

Original Research Article

IMPACT OF SEPSIS CODE IMPLEMENTATION ON COMPLIANCE WITH THE SURVIVING SEPSIS CAMPAIGN HOUR-1 BUNDLE AND CLINICAL OUTCOMES: A CLINICAL AUDIT

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Received : 30/07/2026
Received in revised form : 27/08/2026
Accepted : 08/09/2026

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DOI: 10.70034/ijmedph.2026.3.908

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2026; 16 (3); 5896-5904

ABSTRACT

Background: Sepsis is a life-threatening organ dysfunction associated with substantial morbidity and mortality. Delays in recognition, antimicrobial administration, haemodynamic stabilization, and escalation of care may adversely affect outcomes. The Surviving Sepsis Campaign recommends timely completion of the Hour-1 Bundle. A structured Sepsis Code, designated was implemented to facilitate rapid recognition, coordinated multidisciplinary management, and standardized delivery of evidence-based sepsis care. The aim is to evaluate the impact of Sepsis Code implementation on compliance with the Surviving Sepsis Campaign Hour-1 Bundle and clinical outcomes among adult patients with sepsis.

Materials and Methods: This hospital-based before-and-after clinical audit included 200 adult patients with sepsis. Of these, 100 patients were managed before the implementation of the structured Sepsis Code, and 100 patients were managed after its implementation. Data were collected on demographic characteristics, comorbidities, admission Sequential Organ Failure Assessment (SOFA) scores, sources of infection, compliance with individual components and the complete Surviving Sepsis Campaign Hour-1 Bundle, treatment timelines, intensive care unit (ICU) transfer, quality of clinical documentation, organ-support requirements, length of hospital stay, and in-hospital outcomes. Continuous variables were expressed as mean $\pm$ standard deviation and compared using the independent-samples t-test. Categorical variables were presented as frequencies and percentages and analysed using the chi-square test or Fisher's exact test, as appropriate. Odds ratios with 95% confidence intervals were calculated, and a p-value of <0.05 was considered statistically significant.

Results: The pre- and post- groups were comparable in age, sex, comorbidities, admission SOFA score, and infection source. Following implementation, serum lactate measurement within one hour increased from 48.0% to 91.0%, blood cultures before antibiotics from 56.0% to 92.0%, antibiotics within one hour from 39.0% to 86.0%, appropriate crystalloid administration from 61.0% to 90.0%, and appropriate vasopressor initiation from 84.6% to 94.9%. Overall, Hour-1 Bundle compliance increased from 36.0% to 93.0% ($p<0.001$). Mean door-to-antibiotic time decreased from 84.8 ± 24.6 to 46.2 ± 18.4 minutes, while ICU transfer time decreased from 4.2 ± 1.6 to 2.3 ± 1.1 hours. ICU transfer within three hours increased from 44.0% to 82.0%, and documentation completeness increased from 58.0% to 96.0% (all $p<0.001$). In-hospital mortality decreased from 21.0% to 9.0% ($p=0.018$). Mechanical ventilation, vasopressor requirement, ICU stay, and hospital stay were also significantly reduced, while discharge alive increased from 79.0% to 91.0%.

Conclusion: Implementation significantly improved compliance with the Surviving Sepsis Campaign Hour-1 Bundle, accelerated delivery of time-sensitive interventions, and improved several clinically important outcomes. A structured multidisciplinary sepsis-response pathway may be an effective quality-improvement strategy for reducing delays, organ-support requirements, length of stay, and in-hospital mortality.

Keywords: Sepsis Code; Hour-1 Bundle; Clinical audit.

INTRODUCTION

Sepsis is a life-threatening organ dysfunction caused by a dysregulated host response to infection and remains one of the leading causes of mortality and healthcare burden worldwide. According to the Global Burden of Disease Study, sepsis accounts for nearly 49 million cases and approximately 11 million deaths annually, representing almost one-fifth of all global deaths. Despite advances in critical care, delayed recognition and inappropriate initial management continue to contribute substantially to poor patient outcomes. Early diagnosis and timely initiation of evidence-based interventions are therefore essential to reduce mortality, organ dysfunction, intensive care unit (ICU) admissions, and healthcare costs.^[1]

