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Assessing and Improving Sepsis Bundle Compliance Among Emergency Medicine and Internal Medicine Residents and Outcomes Associated With Septic Shock Through an Educational Intervention

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Abstract

Objective

To assess whether a structured educational intervention for Emergency Medicine and Internal Medicine residents improved sepsis-bundle compliance and patient outcomes. Methods: A quasi-experimental before-and-after study at King Hamad University Hospital compared 150 patients before and 150 after face-to-face and online teaching on sepsis recognition and management. Outcomes included lactate measurement, blood cultures before antibiotics, intravenous fluids and antibiotics within 1 hour, complete four-component bundle compliance, mortality, supportive therapies, and hospital length of stay. Results: Compliance improved for lactate measurement (57.3% to 71.3%), blood cultures before antibiotics (49.3% to 68.7%), intravenous fluids within 1 hour (49.3% to 66.7%), antibiotics within 1 hour (61.3% to 74.0%), and all four components (20.7% to 42.0%). Mortality decreased from 56.0% to 24.0%, and median hospital stay from 12.5 to 5.0 days. Post-intervention status remained independently associated with lower mortality (adjusted OR 0.25, 95% CI 0.14–0.43; $p < 0.001$). Conclusion: Structured resident education was associated with improved sepsis-bundle compliance and better overall clinical outcomes, although the mortality reduction in the septic-shock subgroup was not statistically significant.

Key Points

Structured education for Emergency Medicine and Internal Medicine residents was associated with improved compliance across all four evaluated sepsis-bundle components.

Complete four-component bundle compliance increased from 20.7% before the intervention to 42.0% after the intervention.

In-hospital mortality decreased from 56.0% to 24.0%, while median hospital length of stay decreased from 12.5 to 5.0 days.

The post-intervention period remained independently associated with lower mortality after adjustment, but the mortality reduction in the septic-shock subgroup was not statistically significant.

Introduction

Sepsis and septic shock are still a huge burden on the health care system and are still a significant cause of morbidity and mortality in the world. According to data from the Global Burden of Disease Study, there were estimated to be 48.9 million incident cases of sepsis and 11.0 million deaths due to sepsis in 2017, representing an estimated 20% of all deaths worldwide (1). The burden is particularly high in low and middle income countries where the lack of early recognition, diagnostic services, timely antimicrobial therapy and critical care services may add to poor outcomes (2). Sepsis is a life-threatening organ dysfunction that results from a dysregulated host response to infection and septic

shock is a more severe form that is characterized by circulatory and metabolic abnormalities, together with a higher risk of death (3). Sepsis is time sensitive and early recognition and treatment is critical.

Surviving Sepsis Campaign (SSC) was created to increase awareness, uniform practice and evidence-based management of sepsis and septic shock to reduce preventable sepsis and septic shock deaths. The recommendations provided in the SSC seek to highlight the importance of early implementation of structured sepsis bundles. The 2018 update combined the three-hour and six-hour interventions into a single one-hour intervention package which consists of measuring serum lactate, obtaining blood cultures prior to the start of antimicrobial therapy, early administration of broad-spectrum antibiotics if indicated, early IV crystalloid resuscitation if indicated, and early administration of vasopressors for ongoing hypotension (4). It is these principles that are still key in the current SSC guidelines (5).

Improved clinical outcomes have been reported with compliance to sepsis bundles. A systematic review and meta-analysis found that performance improvement programs can substantially improve bundle compliance, and that they can potentially reduce mortality (6). Sepsis care that occurs at the right time has also been linked to better survival and reduces health care costs (7). However, implementation of recommended interventions is still difficult, especially in the ED and general medical wards, where patients can have non-specific symptoms and other clinical issues.

Emergency Medicine and Internal Medicine residents play an important role in identifying and initial treatment of sepsis. Patients with septic shock may be initially treated in the emergency department and then admitted to medical wards or more acutely ill units and/or may develop sepsis in hospital. Failing to recognize delayed symptoms, lack of knowledge, or failure to follow treatment protocols and insufficient communication between teams can then reduce the amount of time that it takes to provide care. Prior studies have found inconsistent knowledge and adherence to sepsis guidelines among resident physicians which indicates the need for education programs that effectively and systematically teach physicians about sepsis (8, 9).

Sepsis guidelines could be translated into routine practice through the use of an educational intervention such as lecture, case-based discussion, simulation or quality-improvement programs. Using simulation-based education, clinicians can detect deterioration, make decisions regarding treatment and engage in communication in a safe setting. However, Dugan et al. demonstrated that simulation enhanced pediatric residents' recognition and management of septic shock and that further simulation enhanced this, as well (10). Organized quality improvement efforts that include education, feedback, and organizational support also have been linked to higher adherence rates to the bundles and improved patient outcomes (6, 11).

The goal of the current study, therefore, was to determine the impact of an educational intervention on compliance with sepsis bundle in EM and IM residents. Secondary aims included increasing awareness and management of sepsis, assessing mortality rates before and after the implementation, reducing hospital stay and facilitating good team working between the two resident groups.

Methods

Study Design

The objective of this study was to determine if a structured educational intervention for residents had an impact on adherence to recommended sepsis management and patient outcome in a quasi-experimental before and after design. The project was designed to be a quality improvement project that had two strands of evaluation. The original protocol called for assessment of residents' knowledge both pre- and post-training at the provider level with the residents who participated in the training as their own controls. The clinical practice and outcomes at the patient level was compared between the pre-intervention period and post-intervention period. This design was chosen because of the need to see changes in routine clinical practice following the implementation of the education program, as in the case of quality-improvement before and after an educational program in sepsis care.

Study Setting

The study was carried out in King Hamad University Hospital (KHUH). The intervention was focused on the Emergency Medicine and Internal Medicine services since they have direct access to the patients with sepsis and septic shock and provide the initial stabilization, ongoing care and transfer of these patients to other facilities. Patients can usually be identified in both the Emergency Department and then admitted to Internal Medicine or a higher acuity environment for treatment or may develop sepsis after admission for an inpatient visit. Hence, it was planned to include both clinical services to promote continuity of sepsis management throughout the patient journey and a common strategy to early recognition and treatment of sepsis.

