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Trend of mortality and length of stay in the emergency department following implementation of a centralized sepsis alert system

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Abstract

Introduction: Sepsis alerts based on laboratory and vital sign criteria were found insufficient to improve patient outcomes. While most early sepsis alerts were implemented into smaller scale operating systems, a centralized new approach may provide more benefits, overcoming alert fatigue, improving deployment of staff and resources, and optimizing the overall management of sepsis. The objective of the study was to assess mortality and length of stay (LOS) trends in emergency department (ED) patients, following the implementation of a centralized and automated sepsis alert system.

Methods: The automated sepsis alert system was implemented in 2021 as part of a hospital-wide command and control center. Administrative data from the years 2018 to 2021 were collected. Data included ED visits, in-hospital mortality, triage levels, LOS, and the Canadian Triage and Acuity Scale (CTAS).

Results: Mortality rate for patients classified as CTAS I triage level was the lowest in 2021, after the implementation of the automated sepsis alert system, compared to 2020, 2019, and 2018 ($p < 0.001$). The Kaplan–Meier survival curve revealed that for patients classified as CTAS I triage level, the probability of survival was the highest in 2021, after implementation of the sepsis alert algorithm, compared to previous years (Log Rank, Mantel–Cox, $\chi^2=29.742$, $p < 0.001$). No significant differences in survival rate were observed for other triage levels.

Conclusion: Implementing an automated sepsis alert system as part of a command center operation significantly improves mortality rate associated with LOS in the ED for patients in the highest triage level. These findings suggest that a centralized early sepsis alert system has the potential to improve patient outcomes.

Keywords

Emergency department, centralized sepsis alert system, mortality, length of stay, command center

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Introduction

Sepsis is a life-threatening organ dysfunction caused by a dysregulated systemic response to infection,[1] which is a major cause of mortality.[2] Indeed, prolonged emergency department (ED) length of stay (LOS) is significantly associated with a higher risk of in-hospital mortality,[3–6] especially in patients with sepsis.[5] Furthermore, delayed

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diagnosis and treatment of sepsis is a major concern, leading to adverse clinical outcomes, including increased mortality.[7,8] Early identification of sepsis and prompt treatment improve patient outcomes[9]; however, sepsis alerts based on laboratory and vital sign criteria are insufficient to improve outcomes, and alert fatigue may contribute to suboptimal outcomes.[10]

In recent years, automated digital alerting systems, which leverage prediction algorithms and machine learning to provide early warning for sepsis detection, have generated increasing interest.[11] The impact of digital alerting systems on sepsis-related outcomes was reported in a systematic review and meta-analysis, demonstrating significant benefits, including reducing hospital LOS, but no significant association was found between digital alerts and the mortality rate.[12] While most early sepsis alerts were implemented into smaller scale operating systems, a centralized approach may provide more benefits, such as overcoming alert fatigue, improving deployment of staff and resources, and overall management of sepsis. In 2021, a sepsis alert algorithm was implemented as part of Humber River Health's command center—a centralized management system—supported by information technology and real-time data to predict the deterioration of patients and to enable optimal clinical decision-making throughout the hospital. The objective of the study was to assess mortality and LOS trends in the ED following implementation of the command center's automated sepsis alert system.

Methods

Study design

A retrospective study was undertaken using administrative data from Humber River Health, Toronto, Ontario, Canada. Humber River Health is a large community hospital located in the North-West Greater Toronto Area. The study was approved by Veritas ethics review board, an independent ethics review board. Informed consent was waived by the ethics review board.

Administrative data

Administrative data from 2018 to 2021 were collected. Data included all ED visits, and the main outcomes included in-hospital mortality, triage levels, and LOS in the ED. LOS was defined as the length of time (hours) from triage to the time the patient was discharged from the ED. Patients were classified based on the Canadian Triage and Acuity Scale (CTAS)[13]: CTAS I: severely ill, requires resuscitation; CTAS II: requires emergent care and rapid medical intervention; CTAS III: requires urgent care; CTAS IV: requires less-urgent care; and CTAS V: requires non-urgent care. In addition, discharge description was reported.