The Surviving Sepsis Campaign (SSC) has developed internationally accepted guidelines to standardize the early management of sepsis and septic shock. The latest SSC guidelines emphasize the Hour-1 Bundle, which includes prompt measurement of serum lactate, obtaining blood cultures before antibiotic administration, administration of broad-spectrum intravenous antibiotics within one hour, rapid fluid resuscitation with crystalloids in patients with hypotension or elevated lactate, and early initiation of vasopressors when indicated to maintain adequate mean arterial pressure. Numerous studies have demonstrated that compliance with these bundle elements significantly improves survival and reduces complications.^[2,3]

To facilitate rapid recognition and coordinated multidisciplinary management, many hospitals have implemented structured sepsis response systems such as Sepsis Code. These hospital-based activation protocols employ predefined screening criteria, standardized assessment tools, treatment algorithms, and communication pathways involving emergency physicians, intensivists, nursing staff, microbiology laboratories, and pharmacy services. The protocol incorporates an ABCDE-based infection screening approach, early warning signs, SOFA score assessment, rapid activation criteria, and standardized management including blood cultures, empirical antibiotics, intravenous fluids, vasopressor support, and ICU referral in accordance with SSC recommendations. The protocol also includes continuous monitoring and documentation to improve adherence to quality indicators.

Clinical audit is an important quality improvement strategy that systematically evaluates current clinical practice against established standards, identifies

deficiencies, implements corrective interventions, and reassesses performance through repeated audit cycles. Measuring compliance with the Hour-1 bundle before and after implementation of a structured Sepsis Code provides objective evidence regarding its effectiveness in improving process indicators and patient outcomes. Previous studies have reported that implementation of hospital-wide sepsis protocols significantly increases compliance with early antibiotic administration, blood culture collection, lactate estimation, timely ICU transfer, and overall bundle adherence while reducing mortality and hospital length of stay.^[3-5]

Ruby Hall Clinic implemented across the Emergency Department and ICU, with standardized activation criteria, Sepsis Code Record Forms, regular staff training, and continuous monitoring. Preliminary institutional audit findings demonstrated progressive improvement in antibiotic administration within one hour, overall bundle compliance, ICU transfer time, and mortality following implementation. The present clinical audit was therefore undertaken to evaluate the impact of implementation on compliance with the Surviving Sepsis Campaign Hour-1 Bundle and important clinical outcomes, thereby identifying strengths, gaps, and opportunities for sustained quality improvement in sepsis management.

Aim: To evaluate the impact of Sepsis Code implementation on compliance with the Surviving Sepsis Campaign Hour-1 Bundle and clinical outcomes among adult patients with sepsis.

Objectives

1. To assess compliance with individual components and overall compliance of the Surviving Sepsis Campaign Hour-1 Bundle following implementation of Sepsis Code.
2. To compare door-to-antibiotic time, ICU transfer time, and other process indicators before and after implementation.
3. To evaluate the effect of implementation on mortality, ICU admission, and hospital length of stay among patients with sepsis.

MATERIALS AND METHODS

Source of Data: The data were collected from adult patients diagnosed with sepsis or septic shock admitted through the Emergency Department or managed in the ICU of Ruby Hall Clinic, Pune. Information was obtained from hospital medical records, Sepsis Code Record Forms, laboratory reports, nursing records, ICU charts, and electronic health records. Data regarding compliance with the

Hour-1 Bundle and clinical outcomes were extracted using a structured clinical audit proforma developed according to the Surviving Sepsis Campaign 2021 recommendations.

Study Design: Hospital-based retrospective and prospective clinical audit (before-and-after quality improvement study).

Study Location: Emergency Department and Intensive Care Unit (ICU), Ruby Hall Clinic, Pune, Maharashtra.

Study Duration: The study was conducted over 24 months from August 2023 to July 2025. Baseline (pre) data were collected retrospectively, while post-implementation data were collected prospectively after implementation of Sepsis Code.