Study Population

The study protocol included residents of Emergency Medicine and Internal Medicine who were working at KHUH. These residents were chosen as they are front-line clinicians who treat patients with sepsis and septic shock in the initial stages of assessment and treatment. The educational component was to enhance awareness of sepsis recognition and management and ensure the educational collaboration between the two clinical teams.

The final sample consisted of 300 patients (150 treated prior to the educational intervention, and 150 treated following the intervention) for the evaluation of clinical practice and patient outcomes. The database consisted of patients with severe sepsis (SS) or septic shock (SSS), along with baseline demographic and clinical characteristics, specific comorbidities, specific components of the sepsis bundle, treatment needed for supportive measures, hospital death, and hospital length of stay.

Sample Size

The original protocol involved calculating the provider sample size based on a paired comparison design, with pre and post scores of provider knowledge. The original protocol involved calculating a provider sample size based on a paired comparison design (pre and post scores of provider knowledge). The proposal had a statistical power of 80%, an expected effect size of 0.7 and a standard deviation of 2.5. It also had an alpha value of 0.5. This value is not typical of biomedical research, and no corrected value is given in the source documents, so this value should be checked against the original sample-size calculation before the manuscript is sent to the journals—not assumed to be true and silently changed.

All 300 observations in the final analytical dataset were used in the patient-level analysis; and there were an equal number of patients in each group (pre-intervention and post-intervention, n = 150 in each group). No information of a second patient sample size calculation was provided in the provided study materials.

Educational Intervention

The educational intervention aimed to enhance the recognition and evidence-based management of sepsis for Emergency Medicine (EM) and Internal Medicine (IM) residents. The training was provided in-person, as well as via Zoom, with course facilitators. The programme also included discussion of uncomplicated and complicated sepsis related clinical scenarios to further reinforce residents' understanding of how to recognize, investigate, prioritize treatment, escalate care and communicate with respect to a scenario they may find themselves in a similar situation to routine clinical practice. Residents have previously been found to have suboptimal recognition and management of septic shock, and simulation and case-based education have been demonstrated to help improve them (10).

The intervention focused on the early implementation of key sepsis-management interventions based on the Surviving Sepsis Campaign (5). The following four components of the bundle were evaluated in the patient-level analysis: measure serum lactate, obtain blood cultures prior to antibiotics, give intravenous fluids within 1 hour, and give antibiotics within 1 hour. All four are deemed to be a complete bundle.

The intervention also was designed to enhance the coordination of the EM and IM residents. Concurrently training both groups was designed to minimize variability in sepsis recognition and initial care, strengthen common goals of care, and enhance communication between the two when transferring care, and facilitate the prompt and standardized implementation of evidence-based sepsis management.

Study of Intervention

The project was divided into three stages: The project was divided into three phases: The pre-intervention (Phase 1) clinical data were taken from the Emergency Department and Internal Medicine services. The protocol was to assess the compliance of existing sepsis bundle and patient mortality and mean hospital LOS in the patients admitted with sepsis, severe sepsis and septic shock. A predefined

questionnaire was also to be used to measure the resident knowledge. This phase aimed to build in practice and to determine barriers to the effective implementation of the sepsis protocol.

The educational intervention comprised Phase 2. Special training was provided to residents on the recognition and management of sepsis, both face-to-face and online. Using clinical scenarios, prompt clinical decision making and application of principles of recommended sepsis management was reinforced. The intervention involved both EM and IM residents to educate on care provided at initial presentation and care provided during inpatient management.

In the post intervention (Phase 3), the clinical data was recollected following a similar general structure. The compliance of the sepsis bundle was re-evaluated following the educational program and outcomes were compared to the pre-intervention period. Patient-level data comprised mortality, hospital length of stay, inotropic requirements, oxygen treatment and mechanical ventilation. Three months before and three months after the intervention, data was collected over a total project duration that included implementation of the educational program, as well as post-intervention data collection.

Definitions

The study protocol specified that sepsis would be recognized early based on the Sepsis-3 guidelines. For sepsis-3, the definition of sepsis is the presence of dysregulated host response to infection with life-threatening organ dysfunction, and septic shock is sepsis with circulatory and metabolic abnormalities that are particularly severe (3). The prompt recognition and initiation of treatment for patients with suspected sepsis or septic shock is also a key message in current recommendations of the Surviving Sepsis Campaign (5).

Severe sepsis" and "septic shock," though, were kept in the final patient dataset. These categories were thus left unchanged from the original recording and not re-classified at the patient level without all the source level clinical variables. Compliance was used for bundle analysis based on documentation of four components of the bundle: measurement of lactate, blood cultures prior to antibiotic use, intravenous fluids within 1 hour, and antibiotic initiation within 1 hour. To comply with all four parts of the bundle, all four parts had to be documented.

Outcome Measures

The major outcome measure was for sepsis bundle compliance pre and post educational intervention. The four components were evaluated separately, and as a total (four-component bundle). Change in compliance was expressed in percentage points.

The major clinical outcomes were in-hospital mortality and hospital stay. Other outcomes that were present in the final dataset included inotropic support, oxygen therapy and mechanical ventilation. The patient groups pre and post intervention were compared for these outcomes.

The original protocol also included objectives for teaching residents about improving their knowledge and teamwork with each other between EM and IM. The final results provided, however, are not pre- or post-intervention knowledge scores nor a direct validated measure of teamwork. These objectives were therefore being retained as planned provider level objectives and it was not analyzed as patient level endpoints in the present results.

Statistical Analysis

Categorical data were described by frequencies and percentages and continuous data were described by either means and standard deviations or medians and interquartile ranges, depending on the type of data. The baseline characteristics of the subjects such as age, body weight, gender, sepsis severity, diabetes mellitus, hypertension, chronic liver disease, chronic kidney disease, and OLD were compared between pre- and post-intervention groups.

Pearson's chi-square test was used to compare categorical variables. The compliance with the sepsis bundle was evaluated on the measurement of lactate, obtaining blood cultures prior to starting antibiotics, administration of intravenous fluids within 1 hour, and administration of antibiotics within 1 hour, as well as a full completion of all four sepsis bundle items. Results were presented as n/N (%), differences in percentage and p values.

The clinical outcomes such as hospital mortality, inotropes, oxygen therapy and mechanical ventilators were compared with Chi-square test. The median and interquartile range were used to report length of stay at the hospital and it was compared by Mann–Whitney U test.

