Development of a Machine Learning Model for Early Detection of Pediatric Sepsis

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Introduction

Sepsis is a dysregulated response to an infection and is a leading cause of morbidity and mortality among hospitalized children. From 2004 to 2012, across 43 hospitals, the prevalence of severe pediatric sepsis was 7.7% with an associated mortality rate of 14.4%[1]. Timely detection and treatment of sepsis is crucial to reducing sepsis-associated mortality rate. However, compared to adults, symptoms of sepsis in children are particularly hard to recognize through routine clinical assessments. This represents an opportunity for machine learning innovation, yet only a few models exist for the recognition of sepsis in children and none have been evaluated prospectively[2,3]. To address this gap, we formed a multidisciplinary team to develop a machine learning model for the real-time detection of pediatric sepsis using electronic health record (EHR) data. The integration of this real-time model into the clinical workflow in our emergency department (ED) could assist clinicians in providing timely care to children at risk of sepsis, and hence mitigate the associated morbidity and mortality.

Methods

We used data collected from 17491 inpatient and ED encounters for 10492 unique patients between 30 days and 18 years old from 11/1/2016 to 12/31/2020. Pediatric sepsis can be defined by the retrospective Weiss definition, which includes the co-occurrence of infection and an indication of acute organ dysfunction (cardiovascular, respiratory, hematologic, and kidney)[4]. The retrospective Weiss definition was modified for real-time implementation (RT-Weiss) as follows: the 4-day antibiotics requirement was reduced to the first administration of antibiotics; patients were removed at the time of death or hospice; the requirement for "increased in noninvasive ventilation to > 20 hour/day" was removed; the overlap between infection and acute organ dysfunction was changed from "$\pm$ 2 days" to "$\pm$ 1 day". Clinical features used to compute the RT-Weiss definition include blood culture, transfer from external healthcare facility, antibiotics, lactate, isotonic fluid boluses, vasoactive medications, ventilation, platelet count, and creatinine. While creating labels, we identified patients who meet the original Weiss definition as the positive samples and used the timestamp associated with the RT-Weiss definition as the onset of sepsis. Vitals and lab values are aggregated by hour and used as input features. The model aims to detect the occurrence of pediatric sepsis 6 hours prior to the onset. The model was trained using LightGBM, a gradient boosting decision tree framework with 70% of the data used for training, and 15% each for validation and testing. We evaluated the model performance using AUCROC and average precision score and chose the best model with the highest validation scores.

Results and conclusion

Of the 17491 encounters, 2050 (11.72%) met the RT-Weiss definition within the first 72 hours of hospital admission, and 716 people (4.09% of cohort) meet the retrospective Weiss definition. A physician has completed chart reviews to validate that patients labeled by the RT-Weiss also meet the clinical presentation of sepsis. The training and testing AUCROC of the model are 0.96 and 0.93 respectively; the training and testing average precision score are 0.11 and 0.05 respectively. As of next steps, we will explore time-series based modeling approach to incorporate the temporal dependencies between observations and evaluate the model's performance in real-time. In addition, due to the rare occurrence of sepsis, the dataset is heavily imbalanced (positive sample: 0.4%). We plan to use one week of data up to the time of sepsis occurrence and the first week of data for non-septic patients while training the model. For integration into clinical workflow, we plan to use push notifications to alert providers onsite when a patient is predicted to meet the definition by the model. We also plan to create a dashboard for monitoring the hospitalized patient population. We aim to further evaluate the performance of our model using sepsis-associated mortality rate, sepsis-recognition time, time to antibiotics, hospital length of stay and ICU length of stay.

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