Sample Size: For estimation of a single proportion:

$$n = \frac{Z_{1-\alpha/2}^2 \times p \times q}{d^2}$$

Where:

Z = 1.96 (95% Confidence Level)

p = Expected compliance with Hour-1 Bundle = 84% (0.84) (based on previous institutional audit)

q = 1 - p = 0.16

d = Absolute precision = 5% (0.05)

Calculation:

$$\begin{aligned} n &= \frac{(1.96)^2 \times 0.84 \times 0.16}{(0.05)^2} \\ n &= \frac{3.84 \times 0.1344}{0.0025} \\ n &= \frac{0.516}{0.0025} = 206.4 \end{aligned}$$

The calculated sample size was approximately 206. Considering feasibility, availability of records, and completeness of data, 200 patients fulfilling the eligibility criteria were included in the clinical audit.

Inclusion Criteria

- Adult patients aged 18 years or older.
- Patients fulfilling Sepsis-3 diagnostic criteria.
- Patients managed under Sepsis Code or evaluated for suspected sepsis.
- Patients admitted through the Emergency Department or ICU.
- Patients with complete clinical records required for audit.

Patients with sepsis as well as septic shock, as defined by the Sepsis-3 criteria, were eligible for inclusion. Septic shock was defined as sepsis requiring vasopressor therapy to maintain a mean arterial pressure of at least 65 mmHg together with a serum lactate level greater than 2 mmol/L despite adequate volume resuscitation.

Exclusion Criteria

- Patients younger than 18 years.
- Trauma patients.
- Patients who died within six hours of admission before initiation of complete sepsis management.
- Patients discharged against medical advice (LAMA).
- Patients with incomplete documentation of key audit variables.

Procedure and Methodology

After obtaining approval from the Institutional Ethics Committee and hospital administration, a clinical audit was conducted using the Plan-Do-Study-Act (PDSA) quality improvement framework. The Surviving Sepsis Campaign 2021 Hour-1 Bundle served as the audit standard.

The following Hour-1 Bundle elements were evaluated:

- Serum lactate measurement
- Blood cultures before antibiotics
- Administration of empirical broad-spectrum antibiotics
- Intravenous crystalloid fluid resuscitation (30 mL/kg when indicated)
- Vasopressor initiation for persistent hypotension
- Overall bundle compliance
- Door-to-antibiotic time
- ICU transfer time
- Hospital mortality
- Length of hospital stay

Sample Processing: Clinical data were extracted from patient case records and verified against nursing charts, ICU records, laboratory information systems, and the Sepsis Code Record Forms. All data were anonymized and entered into a pre-designed Microsoft Excel spreadsheet. Data cleaning, validation, coding, and consistency checks were performed before statistical analysis.

Statistical Methods: The collected data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics version 26.0.

- Continuous variables were expressed as Mean ± Standard Deviation (SD) or Median (Interquartile Range) depending on data distribution.
- Categorical variables were presented as frequency and percentage.
- Comparisons between groups were performed using the Chi-square test or Fisher's exact test for categorical variables.
- Independent Student's t-test or Mann-Whitney U test was used for continuous variables.
- Trends across audit phases were evaluated using appropriate trend analysis.
- A p-value <0.05 was considered statistically significant.
- Results were presented with 95% Confidence Intervals (CI) wherever applicable.

Data Collection: Data were collected using a structured clinical audit proforma based on the institutional Sepsis Code Record Form and the Surviving Sepsis Campaign Hour-1 Bundle recommendations. Variables included demographic characteristics, comorbidities, source of infection, SOFA score, physiological parameters, timing of recognition, blood culture collection, serum lactate measurement, administration of antibiotics, intravenous fluid therapy, vasopressor use, ICU transfer time, hospital length of stay, in-hospital

mortality, and overall compliance with the Hour-1 Bundle. All patient identifiers were removed before analysis to ensure confidentiality.

Handling of missing data: Records were assessed for completeness before inclusion. Patients with missing information on key exposure, Hour-1 Bundle, or primary outcome variables were excluded according to the predefined eligibility criteria. For occasional missing values in non-key variables, an available-case analysis was performed, and the denominator applicable to each variable was reported. No statistical imputation was undertaken. Data were cross-verified using medical records, nursing charts, laboratory systems, ICU records, and Record Forms whenever discrepancies or missing entries were identified.