Multivariable binary logistic regression was performed to examine the independent association of post-intervention period with hospital mortality after adjusting for age, gender, severity of sepsis, diabetes mellitus, hypertension and chronic kidney disease. An adjusted analysis was carried out separately among patients with septic shock. Odds ratios with 95% confidence intervals were reported and the p value < 0.05 (two-sided) was deemed statistically significant.

Ethical Considerations

The study was formally approved by the Royal Medical Services and King Hamad University Hospital Institutional Review Board (RMS-KHUH IRB), Kingdom of Bahrain (reference no. RMS-KHUH/IRB/2025 – 1013). Informed consent to participate was obtained from the Emergency Medicine and Internal Medicine residents before the educational intervention as part of the study participation form. Patient-level clinical data used in the before-and-after analysis were anonymized, and no identifiable patient variables were collected or reported; individual patient consent was therefore not obtained. All methods were performed in accordance with relevant institutional guidelines and regulations and with the principles of the Declaration of Helsinki.

Results

Baseline Characteristics

Table 1 explain the characteristics of 300 patients, 150 of whom were evaluated before the educational intervention and 150 patients' post-intervention. There was not much difference between the two groups when it came to the mean age, dropping from 66.2 ± 16.7 years before the intervention to 64.6 ± 10.4 years after the intervention. There was no significant difference between these ($p = 0.298$). The mean weight of the body before the intervention (68.9 ± 16.0 kg) was significantly higher than after the intervention (64.0 ± 15.9 kg) ($p = 0.009$).

As for gender distribution 56.0% of the patients were in Category 1 prior to the intervention while 64.7% were in Category 1 after the intervention, but the difference was not statistically significant ($p = 0.157$). Likewise, the severity of sepsis and septic shock was not different between groups ($p = 0.424$).

The prevalence of diabetes mellitus and hypertension were significant different. Diabetes and hypertension were lower after the intervention (32.7% and 45.3%, respectively, compared to 71.3% and 71.3% prior to the intervention, respectively), as were both differences in these two conditions ($p < 0.001$). While chronic liver disease ($p = 0.111$), chronic kidney disease ($p = 0.062$) and OLD ($p = 0.210$) had no significant difference between groups, there was a tendency towards it. Mean values of most of the baseline parameter were similar, with significant differences in body weight, diabetes and hypertension.

Table 1
Baseline characteristics of patients before and after the educational intervention.

Characteristics	Before intervention	After intervention	Value of p
Patients, n (%)	150 (50.0%)	150 (50.0%)	
Age - years, n = 300			
Mean (SD)	66.2 (16.7)	64.6 (10.4)	0.298
Median [Q1-Q3]	68.5 [56.2–77.0]	65.0 [56.0-72.8]	
Not available	0	0	
Body weight, n = 300			
Mean (SD)	68.9 (16.0)	64.0 (15.9)	0.009
Median [Q1-Q3]	66.0 [58.0–79.0]	63.0 [54.0–69.0]	
Not available	0	0	
Gender - n (%)			0.157
Category 1	84/150 (56.0%)	97/150 (64.7%)	
Category 2	66/150 (44.0%)	53/150 (35.3%)	
Not available	0	0	
Sepsis severity - n (%)			0.424
Severe sepsis	109/150 (72.7%)	116/150 (77.3%)	
Septic shock	41/150 (27.3%)	34/150 (22.7%)	
Diabetes mellitus - n (%)	107/150 (71.3%)	49/150 (32.7%)	< 0.001
Hypertension - n (%)	107/150 (71.3%)	68/150 (45.3%)	< 0.001
Chronic liver disease - n (%)	17/149 (11.4%)	28/150 (18.7%)	0.111
Chronic kidney disease - n (%)	45/150 (30.0%)	30/150 (20.0%)	0.062
OLD - n (%)	16/150 (10.7%)	9/150 (6.0%)	0.210

Sepsis Bundle Compliance Before and After Educational Intervention

Table 2 explain a significant increase after the educational intervention for each of the components measured in the sepsis bundle. Prior to the intervention compliance was relatively low with each component of the sepsis bundle clearly improving post intervention. Compliance rose from 57.3% to 71.3% (14.0 percentage points increase, p = 0.016) for lactate measurement. Blood cultures pre-antibiotics usage increased from 49.3% to 68.7% (19.3 percentage points, p = 0.001). Similarly, IV fluids

within 1 hour rose from 49.3% to 66.7%, with a 17.3 percentage point gain (p = 0.003). There was also an increase in antibiotic administration within 1 hour, from 61.3% to 74.0%, an increase of 12.7 percentage points (p = 0.026). The greatest result is the significant improvement in the overall completion of all four bundle components with a difference in 21.3 percentage points (P<0.001) between pre- and post-intervention results, from 20.7% to 42.0%. All p-values are < 0.05, which means that these changes are statistically significant.

Overall, the table suggests that the educational intervention was successful in enhanced timely compliance with sepsis management guidelines, particularly in terms of managing the sepsis bundle comprehensively.

Table 2

Comparison of sepsis bundle compliance before and after the educational intervention

Measure	Pre n/N (%)	Post n/N (%)	Change pp	Test	p
Lactate measured	86/150 (57.3%)	107/150 (71.3%)	+ 14.0	Chi-square	0.016
Blood cultures before antibiotics	74/150 (49.3%)	103/150 (68.7%)	+ 19.3	Chi-square	0.001
IV fluids within 1 hour	74/150 (49.3%)	100/150 (66.7%)	+ 17.3	Chi-square	0.003
Antibiotic within 1 hour	92/150 (61.3%)	111/150 (74.0%)	+ 12.7	Chi-square	0.026
All 4 components completed	31/150 (20.7%)	63/150 (42.0%)	+ 21.3	Chi-square	< 0.001

Overall four-component bundle completion increased from 20.7% to 42.0% (p < 0.001).

The bar chart shows the sepsis bundle compliance before and after training. The intervention had a positive effect on compliance overall on all five measures. Lactate measurement improved from 57.3% pre intervention to 71.3% post intervention, indicating a definite improvement in the rate of assessment. One of the biggest improvements on an individual component basis was in the culture of obtaining blood cultures prior to antibiotic treatment, which rose from 49.3% to 68.7%. Administration of IV fluids within one hour was 49.3% prior to the educational intervention, and 66.7% following the intervention. The highest compliance rate overall, following the interventions, was for giving antibiotics within 1 hour, going from 61.3% to 74.0%. The greatest improvement was seen in completion of the 4 components of the sepsis bundle. Prior to the intervention, only 20.7% of patients had all four components, and 42.0% had all four components after the intervention. This is a significant increase in the adherence to complete bundles (Figure-1).

