capacities, we designed a support tool to guide patient transport destination decisions by Durham County EMS (DCEMS), the sole 9-1-1 transporting agency in Durham County.

Methods. We obtained detailed census data from DUH and DRH for a three-year period between 7/1/2018 and 6/30/2021. We selected primary data points based on commonly used criteria in past crowding measures including number of ED patients, waiting room status, ventilator use, patient acuity levels (ESI), number of psychiatry boarders, EMS transports, etc. We also generated summary statistics on the elapsed time spent in the ED summed over all patients (*cumulative time elapsed*). Data granularity was set to the hourly level (26,328 hours summarized per ED over the three-year period), allowing the inclusion of metrics like arrived or triaged in the past hour and time of day comparisons. Hourly census primary data was overlaid with historical diversion status data to validate our primary outcome label.

Results. We defined our primary outcome label of ED workload to be larger when the *number of total patients* was high and the *cumulative time elapsed* was low compared to the time-of-day median. Our algorithm modifies raw capacity (number of patients as percentage of the max count observed for that ED over the three-year historical period) based on the number of severe acuity cases (ESI level 1, 3% capacity buff per case), the number of ventilators in use (10% added per ventilator), and the percentage of triaged patients (10% added if less than half of patients completed triage). We set high workload to be when modified capacity was greater than 55% and medium workload to be when modified capacity was between 33-55%. Critical workload occurred when modified capacity exceeded 55% and the cumulative time elapsed was less than the observed median for that hour of the day between 7/1/2018 and 6/30/2021. Running our algorithm retrospectively over the three-year timeframe, DUH had 1,451 critical hours, 6,222 high workload hours, and 12,418 medium workload hours. We found that retrospectively, the maximum ratio of high and critical workload labels occurred during the 18 hours prior to the start of historical diversion events. Future EMS validation of DCEMS decisions in the field will be based on real-time ED data inputs.

Conclusion. Improved management of EMS transport destinations is a potentially high-value approach to avert downstream overcrowding crises and elevate patient care and safety. We developed an algorithm that identifies high and critical ED workload status, which will be incorporated into an AI tool that helps guide EMS transport decisions and hopefully reduces ambulance diversions. The relative ease of implementation was key for timely integration into existing systems and allowed our algorithm to be tailored to the local environment Duke's Durham EDs operate in. Our algorithm was also highly adaptable to ED-specific protocol changes and patient volume/acuity, both due to and independent of the COVID-19 pandemic. Impact assessment of the EMS capacity meter tool is pending. Future work will include incorporation of capacity status into DCEMS protocols and inclusion of patient conditions and patient preference into ED destination decision. We would also like to see similar design approaches to explore new decision support tools customized to other health system EDs.