RESULTS

[Table 1] compares the baseline demographic and clinical characteristics of patients managed before and after implementation of the Sepsis Code. The

mean age of patients was comparable between the pre- group (60.9±13.6 years) and the post- group (59.8±13.9 years), with no statistically significant difference ($t=0.57$, 95% CI: -2.73 to 4.93, $p=0.569$). Similarly, the proportion of male patients was comparable in both groups (63.0% vs. 61.0%; $\chi^2=0.09$, OR=0.92, 95% CI: 0.52-1.64, $p=0.763$). The prevalence of major comorbidities, including diabetes mellitus (49.0% vs. 52.0%; $p=0.673$), hypertension (65.0% vs. 67.0%; $p=0.763$), chronic kidney disease (30.0% vs. 28.0%; $p=0.752$), and immunocompromised state (17.0% vs. 15.0%; $p=0.699$), did not differ significantly between the two groups. The severity of illness at presentation, assessed by the SOFA score, was also similar (6.7±2.0 vs. 6.5±1.9; $t=0.73$, 95% CI: -0.34 to 0.74, $p=0.465$). Furthermore, the distribution of infection sources, including pulmonary sepsis (51.0% vs. 49.0%; $p=0.778$), intra-abdominal sepsis (29.0% vs. 31.0%; $p=0.766$), and urinary tract infection (20.0% in both groups; $p=1.000$), showed no statistically significant differences.

Table 1: Baseline demographic and clinical characteristics of study participants before and after implementation of Sepsis Code (N=200)

Variable	Pre- (n=100)	Post- (n=100)	Test of significance	95% CI	P value
Age (years), Mean±SD	60.9±13.6	59.8±13.9	$t=0.57$	-2.73 to 4.93	0.569
Male gender	63 (63.0)	61 (61.0)	$\chi^2=0.09$	OR 0.92 (0.52-1.64)	0.763
Diabetes mellitus	49 (49.0)	52 (52.0)	$\chi^2=0.18$	OR 1.13 (0.64-1.98)	0.673
Hypertension	65 (65.0)	67 (67.0)	$\chi^2=0.09$	OR 1.09 (0.61-1.95)	0.763
Chronic kidney disease	30 (30.0)	28 (28.0)	$\chi^2=0.10$	OR 0.91 (0.48-1.72)	0.752
Immunocompromised state	17 (17.0)	15 (15.0)	$\chi^2=0.15$	OR 0.86 (0.40-1.83)	0.699
SOFA score at admission, Mean±SD	6.7±2.0	6.5±1.9	$t=0.73$	-0.34 to 0.74	0.465
Pulmonary source of sepsis	51 (51.0)	49 (49.0)	$\chi^2=0.08$	OR 0.92 (0.53-1.60)	0.778
Intra-abdominal sepsis	29 (29.0)	31 (31.0)	$\chi^2=0.09$	OR 1.10 (0.59-2.04)	0.766
Urinary tract infection	20 (20.0)	20 (20.0)	$\chi^2=0.00$	OR 1.00 (0.49-2.02)	1.000

Table 2: Compliance with individual components of the Surviving Sepsis Campaign Hour-1 Bundle before and after implementation of (N=200)

Hour-1 Bundle Component	Pre- n (%)	Post- n (%)	Test of significance	95% CI	P value
Serum lactate measured within 1 hour	48 (48.0)	91 (91.0)	$\chi^2=43.84$	OR 10.95 (5.14-23.33)	<0.001*
Blood cultures before antibiotics	56 (56.0)	92 (92.0)	$\chi^2=33.61$	OR 9.04 (4.17-19.59)	<0.001*
Broad-spectrum antibiotics within 1 hour	39 (39.0)	86 (86.0)	$\chi^2=48.51$	OR 9.61 (4.89-18.87)	<0.001*
IV crystalloid administered appropriately	61 (61.0)	90 (90.0)	$\chi^2=22.18$	OR 5.75 (2.85-11.61)	<0.001*
Vasopressors initiated when indicated	66/78 (84.6)	75/79 (94.9)	$\chi^2=4.60$	OR 3.39 (1.01-11.39)	0.032*
Overall Hour-1 Bundle compliance	36 (36.0)	93 (93.0)	$\chi^2=72.12$	OR 23.00 (10.10-52.34)	<0.001*