Overall, the graph shows that there was a positive impact of the educational intervention on the practices of sepsis management. The bars are higher post-intervention for all elements of the 4 component bundle of sepsis-related care processes, showing adherence to the recommended care processes is more consistent.

Clinical Outcomes Before and After Educational Intervention

The clinical results of patients receiving the educational intervention or not are compared in Table 3. Results indicate a significant increase in all outcomes assessed after the intervention. There was a significant reduction in mortality from 56.0% before the intervention to 24.0% after the intervention ($p < 0.001$).A similar decrease was observed with the need for inotropic support (26.7% vs 12.0%, $p = 0.002$). Likewise, the number of patients using oxygen therapy before the intervention was 58.7%, but after was 33.3% ($p < 0.001$). A significant change was seen in the use of mechanical ventilation from 41.3% to 12.0% following the education intervention. This difference also was highly significant ($p < 0.001$).

Furthermore, median hospital stays also reduced from 12.5 days (IQR 7.0–20.0) prior to the intervention to 5.0 days (IQR 4.0–12.0) after the intervention. This reduction was statistically significant ($p < 0.001$) by the Mann–Whitney U test. In general, these results indicate that there was a significant improvement in the clinical outcomes of the educational intervention (mortality, need for supportive treatment and length of hospital stay).

Table 3
Clinical outcomes before and after the educational intervention

Outcome	Pre	Post	Test	p
Mortality	84/150 (56.0%)	36/150 (24.0%)	Chi-square	< 0.001
Inotropes	40/150 (26.7%)	18/150 (12.0%)	Chi-square	0.002
Oxygen	88/150 (58.7%)	50/150 (33.3%)	Chi-square	< 0.001
Mechanical ventilation	62/150 (41.3%)	18/150 (12.0%)	Chi-square	< 0.001
Length of stay, median (IQR)	12.5 (7.0–20.0)	5.0 (4.0–12.0)	Mann-Whitney U	< 0.001

Hospital Mortality

The bar graph shows the difference between before and after the educational intervention in terms of mortality. The mortality rate prior to the intervention was 56.0%, meaning that over half of the patients were not alive when the intervention was performed. There was significant reduction in mortality after the educational intervention (24.0%). This is a significant increase in patient outcomes after the intervention, compared with the 32 percentage points decrease.

There has been a significant drop in mortality which indicates that the educational programme might have helped residents to better identify and respond to sepsis. This improvement may have been partly due to improved compliance with sepsis management principles such as performing timely lactate test, taking blood cultures, initiating fluid resuscitation and early antibiotics. The reduction in mortality in the post intervention group compared to the pre intervention group was found to be statistically significant ($p < 0.001$), so the difference is not likely to be due to chance (Figure-2). The entire graph shows that there was a high correlation between the educational intervention and survival in patients with sepsis.

Length of Hospital Stay

The box plot is used to compare the length of stay in hospital before and after the educational intervention. The median hospital stay prior to the intervention was around 12.5 days (IQR 7–20 days). The median was significantly reduced after the intervention to approximately 5 days (IQR 4–12) for the length of stay (Figure-03). The pre intervention group also displays more variation of values, which reflects greater variability in the length of hospital stay. The median and distribution for the post intervention group are comparatively low however, suggesting that patients were discharged earlier at the intervention site. The Mann–Whitney U test was used to test for statistical significance and this was found for the reduction in length of stay ($p < 0.001$). Overall, this graph suggests that the educational intervention was linked with a significant reduction in length of hospital stay, which suggests that sepsis patients had improved and more efficient management.

Multivariable Logistic Regression Analysis for Mortality

The results of multivariable logistic regression analysis for mortality are displayed in Table 4, which shows the independent relationship each of these variables has with the odds of mortality after controlling for the other variables in the model. The most significant and only statistically significant predictor was the post intervention period. However, patients in the post intervention group had significantly lower odds of mortality than those in the pre intervention group (aOR = 0.25, 95% CI: 0.14–0.43, $p < 0.001$). This means that the odds of death were about 75% lower after the education intervention. There was no significant association between age and mortality (OR = 1.00, $p = 0.841$). In the same way, the gender category, diabetes mellitus, hypertension and chronic kidney disease were not significant predictors as the p values were above 0.05 with 1 being included in the confidence intervals. There were higher odds of mortality in patients with septic shock than in severe sepsis after adjusting for other factors (OR = 1.73). This association was close to being statistically significant ($p = 0.057$; 95% CI: 0.98–3.04), however. In conclusion, the regression results indicated that the post-intervention period was still independently associated with decreased mortality after controlling for age, sex, severity of the sepsis, diabetes, hypertension, and chronic kidney disease.

Table 4
Multivariable logistic regression analysis for mortality

Predictor	Adjusted OR	95% CI	p
Post vs pre	0.25	0.14–0.43	< 0.001
Age (per year)	1.00	0.98–1.02	0.841
Gender category 2 vs 1	0.97	0.58–1.62	0.895
Septic shock vs severe sepsis	1.73	0.98–3.04	0.057
DM: yes vs no	1.20	0.69–2.08	0.523
HTN: yes vs no	0.94	0.55–1.62	0.831
CKD: yes vs no	0.68	0.38–1.23	0.201

Septic Shock Subgroup Analysis

Table 5 shows the adjusted analysis of factors associated with hospital mortality of septic shock patients. All p values were > 0.05 and none of the variables studied were statistically significant when adjusted for age, gender, diabetes mellitus, hypertension and chronic kidney disease. Patients subjected to the educational intervention had reduced odds of hospital death after the educational intervention relative to their odds of death prior to the intervention (OR = 0.52, 95% CI: 0.17–1.58, p = 0.251). The association was not statistically significant, however, due to the confidence interval containing 1, which indicates ~ 48% decreased risk of death.