Command center's automated sepsis alert system

The automated sepsis alert system was implemented in 2021 as part of the operation of the command center, a centralized management system, which is supported by information technology and real-time data (GE HealthCare Technologies, Inc. Chicago, Illinois, USA). The system is critical for improving organizational communication, coordination, and accountability, as well as achieving high performance.[14]

Prior to implementation, a technical feasibility investigation was conducted and included the mapping requirements of ED. Mapping the location of the patients within Meditech (the hospital electronic medical record for patient demographics, location, and clinical documentation; Medical Information Technology, Inc. MA, USA); and integrating a link to the clinical team member in charge. In February, a web service was implemented, which is an interface transmitting ED clinical information to the ASCOM (Nurse to patient assignment and nurse contact information; ASCOM Holding AG, Zurich, Swiss) of assigned nurse for sepsis risk. Testing and ED staff training occurred in March. The sepsis alert system was launched in full scale in May of 2021 in the ED.

Using the command center's automated sepsis alert system, visual flags were displayed on the tracker based on the patient's Systemic Inflammatory Response Syndrome (SIRS) criteria[15,16] in ED and in the command center tiles. Each tile consists of one to two large screens with the appropriate information required for monitoring patients.

The SIRS criteria used for sepsis and organ failure included the following:

1. Temperature >38°C or <36°C.
2. Heart rate >90/min.
3. Respiratory rate >20/min or PaCO2 < 32 mm Hg (4.3 kPa).
4. Leukocyte count greater than 12000 or less than 4000 /microliters or over 10% immature forms or bands.

Statistical analysis

The IBM SPSS statistics software (IBM SPSS Statistics for Windows, Data analysis was performed using Version 23.0. Armonk, NY: IBM Corp). Descriptive statistics were performed and data are presented as mean ± standard error or percentages as appropriate. Chi-square tests were used to assess differences in mortality rate in different years and different triage levels and discharge description. One-way analysis of variance was used to assess LOS at the ED by years and triage level. A Kaplan–Meier survival analysis was used to estimate the probability of survival during ED LOS, stratified by triage levels. Log-rank tests were used to test statistically significant differences in the survival of patients at different triage levels.

Univariable Cox proportional hazard regression analyses were performed to assess the risk of death associated with LOS in the ED for each year of the study, demographic, and diagnosis variables. The covariates, including age, sex, and diagnosis were evaluated and entered into the multivariable Cox regression model if $p < 0.05$, using backward variable elimination. A p-value of <0.05 was considered significant.

Results

From 2018 to 2021, 511,456 patients were admitted to the ED of Humber River Health. Table 1 presents the age, sex, and major diagnosis for the years 2018 to 2021.

There were no differences in the average age of the patients during the years of the study with an average age of 45.11 (yrs) in 2018; 45.13 (yrs) in 2019; 47.25 (yrs) in 2020; and 46.43 (yrs) in 2021. There were no sex differences as well, with 53.42% female patients in 2018; 53.05% in 2019; 51.87% in 2020; and 52.05% in 2021. In-hospital mortality in the ED from the years 2018 to 2021 was 0.088% (n = 459). In total, 96,324 patients were admitted to the ED in 2018 with a mortality rate of 0.082% (n = 79); 136,819 in 2019 with 0.083% (n = 114) mortality rate; 141,393 in 2020 with 0.097% (n = 138) mortality rate; and 136,920 in 2021 with 0.093 (n = 128) mortality rate. There were no differences in mortality rate from 2018 to 2021 in the ED department (χ^2=2.45, df = 3, $p = 0.483$).

LOS in the ED was the highest in 2021 during the second year of the pandemic with a mean of 4.00 h, compared to the LOS in 2018, 2019, and 2020 (3.63 h, 3.34 h, 3.61 h, respectively) (F = 1038.03, df = 3 $p < 0.001$).

The highest LOS in the emergency room was for CTAS II (4.58 h) followed by CTAS III (3.65 h), CTAS I (2.9646 h), as well as CTAS V and CTAS IV (2.15 and 2.03 h, respectively) (F = 6114.67, df = 4 $p < 0.001$). The LOS significantly differ in each triage level, except for the LOS at triage level CTAS IV and CTAS V, where there are no differences.