[Table 2] demonstrates a marked improvement in compliance with all components of the Surviving Sepsis Campaign Hour-1 Bundle following implementation of the Sepsis Code. Measurement of serum lactate within one hour increased significantly from 48.0% before implementation to 91.0% afterward ($\chi^2=43.84$, OR=10.95, 95% CI: 5.14-23.33, $p<0.001$). Blood culture collection before antibiotic administration also improved substantially from 56.0% to 92.0% ($\chi^2=33.61$, OR=9.04, 95% CI: 4.17-19.59, $p<0.001$). Timely administration of broad-spectrum antibiotics within one hour showed one of the greatest improvements, increasing from 39.0% to

86.0% ($\chi^2=48.51$, OR=9.61, 95% CI: 4.89-18.87, $p<0.001$). Appropriate intravenous crystalloid administration increased significantly from 61.0% to 90.0% ($\chi^2=22.18$, OR=5.75, 95% CI: 2.85-11.61, $p<0.001$). Among patients requiring vasopressor therapy, appropriate initiation improved from 84.6% to 94.9%, which was also statistically significant ($\chi^2=4.60$, OR=3.39, 95% CI: 1.01-11.39, $p=0.032$). Most importantly, overall compliance with the complete Hour-1 Bundle increased dramatically from 36.0% before implementation to 93.0% afterward ($\chi^2=72.12$, OR=23.00, 95% CI: 10.10-52.34, $p<0.001$).

Table 3: Comparison of door-to-antibiotic time, ICU transfer time and process indicators before and after implementation of (N=200)

Process Indicator	Pre-	Post-	Test of significance	95% CI	P value
Door-to-antibiotic time (minutes), Mean±SD	84.8±24.6	46.2±18.4	$t=12.63$	32.57 to 44.63	<0.001*
ICU transfer time (hours), Mean±SD	4.2±1.6	2.3±1.1	$t=9.73$	1.52 to 2.28	<0.001*
ICU transfer within 3 hours	44 (44.0)	82 (82.0)	$\chi^2=31.49$	OR 5.80 (3.04-11.08)	<0.001*

Time to lactate report (minutes), Mean±SD	55.7±16.5	33.8±11.4	t=10.86	17.92 to 25.88	<0.001*
Time to blood culture collection (minutes), Mean±SD	31.6±10.2	18.4±7.3	t=10.52	10.72 to 15.68	<0.001*
Documentation completeness	58 (58.0)	96 (96.0)	$\chi^2=39.23$	OR 17.38 (5.10-59.24)	<0.001*

[Table 3] compares key process indicators before and after implementation of the Sepsis Code. The mean door-to-antibiotic time was significantly reduced from 84.8±24.6 minutes in the pre- group to 46.2±18.4 minutes in the post- group (t=12.63, 95% CI: 32.57-44.63, p<0.001). Likewise, the mean ICU transfer time decreased significantly from 4.2±1.6 hours to 2.3±1.1 hours (t=9.73, 95% CI: 1.52-2.28, p<0.001). The proportion of patients transferred to the ICU within three hours increased significantly from 44.0% before implementation to 82.0% after implementation ($\chi^2=31.49$, OR=5.80, 95% CI: 3.04-

11.08, p<0.001). Laboratory turnaround time also improved considerably, with the mean time to lactate reporting decreasing from 55.7±16.5 minutes to 33.8±11.4 minutes (t=10.86, 95% CI: 17.92-25.88, p<0.001). Similarly, the mean time required for blood culture collection was significantly shortened from 31.6±10.2 minutes to 18.4±7.3 minutes (t=10.52, 95% CI: 10.72-15.68, p<0.001). Documentation completeness improved remarkably from 58.0% before implementation to 96.0% afterward ($\chi^2=39.23$, OR=17.38, 95% CI: 5.10-59.24, p<0.001).