There was no significant association between age and mortality (OR = 0.99, p = 0.440). Likewise, there was no significant association with the gender category 2 (OR = 0.89, p = 0.813). Diabetes mellitus was found to have a positive association with mortality (1.40) although this was not significant (p = 0.548). Hypertension (OR = 0.54, p = 0.304) and chronic kidney disease (OR = 0.77, p = 0.649) were also not significant predictors. In summary, none of the individual factors was found to be an independent predictor of hospital mortality in the septic shock sub-group and the large confidence intervals provide a high degree of uncertainty in the estimates.

Table 5

Adjusted analysis of factors associated with hospital mortality among patients with septic shock.

Variable	Adjusted OR (95% CI)	Value of p (Wald test)
After vs. before intervention	0.52 (0.17–1.58)	0.251
Age (per year)	0.99 (0.95–1.02)	0.440
Gender category 2 vs. 1	0.89 (0.33–2.37)	0.813
Diabetes mellitus (Yes vs. No)	1.40 (0.47–4.23)	0.548
Hypertension (Yes vs. No)	0.54 (0.17–1.75)	0.304
Chronic kidney disease (Yes vs. No)	0.77 (0.25–2.34)	0.649

Discussion

The present study aimed to assess the effectiveness of an educational intervention to enhance compliance with the sepsis bundle and clinical outcomes of severe sepsis and septic shock patients. The results showed significant gains across all the domains of the adherence to recommended practices for sepsis management following the educational intervention. The benefits of these changes included decreased mortality, need for fewer inotropic agents, oxygen, and mechanical ventilation and decreased hospital length of stay. These results concur, then, with the use of structured educational and quality improvement initiatives to enhance recognition and early management of sepsis. The baseline characteristics revealed that there was no significant difference between the pre- and post-intervention groups regarding age, gender, severity of sepsis, chronic liver disease, chronic kidney disease and obstructive lung disease. However, the differences were great in case of body weight, diabetes mellitus and hypertension. The pre-intervention group had a higher prevalence of diabetes mellitus than the post-intervention group and hypertension was also significantly higher in the pre-intervention group compared to the post-intervention group. The differences from these baselines are relevant as they may be associated with different prognosis in those who are critically ill and have co-morbidities. Therefore, the bare facts of the improved mortality must not be deemed to be solely due to the intervention without taking account of the (potential) confounding factors. However, multivariate regression analysis revealed that the post-intervention period continued to be significantly protective against mortality after controlling for several important patient characteristics.

An improvement in compliance with individual components of the sepsis bundle was one of the most important findings of this study. The percentage of patients having lactate levels measured before and after antibiotic use increased from 57.3% to 71.3%, blood cultures taken prior to antibiotic use went up from 49.3% to 68.7%, and the percentage of patients receiving IV fluids within one hour went up from 49.3% to 66.7%, while antibiotic use within one hour increased from 61.3% to 74.0%. Most important, there was a significant change in the percentage that completed all four bundle components from pre-intervention (20.7%) to post-intervention (42.0%). All these differences were statistically significant.

In previous studies, which have shown that educational and performance improvement programs can markedly improve adherence to sepsis guidelines, these findings support this. In a multicenter study in Spain, Ferrer et al. (12) showed that a national educational program that incorporated the Surviving Sepsis Campaign guidelines led to an increase in the compliance with the recommended "processes of care" and was correlated with a decrease in the hospital mortality rate. In a systematic review and meta-analysis, Damiani et al. (6) demonstrated that performance-enhancement programs were effective in improving compliance with sepsis bundles and there was a significant association between the programs and decreased mortality. In this study, the improvement noted, therefore, constitutes additional evidence supporting the effectiveness of structured provider education as an effective method to implement sepsis guidelines into the routine practice of health care providers (18–22). Antibiotics play a crucial role in the treatment of sepsis and septic shock, especially when given early on. The antibiotic administration within one hour was increased from 61.3% to 74.0% post the education session (present study). Kumar et al. (13) showed that the length of time before effective antimicrobial treatment was started after development of hypotension was found to be inversely linked to survival rates in patients with septic shock. Ferrer et al. (14) also reported an association between when antibiotics were administered and patient mortality in patients with severe sepsis and septic shock. More recently, Seymour et al. (15) showed an association between increased time to antibiotic administration with increased risk adjusted in-hospital mortality. This improvement in the timely delivery of antibiotics in this study could thus have been a factor in the improved clinical outcomes during the post-intervention period.

One of the most clinically significant was the decreased mortality. The mortality rate went down from 56.0% prior to the intervention to 24.0% following the intervention. Multivariate logistic regression analyses also revealed that the adjusted odds for mortality were 75% lower in patients in the post-intervention period than in patients before the intervention (adjusted OR = 0.25, 95% CI: 0.14–0.43, $p < 0.001$). This association remained even after accounting for age, sex, severity of sepsis, diabetes mellitus and hypertension/chronic kidney disease. The finding is in line with previous studies which have shown that compliance with the sepsis bundles is associated with improved mortality (23–28). In the study by Levy et al. (16), improvement in compliance with Surviving Sepsis Campaign performance measures was correlated with decreases in mortality in the hospitals that participated in the study. The latter also supports the results with other clinical outcomes improving. The need for inotropes dropped from 26.7% to 12.0%, mechanical ventilation dropped from 41.3% to 12.0%, and the use of oxygen therapy dropped from 58.7% to 33.3%. Early recognition of sepsis, prompt use of appropriate antimicrobial therapy and appropriate fluid resuscitation may be beneficial in reducing the progression of sepsis to organ dysfunction and either cardiovascular or respiratory failure. Evans et al. (5) highlighted key components of treating sepsis, including the need to assess patients quickly, provide early antimicrobial treatment, obtain a lactate level, provide hemodynamic resuscitation, and manage fluid, which are all crucial components of sepsis care. Also, the median hospital stay was significantly reduced from 12.5 days prior to the intervention to 5.0 days post the intervention. This reduction could be due to earlier diagnosis of sepsis and to a better management of treatment and fewer complications. There

have been similar quality improvement initiatives that have seen clinical, and resource utilization, benefits after implementing standardized sepsis protocols. For instance, Miller et al. (17) showed that compliance with the sepsis bundle was higher in a multicenter sepsis treatment program resulting in better patient outcomes (29–33).

