Emergency Department Sepsis Alert System for Children

Devin Singh MD[1], Carson McLean[2], Lebo Radebe[2], Lauren Erdman[2], Erik Drysdale[2],
Michael Brudno PhD[1], Anna Goldenberg PhD[1]
Hospital for Sick Children[1], University of Toronto, Department of Computer Science[2]

Background: One in every 18 deaths in Canada is attributed to sepsis with mortality rates up to 30.5% in children posing a significant burden on families and health care resources.[1-3] Given the life-threatening nature of sepsis in pediatric patients, it is of critical importance to diagnose sepsis early in children presenting to Emergency Departments (EDs). Despite the large body of research dedicated to sepsis, there is yet to exist a widespread, clinically implemented, machine learning (ML) based sepsis prediction tool for children in EDs. Two well-known early warning systems for septic shock are currently in use at Johns Hopkins University (TREWscore) and Duke University (Sepsis Watch). While these two systems are effective, their ability to be transferred to a pediatric context is limited as they were not developed for use in children.[4-5] In addition, the few pediatric tools that do exist are built for patients in an intensive care setting with large volumes of streaming data and cannot be applied directly to EDs where data is relatively limited.[6] Currently, modern electronic health record (EHR) systems have sepsis alert functionality however there are significant limitations. At the Hospital for Sick Children (SickKids) in Toronto, a sepsis alert system exists at the time of triage and is effective at ruling out children with sepsis. However, there are two significant deficiencies: **1.** The system has a high false positive rate, which can contribute to alert fatigue and over-testing in patients. **2.** The tool is not completely automated and requires a repeat manual nursing assessment prior to the tool alerting a physician, leading to inefficiencies in workflow and potential for human error to occur.

Hypothesis: We hypothesize that sepsis can be predicted in children 0-18 years of age presenting to Emergency Departments (ED) at triage using modern machine learning (ML) techniques that outperform current benchmark sepsis alert tools already in use in our ED at SickKids.

Methods: Data was collected from Epic EHR system from July 2018-March 2019 for all ED patients at SickKids (48,803 patients). Logistic regression (LR), random forest (RF), and fully connected feed forward artificial neural networks (ANN) were trained to predict if a patient had sepsis at time of triage. A binary cross-entropy loss function was utilized for ANN models. Input features include: heart rate, respiratory rate, oxygen saturation, blood pressure, temperature, Canadian Triage Acuity Scale (CTAS) score, patient weight, day and time of triage, presenting symptoms, age, language, distance from home to nearest pediatric clinic, and average median household income per postal code. Preliminary labels for sepsis were determined using ICD-10 Canada codes. Model performance was compared to the current nursing (RN) and physician (MD) sepsis alert tools used at triage. Outcome metrics include area under the receiver operator curve (AUROC), true positive rate (TPR), and true negative rate (TNR). Feature importance of our ANN model was estimated by computing the decrease in performance when each feature value was randomly permuted.

Results: All of the considered ML models were able to obtain a higher AUROC than the RN and MD sepsis prediction tools currently in use (Tables 1, 2), with the largest performance improvement by the ANN model (Table 1).

Model	AUROC	TPR	TNR
RN Sepsis Alert Tool	0.84	0.72	0.95
MD Sepsis Alert Tool	0.83	0.69	0.98
ANN Sepsis Tool	**0.92**	**0.88**	**0.96**

Table 1. Comparing ANN sepsis model to tools baseline EHR tools

Model	AUROC
ANN	0.92
RF	0.90
LR	0.85

Table 2. Method comparison of AUROC

Feature importance for the ANN model was approximated by using a permutation approach yielding the following top 5 features: CTAS score 1 (0.17), age (0.07), pulse (0.05), newborn feeding difficulties (0.03), and arrival via air ambulance (0.03).

Conclusions: Our preliminary models demonstrate the potential for ANNs to exceed the performance of standard sepsis prediction tools for children in an ED at time of triage. Overall, our ANN model achieved an AUROC of 0.92 exceeding our current baseline standard. Our model maintained a high TNR similar to tools currently in practice and therefore exhibits high specificity for predicting sepsis and will rarely miss cases. This is a critical feature for sepsis prediction tools as the consequence of missing the diagnosis can be life threatening. Our model is unique on account of its relatively high TPR, indicating the potential for less false positives compared to both RN and MD sepsis alert tools currently in use. Estimated feature importance for the ANN model demonstrated clinically relevant features associated with sepsis. We believe that this improvement from baseline models can aid in diagnosing sepsis without having excess false positives thereby reducing alert fatigue, unnecessary testing, and over-treatment in pediatric patients.[7] In doing so, we can add automation to the way we detect sepsis in children in EDs while enhancing our overall diagnostic accuracy.

References:

1. Thompson, G. C. & Kissoon, N. Sepsis in Canadian children: a national analysis using administrative data. *Clin. Epidemiol.* **6**, 461–469 (2014).
2. Husak, L. *et al.* National analysis of sepsis hospitalizations and factors contributing to sepsis in-hospital mortality in Canada. *Healthc. Q.* **13 Spec No**, 35–41 (2010).
3. Government of Canada, Statistics Canada. Deaths involving sepsis in Canada. (2016). Available at: https://www150.statcan.gc.ca/n1/pub/82-624-x/2016001/article/14308-eng.htm#a9-2. (Accessed: 6th March 2019)
4. Henry, K. E., Hager, D. N., Pronovost, P. J. & Saria, S. A targeted real-time early warning score (TREWScore) for septic shock. *Sci. Transl. Med.* **7**, 299ra122 (2015).
5. Strickland, E. Hospitals Roll Out AI Systems to Keep Patients From Dying of Sepsis. *IEEE Spectrum: Technology, Engineering, and Science News* (2018). Available at: https://spectrum.ieee.org/biomedical/diagnostics/hospitals-roll-out-ai-systems-to-keep-patients-from-dying-of-sepsis. (Accessed: 5th March 2019)
6. Kamaleswaran, R. *et al.* Applying Artificial Intelligence to Identify Physiomarkers Predicting Severe Sepsis in the PICU. *Pediatr. Crit. Care Med.* **19**, e495–e503 (2018).
7. Austrian, J. S., Jamin, C. T., Doty, G. R. & Blecker, S. Impact of an emergency department electronic sepsis surveillance system on patient mortality and length of stay. *J. Am. Med. Inform. Assoc.* **25**, 523–529 (2018).