Table 4: Clinical outcomes before and after implementation of Sepsis Code (N=200)

Clinical Outcome	Pre- n (%) / Mean±SD	Post- n (%) / Mean±SD	Test of significance	95% CI	P value
In-hospital mortality	21 (21.0)	9 (9.0)	$\chi^2=5.64$	OR 0.37 (0.16-0.85)	0.018*
ICU admission	69 (69.0)	56 (56.0)	$\chi^2=3.67$	OR 0.57 (0.32-1.01)	0.055
Mechanical ventilation	34 (34.0)	21 (21.0)	$\chi^2=4.22$	OR 0.52 (0.27-0.99)	0.040*
Vasopressor requirement	41 (41.0)	28 (28.0)	$\chi^2=3.82$	OR 0.56 (0.31-0.99)	0.049*
Length of ICU stay (days), Mean±SD	6.8±3.4	4.9±2.6	t=4.46	1.06 to 2.74	<0.001*
Hospital length of stay (days), Mean±SD	11.6±4.8	8.9±3.9	t=4.36	1.48 to 3.92	<0.001*
Discharged alive	79 (79.0)	91 (91.0)	$\chi^2=5.64$	OR 2.72 (1.18-6.22)	0.018*

* Statistically significant (p < 0.05).

[Table 4] presents the comparison of clinical outcomes before and after implementation of the Sepsis Code. In-hospital mortality decreased significantly from 21.0% in the pre- group to 9.0% in the post- group ($\chi^2=5.64$, OR=0.37, 95% CI: 0.16-0.85, p=0.018). Although ICU admission rates declined from 69.0% to 56.0%, this reduction did not reach statistical significance ($\chi^2=3.67$, OR=0.57, 95% CI: 0.32-1.01, p=0.055). The requirement for mechanical ventilation decreased significantly from 34.0% to 21.0% ($\chi^2=4.22$, OR=0.52, 95% CI: 0.27-0.99, p=0.040). Similarly, vasopressor requirement was significantly reduced from 41.0% to 28.0% following implementation ($\chi^2=3.82$, OR=0.56, 95% CI: 0.31-0.99, p=0.049). The mean ICU stay was significantly shortened from 6.8±3.4 days to 4.9±2.6 days (t=4.46, 95% CI: 1.06-2.74, p<0.001), while the overall hospital length of stay decreased from 11.6±4.8 days to 8.9±3.9 days (t=4.36, 95% CI: 1.48-3.92, p<0.001). Consequently, the proportion of patients discharged alive increased significantly from 79.0% before implementation to 91.0% after implementation ($\chi^2=5.64$, OR=2.72, 95% CI: 1.18-6.22, p=0.018).

DISCUSSION

The present before-and-after clinical audit evaluated the association between the implementation of a structured Sepsis Code and adherence to the Surviving Sepsis Campaign Hour-1 Bundle. The implementation of the Sepsis Code was associated

with substantial improvements in lactate measurement, collection of blood cultures before antibiotic administration, timely initiation of antimicrobial therapy, appropriate fluid resuscitation, timely vasopressor initiation, and overall bundle completion. These improvements were accompanied by shorter treatment initiation and intensive care unit transfer times, more complete clinical documentation, reduced requirements for organ support, shorter hospital and intensive care unit stays, and lower in-hospital mortality. Collectively, these findings indicate that effective sepsis management depends not only on individual therapeutic interventions but also on timely recognition, coordinated communication, clearly defined responsibilities among healthcare professionals, and rapid escalation of care.

Baseline demographic and clinical characteristics:

The pre- and post- groups were comparable in age, sex, comorbidities, admission SOFA score and source of infection. The mean age was approximately 60 years in both groups, nearly two-thirds of participants were male, and diabetes mellitus and hypertension were common. Pulmonary infection was the leading source of sepsis, followed by intra-abdominal and urinary infections. Abe et al. (2018).^[1] similarly found that severe sepsis predominantly affected older adults and commonly originated from respiratory, abdominal and urinary infections. Fesnak et al. (2020).^[2] also reported a considerable burden of complex comorbidities among patients assessed through emergency department sepsis-alert systems.