An interesting finding was that of the subgroup analysis restricted to the patients with septic shock, there was no significant difference between either of the groups. The adjusted odds ratio for mortality at the end of the intervention (OR = 0.52) was lower, but did not reach statistical significance (95% CI: 0.17–1.58, p = 0.251). Other variables that were assessed in this group, such as diabetes mellitus, hypertension and chronic kidney disease, were not significant predictors of death. That this should not be interpreted as meaning that there was no benefit for patients with septic shock. The wide confidence interval indicates poor precision, which could be due to either the relatively small size of the sample of septic shock patients and/or low statistical power. Larger studies would thus need to be performed to further elucidate the impact of educational interventions particularly in patients with septic shock. While the results are favorable, there are a number of issues that need to be taken into account. The study was not randomized controlled design but was before and after design. Improvements could, therefore, be due to changes in staffing, clinical experience, hospital policies or patient characteristics over time. The two groups were also not the same, however, since there were a number of baseline differences in diabetes, hypertension, and body weight. While a number of potential confounders were adjusted for in a multivariable regression, residual confounding cannot be ruled out. In addition, while good knowledge and collaboration amongst the providers are key objectives of education, they should be assessed directly using validated tools, but this is not a target for improvement. Finally, adherence to all elements of the sepsis management bundle was significantly improved after the educational intervention and there was a significant increase in the complete sepsis management bundle. These improvements have been matched by a decrease in mortality, requirement for supportive therapies and hospitalization. Structured sepsis education was also independently associated with decreased mortality during the period after the intervention, confirming the possible clinical value of the intervention. Sustaining such improvements and further improving the quality of sepsis care may be supported by ongoing education programmes, regular audits, feedback mechanisms and by the regular monitoring of the compliance of the bundles.

Conclusion

The current study compared the success of an educational intervention in compliance with the sepsis bundle and survival in patients with severe sepsis/septic shock. Results indicated that the intervention was found to be significantly correlated with increases in adherence to recommended sepsis management practices. Compliance improved after the intervention for lactate measurement, obtaining blood cultures before antibiotics, administration of IV fluids within 1 hour and administration of antibiotics within 1 hour. Improvements were also observed with respect to the completion of all four sepsis bundle elements, which also rose significantly, showing improved overall adherence to evidence-based sepsis care. Better clinical outcomes were associated with the improvement in bundle

compliance. Significant reduction in mortality after the intervention, reduction in the requirement for inotropic support, oxygen therapy and mechanical ventilation. Moreover, the length of hospital stay was significantly shorter in the post-intervention group, demonstrating improved and timely care of patients with sepsis. Multivariable logistic regression also showed that the post-intervention period was independently associated with reduced mortality even after correcting for age, sex, severity of sepsis, diabetes mellitus, hypertension and chronic kidney disease. However, mortality was non-statistically significantly reduced only among patients with septic shock alone, and may be due to the lower number of patients in this group and to limited statistical power.

Finally, this study shows that an educational program can have a substantial effect on compliance with sepsis management bundles and may help to improve clinical outcomes. These educational sessions should be conducted routinely, sepsis protocols should be reinforced, clinical audits to track compliance with the sepsis bundle, timely feedback, and ongoing monitoring of sepsis bundle compliance should therefore be part of routine hospital practice (34, 35). If these are maintained, then there is the potential to improve early sepsis identification, prompt treatment, mortality and morbidity, hospital length of stay and, ultimately, the quality of care for septic patients.

Declarations

Author Biographies

Madiha Iqbal: Dr Madiha Iqbal, MBBS, FCPS (Internal Medicine), MRCP (UK), is an Internal Medicine physician and Infectious Diseases Registrar at King Hamad University Hospital, Bahrain. Her clinical and research interests include sepsis, critical care, infectious diseases, quality improvement, and medical education. She is currently pursuing an MSc in Clinical Research.

Shaikha Sami Abdulrahman Al Jawder: Shaikha Sami Abdulrahman Al Jawder is Chief Resident in the Emergency Medicine Department at King Hamad University Hospital – Royal Medical Services, Bahrain. Her clinical work is based in emergency medicine, and she contributed as an author to this study on improving sepsis bundle compliance through educational intervention.

Malak Mohamed Rasmy Wahba: Malak Mohamed Rasmy Wahba is an RCSI Batch of 2025 graduate and KHUH intern. She contributed to data collection for this study evaluating sepsis bundle compliance and clinical outcomes before and after an educational intervention at King Hamad University Hospital, Bahrain.

Zainab Mansoor Jasim Ahmed Sarhan: Zainab Mansoor Jasim Ahmed Sarhan completed the Mansoura Manchester Program for Medical Education, Batch of 2024, and is an RMS intern at King Hamad University Hospital. She contributed to data collection for this study examining educational intervention and sepsis bundle compliance.

Aalia Abdul Latif: Aalia Abdul Latif is an Internal Medicine Resident at King Hamad University Hospital, Bahrain. She contributed to data collection for this study assessing the effect of structured educational intervention on sepsis bundle compliance and clinical outcomes among patients with severe sepsis and septic shock.

Noor Mohamed Yusuf Abdulla Khalifa AlHamad: Noor Mohamed Yusuf Abdulla Khalifa AlHamad is a Junior Resident in Medical Oncology at King Hamad University Hospital/Bahrain Oncology Center. She contributed to data collection for this study evaluating sepsis bundle compliance and clinical outcomes following a structured educational intervention.

Haya Alaudeen Alomari: Haya Alaudeen Alomari is a Senior Medical Resident in the Internal Medicine Department at King Hamad University Hospital, Bahrain. She contributed to the study as an author and tutor, supporting work evaluating educational intervention, sepsis bundle compliance, and associated clinical outcomes.

Osama Zahid: Osama Zahid holds FCPS in Emergency Medicine and is a Senior Resident in the Emergency Medicine Department at King Hamad University Hospital, Bahrain. He contributed as an author to this study examining the impact of educational intervention on adherence to recommended sepsis management practices.

Sania Ashraf: Sania Ashraf holds FCPS in Nephrology and MRCP and is a Senior Resident in Nephrology at King Hamad University Hospital, Bahrain. She contributed as an author to this study evaluating educational intervention and its association with sepsis bundle compliance and patient outcomes.

Shaikha Asheer: Shaikha Asheer is a Consultant in Infectious Diseases at King Hamad University Hospital, Bahrain. She contributed as an author to this study examining sepsis management, including the effect of an educational intervention on adherence to sepsis bundle components and associated patient outcomes.