The percentage of patients classified as CTAS I was the highest in 2021 (0.70%), compared to 2020 (0.40%), 2019 (0.40%), and 2018 (0.40%), while he highest percentage of patients classified as CTAS V was also in 2021 (3.70%), compared to 2020 (0.60%), 2019 (0.50%), and 2018 (0.50%) ($p < 0.001$) (Figure 1).

The total number of patients that were classified as triage level I from 2018 to 2021 was 2511, and the rate of

Table 1. Patients' characteristics from the years 2018 to 2021.

Discharge description	2018 n = 96,324	2019 n = 136,819	2020 n = 141,393	2021 N = 136,920
LOS in the ED (hrs) Mean (SD)	3.63 (3.11)	3.34 (3.00)	3.61 (3.07)	4.00 (3.33)
Age (yrs) Mean (SD)	45.11 (29.67)	45.13 (29.91)	47.25 (29.66)	46.43 (29.76)
Sex (female %)	n = 51,456 (53.42%)	n = 72,582 (53.05%)	n = 73,340 (51.87%)	n = 71,267 (52.05%)
Mortality rate % (n)	n = 79 (0.082%)	n = 114 (0.083%)	n = 138 (0.097%)	n = 128 (0.093%)
Chest pain % (n)	n = 3612 (3.75%)	n = 5473 (4.00%)	n = 5118 (3.62%)	n = 5299 (3.87%)
Dizziness and giddiness % (n)	n = 1252 (1.30%)	n = 1738 (1.27%)	n = 1524 (1.078%)	n = 1643 (1.20%)
Headache % (n)	n = 1349 (1.40%)	n = 2148 (1.57%)	n = 2121 (1.50%)	n = 2286 (1.67%)
Low back pain % (n)	n = 1165 (1.21%)	n = 1696 (1.24%)	n = 1725 (1.22%)	n = 1794 (1.31%)
Abdominal pain % (n)	n = 4113 (4.27%)	n = 5746 (4.20%)	n = 4963 (3.51%)	n = 5203 (3.80%)
Urinary tract infection % (n)	n = 1753 (1.82%)	n = 2408 (1.76%)	n = 2488 (1.76%)	n = 2410 (1.76%)
Respiratory infection/disorder % (n)	n = 5346 (5.55%)	n = 6896 (5.04%)	n = 9247 6.54%	n = 9064 (6.62%)
Other diagnosis % (n)	n = 77734 (80.7%)	n = 110714 (80.9%)	n = 114207 (80.7%)	n = 109221 (79.7%)

Table 1 presents the demographics and clinical data, including the most common diagnosis. LOS: length of stay; ED: emergency department; hrs: hours; SD: standard deviation; CTAS: Canadian Triage and Acuity Scale.