The mean admission SOFA scores were similar before and after implementation (6.7 ± 2.0 versus 6.5 ± 1.9), suggesting broadly comparable initial organ dysfunction. This baseline similarity reduces, but does not eliminate, the possibility that the post-implementation improvements resulted from differences in patient characteristics or illness severity. The combined use of physiological warning signs, clinical assessment and SOFA scoring was consistent with contemporary recommendations for recognizing and assessing adult patients with sepsis and septic shock, as described by Evans et al. (2021),^[3] and Guarino et al. (2023).^[4]

Compliance with the Hour-1 Bundle: implementation produced marked improvements across the principal diagnostic and therapeutic components of the Hour-1 Bundle. Lactate measurement within one hour increased from 48.0% to 91.0%, blood-culture collection before antibiotics increased from 56.0% to 92.0%, and administration of broad-spectrum antibiotics within one hour increased from 39.0% to 86.0%. Gatewood et al. (2015),^[5] MacMillan et al. (2019),^[6] Bruce et al. (2015),^[7] and Tedesco et al. (2017),^[8] similarly demonstrated that structured protocols, nurse-initiated pathways and multidisciplinary interventions improved timely completion of sepsis investigations and treatment measures. These collective findings suggest that standardized activation pathways reduce delays arising from recognition, clinical authorization, specimen collection, medication preparation and communication between departments.

The improvement in antibiotic administration was particularly important, with the odds of receiving antibiotics within one hour being approximately ten times higher after implementation. Comparable improvements in antimicrobial timeliness following electronic alerts, digital sepsis systems and inpatient Code Sepsis protocols were reported by Narayanan et al. (2016),^[9] Honeyford et al. (2020),^[10] and Richardson et al. (2024).^[11] These findings support the use of a coordinated activation mechanism to address practical barriers to timely antibiotic delivery.

Nevertheless, the relationship between antibiotic timing and survival remains influenced by illness severity, septic shock, diagnostic certainty and the probability of bacterial infection. Seymour et al. (2017),^[12] associated longer time to completion of sepsis treatment, particularly antibiotic administration, with increased mortality. Philippon et al. (2025),^[13] also found that antibiotic administration beyond one hour was associated with an increased risk of 28-day in-hospital mortality among patients with suspected sepsis. In contrast, Sterling et al. (2015),^[14] found insufficient evidence for a consistent mortality benefit from administering antibiotics within rigid time thresholds, while Althunayyan et al. (2021),^[15] observed no significant mortality difference between administration within one hour and administration between one and three

hours. Therefore, the improvement in antibiotic timing in the present audit should be interpreted alongside clinical assessment and antimicrobial stewardship rather than as justification for indiscriminate antibiotic administration.

Appropriate intravenous crystalloid administration increased from 61.0% before implementation to 90.0% after implementation, indicating improved recognition and management of sepsis-induced hypoperfusion. Among patients with an indication for vasopressor therapy, the proportion receiving timely and appropriate vasopressor initiation increased from 84.6% to 94.9%. These findings suggest that implementation of the structured Sepsis Code facilitated earlier haemodynamic assessment, protocol-guided fluid resuscitation, and timely escalation of care to critical care teams. This approach was consistent with the recommendations of Evans et al. (2021),^[3] who emphasised prompt crystalloid resuscitation, repeated assessment of fluid responsiveness, and initiation of vasopressor therapy for persistent hypotension while avoiding both inadequate resuscitation and fluid overload.

Overall Hour-1 Bundle compliance increased from 36.0% to 93.0%, corresponding to an OR of 23.00. Gatewood et al. (2015),^[5] reported a similar improvement in bundle compliance following a multifaceted quality-improvement programme. Rhodes et al. (2015),^[16] Damiani et al. (2015),^[17] and Levy et al. (2015),^[18] collectively demonstrated that standardized performance-improvement strategies increased sepsis-bundle adherence and were frequently associated with improved survival. However, Prachanukool et al. (2021),^[19] did not find a significant mortality difference between patients receiving complete and incomplete Hour-1 Bundle care, while Ko et al. (2021),^[20] showed that the effect of bundle achievement may vary according to individual components, severity and timing of recognition. Bundle compliance should therefore be considered an indicator of organized and timely care rather than a guarantee of survival in every patient.

Process indicators: The mean door-to-antibiotic time decreased by 38.6 minutes, from 84.8 to 46.2 minutes. This reduction probably reflected the combined effect of rapid protocol activation, predefined antibiotic guidance, staff training, medication readiness and improved interdepartmental communication. Narayanan et al. (2016),^[9] and Richardson et al. (2024),^[11] similarly reported shorter antibiotic-administration times following electronic sepsis alerts and inpatient Code Sepsis implementation.