Ethics approval and consent to participate

This study was formally approved by the Royal Medical Services and King Hamad University Hospital Institutional Review Board (RMS-KHUH IRB), Kingdom of Bahrain (reference no. RMS-KHUH/IRB/2025-1013). Informed consent to participate was obtained from all participating Emergency Medicine and Internal Medicine residents before the educational intervention as part of the study participation form. Patient-level clinical data were anonymized and no identifiable patient variables were collected or reported; individual patient consent was not obtained. All methods were performed in accordance with relevant institutional guidelines and regulations and with the principles of the Declaration of Helsinki.

Availability of Data and Materials

The datasets generated and/or analysed during the current study are not publicly available because they contain institutional clinical data. Requests for access to de-identified data may be directed to the corresponding author and are subject to approval by Royal Medical Services and applicable institutional and data-protection requirements.

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Figures

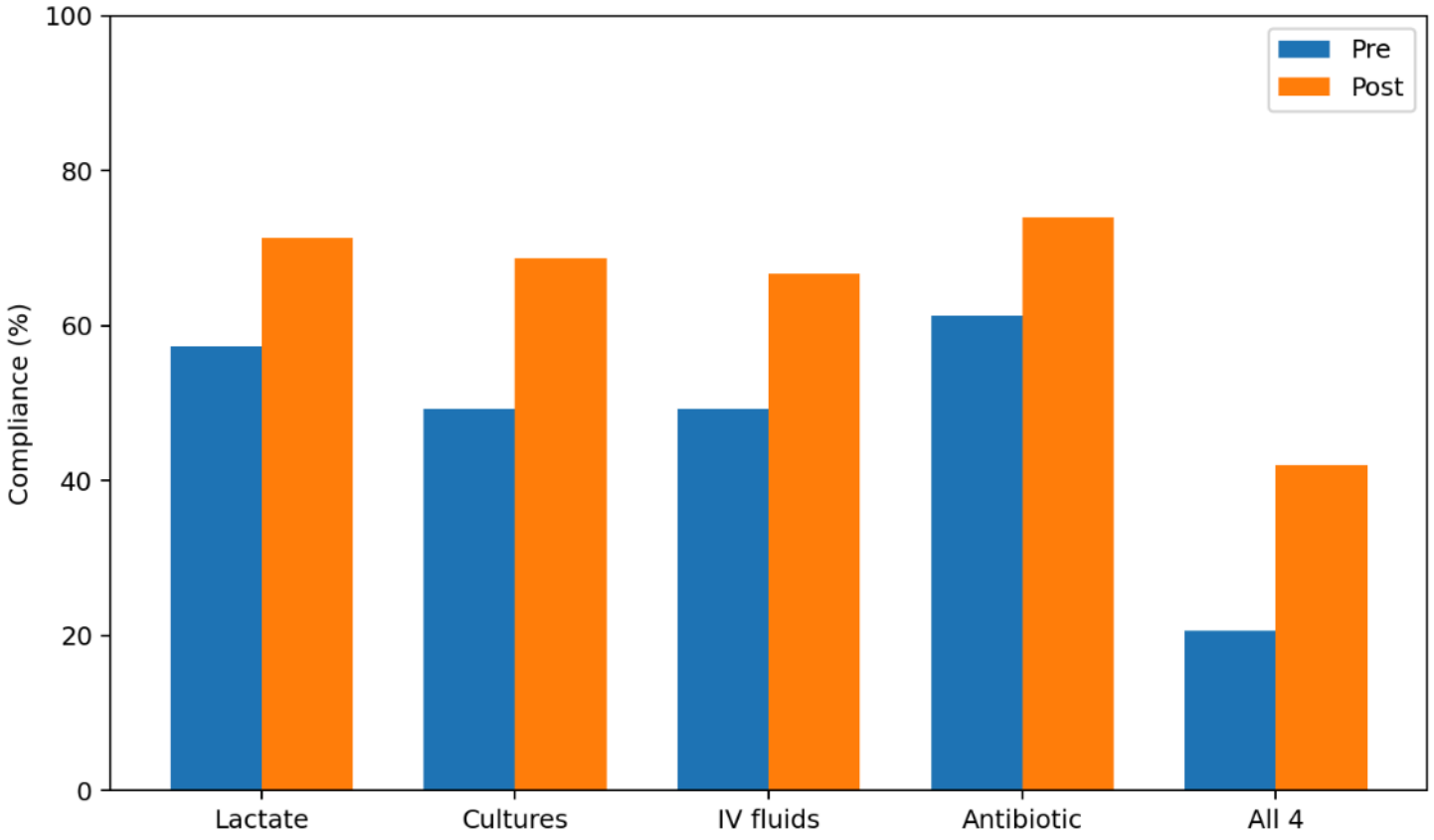


Figure 1

Pre- and Post-Intervention Comparison of Compliance with Individual Components of the Sepsis Management Bundle