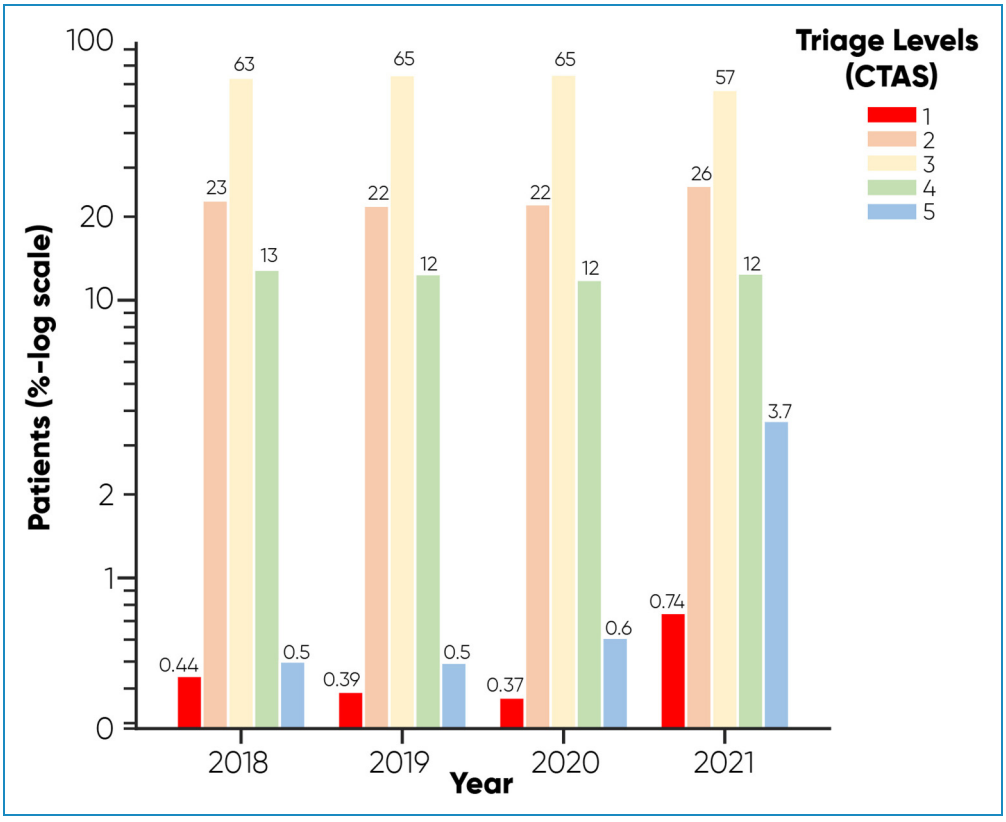

Figure 1. Percentages of patients at each triage levels. The percentage of patients classified as CTAS I and CTAS V was the highest in 2021 compared to 2018, 2019, and 2020. CTAS: Canadian Triage and Acuity Scale.

mortality was 13.9% (n = 350). Breakdowns by year are found in Table 2. The mortality rate for patients classified as CTAS I triage level was the lowest (10.0%, n = 102) in 2021, compared to 2020 (19.0%, n = 100), 2019 (15.7%, n = 84), and 2018 (14.9%, n = 64) ($\chi^2 = 26.85$, df = 3, $p < 0.001$) (Table 2). Discharge description by year is presented in Table 3. The Kaplan–Meier survival curve revealed that for patients classified as CTAS I triage level, the probability of survival was the highest in 2021, after implementation of the sepsis alert algorithm, compared to previous years (Log Rank, Mantel–Cox, χ^2=29.742, $p < 0.001$). No significant differences in survival rate were observed for other triage levels (Figure 2). A Cox proportional analysis, indicated that for patients classified as CTAS I triage level, the risk of mortality was the lowest in 2021, compared to earlier years of the study, while demographic and diagnosis covariates were not significantly associated the risk of mortality related to ED LOS (HR = 0.89, CI = 0.82–0.96, Wald = 7.87, $p = 0.005$). The model of fit evaluation suggested that the model is a significant improvement in fit relative to the null model [χ^2=7.78, $p = 0.0005$]. The most frequent diagnoses of the patients who died within the hospital were cardiac arrest (64.1%), followed by unspecified causes of mortality (5.4%), and acute myocardial infarction (3%).

Table 2. Percentages of death across CTAS triage levels from 2018 to 2021.

Triage levels	2018	2019	2020	2021	*p*-value
CTAS I	15.0%	15.8%	19.0%	10.0%	<0.001
CTAS II	0.1%	0.1%	0.1%	0.1%	N.S
CTAS III	0.0%	0.0%	0.0%	0.0%	N.S
CTAS IV	0.0%	0.0%	0.0%	0.0%	N.S
CTAS V	0.0%	0.0%	0.0%	0.0%	N.S

Percentages of death in patients who were classified as CTAS I during 2021 were the lowest compared to those from 2018 to 2020. No differences were found in percentages of death in CTAS groups across the years 2018 to 2021. CTAS: Canadian Triage and Acuity Scale.

Discussion

After the implementation of the command center's automated sepsis alert system in 2021, we observed significant improvement in the mortality rate associated with LOS in the ED for patients classified as CTAS I triage level. This observation is interesting because during 2021, the LOS

Table 3. Discharge description by year from 2018 to 2021.

Discharge description	2018	2019	2020	2021	Total
Discharge home without support (%)	79.6%	79.8%	79.8%	76.3%	78.9%
Discharge home with support (%)	2.7%	1.2%	0.6%	0.6%	1.3%
Transfer supportive living / Residential care (%)	1.2%	1.3%	1.3%	1.5%	1.3%
Intra-facility transfer to clinic (%)	11.7%	11.8%	13.7%	14.3%	12.8%
Admit to critical care unit / operating room (%)	0.6%	0.8%	0.7%	0.8%	0.7%
Intra-facility transfer to day surgery (%)	0.1%	0.0%	0.0%	0.0%	0.0%
Transfer to another acute care Facility (%)	0.4%	0.5%	0.6%	0.8%	0.6%
Transfer to another non-acute care facility (%)	0.1%	0.1%	0.1%	0.1%	0.1%
Transfer to correctional facility (%)	0.1%	0.1%	0.1%	0.1%	0.1%
Left at his/her own risk (%)	3.50%	4.40%	3.10%	5.50%	4.20%

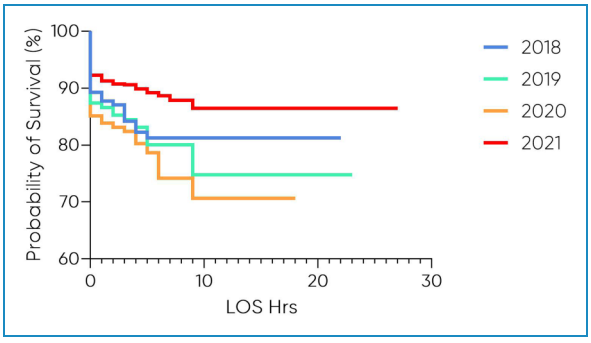

Figure 2. The Kaplan–Meier survival curve displaying survival rate associated with length of stay in patients classified as CTAS I triage level. In patients classified as CTAS I triage level, the probability of survival was the highest in 2021, after implementation of the sepsis alert algorithm, compared to 2018, 2019, and 2020. No significant differences in survival rate were observed for other triage levels. CTAS: Canadian Triage and Acuity Scale.

in the ED was the longest in all patients admitted to the ED, and the percentage of patients classified as CTAS I triage level was the highest compared to previous years. Our findings that LOS at the ED department was the longest during 2021, during the second year of the COVID-19 pandemic, was consistent with the reports of previous studies from the USA, Korea, and China, observing that LOS in the ED was significantly higher in the COVID-19 period compared to the pre-COVID-19 period in South Korea,[17] USA,[18] and China.[19]

Furthermore, previous studies have shown that longer ED LOS is associated with a higher risk of in-hospital mortality.[4–6] A previous study from Ontario, Canada reported that the risk of death increased incrementally with each additional hour of waiting time per shift, and the absolute rates of death and admission were much higher in high acuity than in low-acuity patients.[4] In a study from South Korea, prolonged ED LOS was reported to be associated with in-hospital mortality and 25.3% of adult patients admitted to the intensive care unit (ICU) from the ED had a prolonged ED LOS, which was significantly associated with an increased in-hospital mortality risk.[6] During the COVID-19 pandemic, a study in South Korea demonstrated that longer ED LOS was also reported as a risk factor for in-hospital mortality in patients with severe pneumonia.[20] In sepsis patients, prolonged ED LOS was independently associated with an increased risk of in-hospital mortality requiring ICU admission; specifically, when compared to the group of patients with ED LOS <6 h, those with ED LOS between 12 and 24 h and ED LOS >24 h, prolonged ED LOS was significantly and independently associated with increased risk of hospital mortality.[5] The association remained significant after adjusting for PaO2/FiO2, serum creatinine, age, Sequential Organ Failure Assessment, body mass index, lactate, comorbidities, and infection site.[5]

A study from Ontario, Canada reported that in multivariable analyses, the risk of death within 7 days after leaving the ED increased incrementally with each additional hour of mean waiting time, while the absolute rates of death and admission were much higher in high rather than in low-acuity patients.[4] A study from Sweden found that 7-day and 30-day mortality rates from registration to the ED were in the highest triage priority level, which was similar to our observation.[3] In contrast, prolonged ED LOS was associated with increased mortality in patients

with lower clinical urgency, whereas a negative association was observed between ED LOS and mortality in patients with the highest triage priority.[3]