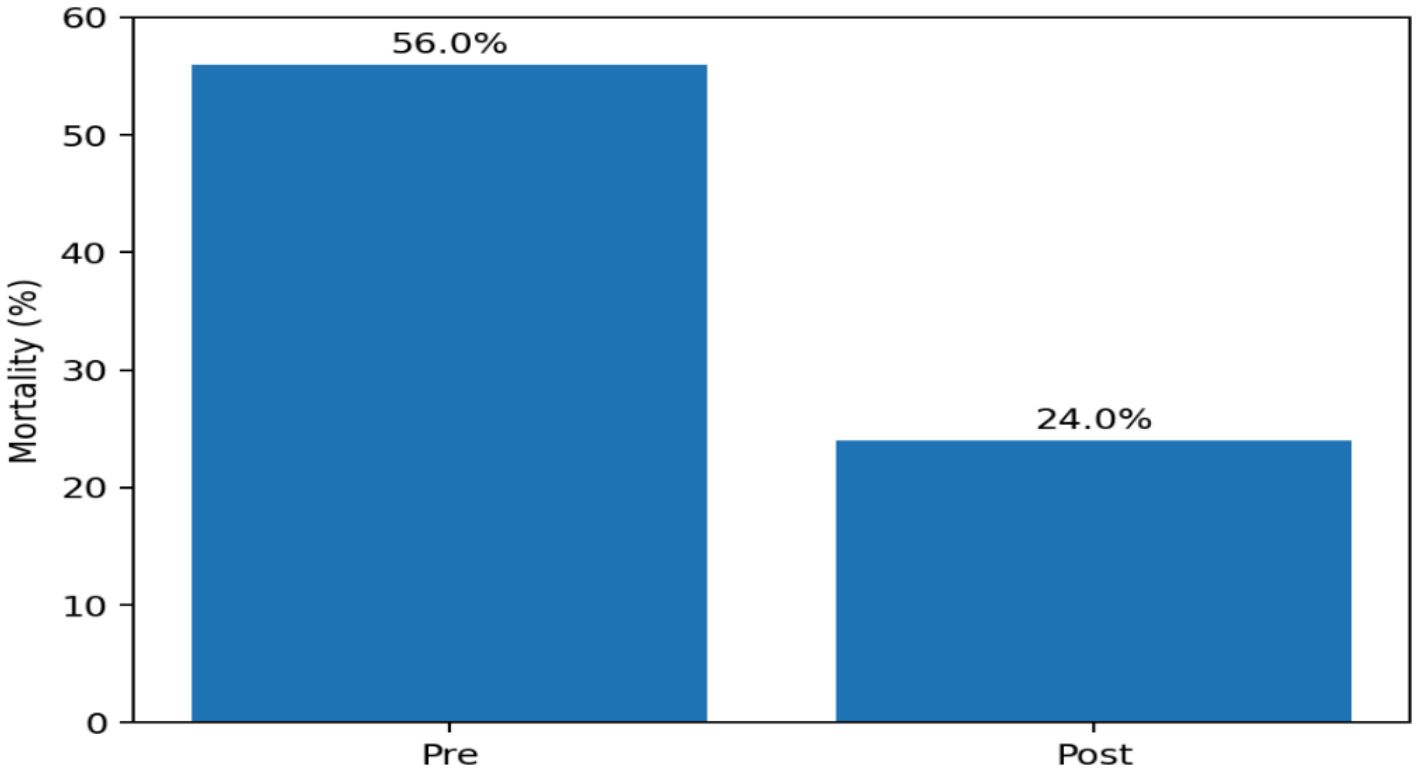


Figure 2

Pre- and Post-Intervention Comparison of Mortality Among Patients with Sepsis

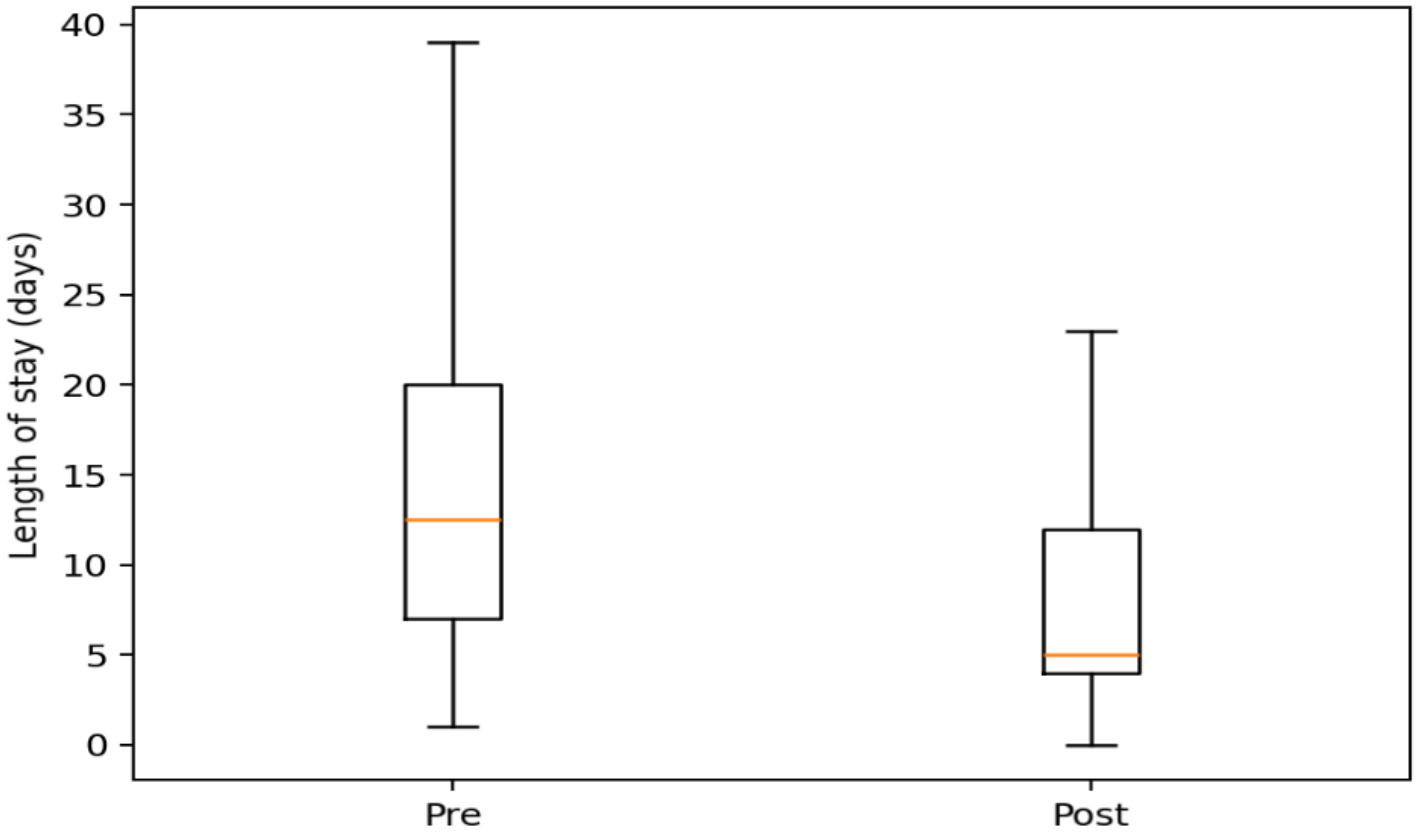


Figure 3

Pre- and Post-Intervention Comparison of Length of Hospital Stay Among Patients with Sepsis