In our study, we found that in-hospital mortality was similar during the years 2018 to 2021 in all patients admitted to the ED, whereas in the subgroup of patients who were classified as CTAS I triage, the mortality rate was the lowest in 2021 compared to previous years. This was akin to the findings in the literature, wherein the absolute rates of death and admission were much higher in high rather than low-acuity patients.[4] Furthermore, among severely ill patients during the COVID-19 pandemic, ED LOS increased by 203.7%.[21] The findings of this study are similar to our observation that the highest LOS in the ED was for CTAS I to CTAS III. A previous study reported that during the COVID-19 pandemic, ED mortality increased significantly.[17]

Studies have previously implemented early sepsis warning systems in smaller scale operating systems.[12,22,23] Implementation of a real-time computerized sepsis alert in non-ICU patients resulted in an increase in early appropriate therapeutic and diagnostic interventions among non-intensive care patients at risk for sepsis.[22] Compared with the non-intervention group, patients in the intervention group, flagged by the early sepsis warning system, were more likely to have received at least one medical intervention for sepsis, including increases in antibiotic escalation, intravenous fluid administration, and oxygen therapy. However, both groups had similar rates of ICU transfer, hospital mortality, and hospital LOS. Another automated early warning and response system for sepsis implementation and increased identification of sepsis in at-risk patients resulted in increases in early sepsis care, ICU transfer, and system activations for the general medicine units, but only a trend was found in decreased sepsis mortality and increased discharge from hospital.[23] In a systematic review and meta-analysis on the impact of digital alerting systems on sepsis-related outcomes, reported a significant benefit in reducing LOS by 1.31 days and ICU LOS by 0.766 days, whereas there was no significant association between sepsis digital alerts and mortality rates.[12]

We observed an improvement in mortality rate, while other studies did not observe significant reduction in mortality rate despite the improvement in the management of the patients with sepsis with sepsis alert system implementation. The main difference of our sepsis alert system is that a hospital-wide, centralized approach was taken allowing the diversion of staff and resources to patients at risk of sepsis, rather than a decentralized approach in specific clinical settings. The results may also be attributed to implementing a sepsis alert system as part of the command center, which is a centralized management system, supported by information technology, predictive analytics, and real-time data in the entire hospital.[24,25] Previous studies implemented early sepsis warning system outside a command center domain, while in our hospital sepsis alert was implemented as part of the command center, which has centralized monitoring and operating system for the entire hospital, optimizing patient flow, delivery of care, and clinical outcomes, but rather in smaller scale centralized operating systems. This may explain the lack of effects on mortality of an automated early sepsis warning system in smaller scale centralized operating systems. A sepsis warning system as part of a command center operation may allow better deployment of staff and resources and management of sepsis.

The major limitation of the study is that this is an observational study using administrative data. Also, the study was conducted in a single center. Future studies should confirm the findings in a large multi-center study. In our study, we did not analyze variables, such as arrival by ambulance, vital signs, and admission categories. Future studies should include these variables since they may affect the outcomes of the study. Since, we analyzed yearly data, we did not exclude data during web service implementation, testing, and training in addition to data obtained after a full-scale launch of the sepsis alert system. Nevertheless, it is possible that the results could be even more promising with more experience and resolution of technical challenges that are common during the first stage of system implementation.

Conclusion

We observed that an automated sepsis alert system as part of a command center operation significantly improved the mortality rate associated with LOS in the ED for patients in the highest triage level. A sepsis warning system as part of a command center operation has the potential to improve clinical outcomes in the ED.

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Ethical approval: This retrospective study, using administrative data was performed in accordance with ethical guidelines and was approved by the Veritas Institutional Review Board (IRB)

Inc., an independent ethics review board (https://www.veritasirb.com/index.html). All methods were carried out in accordance with ethical guidelines (IRB number: 2023-3316-15634-2).
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