Mean ICU-transfer time decreased from 4.2 ± 1.6 to 2.3 ± 1.1 hours, while the proportion transferred within three hours increased from 44.0% to 82.0%. These findings indicate better coordination among emergency, ward and critical-care teams. Suttapanit et al. (2022),^[21] reported that an early-warning-score-based protocol improved the time to ICU admission, although it did not significantly improve antibiotic administration within one hour. The broader

improvements observed in the present audit may be related to the multicomponent nature, which combined screening, senior clinical review, ICU consultation, laboratory activation and immediate treatment guidance.

Documentation completeness increased from 58.0% to 96.0%. Complete documentation is essential for distinguishing a genuinely delayed or omitted intervention from one that was performed but not recorded. MacMillan et al. (2019),^[6] similarly found that structured documentation combined with multidisciplinary interventions improved sepsis recognition and bundle adherence. Standardized forms may also facilitate real-time feedback, accountability, continuity during transfers and subsequent clinical audit.

Clinical outcomes: In-hospital mortality decreased significantly from 21.0% before implementation to 9.0% afterward, corresponding to an estimated 63% reduction in the odds of death. Mechanical ventilation decreased from 34.0% to 21%, vasopressor requirement decreased from 41.0% to 28.0%, mean ICU stay declined from 6.8 to 4.9 days, and hospital stay declined from 11.6 to 8.9 days. Survival to discharge consequently increased from 79.0% to 91.0%.

The observed clinical improvements may have resulted from the combined effects of earlier recognition, timely antimicrobial treatment, improved diagnostic testing, haemodynamic stabilization and faster ICU escalation rather than from any single bundle component. Rhodes et al. (2015),^[16] reported lower mortality among bundle-compliant patients, while Damiani et al. (2015),^[17] and Levy et al. (2015),^[18] associated performance-improvement programmes and greater bundle compliance with improved survival. Narayanan et al. (2016),^[9] also reported a reduction in hospital length of stay following implementation of an electronic severe-sepsis alert.

The ICU admission rate decreased from 69.0% to 56.0%, although this difference did not reach statistical significance. This may suggest reduced clinical deterioration following earlier treatment; however, ICU admission is influenced by bed availability, institutional admission thresholds, local policies and clinical decision-making. Earlier recognition could also increase ICU admission in some settings by identifying high-risk patients sooner. ICU admission should therefore be interpreted together with mortality, organ-support requirements and length of stay.

The reductions in mechanical ventilation and vasopressor requirement may indicate that earlier infection control and haemodynamic stabilization limited progression to severe respiratory or circulatory failure. Importantly, the lower overall vasopressor requirement after implementation should not be interpreted as reluctance to commence therapy because appropriate initiation among patients with a clinical indication increased. The combination of fewer patients requiring vasopressors and greater

compliance among those requiring treatment suggests both reduced progression and improved management.

Despite comparable measured baseline characteristics, the mortality and other outcome findings require cautious interpretation. Prachanukool et al. (2021),^[19] did not demonstrate a mortality benefit from complete Hour-1 Bundle treatment, and Richardson et al. (2024),^[11] reported improved antibiotic timing without a significant reduction in mortality. Differences between studies may be related to sample size, illness severity, septic shock prevalence, baseline institutional performance, implementation fidelity and healthcare resources.

This was an observational before-and-after quality-improvement study. The findings demonstrate temporal associations following implementation but cannot definitively establish causality. Secular changes in clinical practice, staffing, laboratory services, antimicrobial availability, staff awareness and other unmeasured factors may have contributed to the observed improvements. Nevertheless, the simultaneous improvement in multiple process indicators supports the practical value of a structured multidisciplinary sepsis-response pathway and provides a strong basis for continued monitoring, staff training and periodic re-audit.

CONCLUSION

Implementation of the Sepsis Code was associated with substantial improvements in the early recognition and standardised management of adult patients with sepsis. Compliance with all individual components of the Surviving Sepsis Campaign Hour-1 Bundle increased significantly following implementation. These components included timely serum lactate measurement, collection of blood cultures before antibiotic administration, administration of broad-spectrum antibiotics within one hour, appropriate intravenous crystalloid resuscitation, and initiation of vasopressor therapy when indicated. Overall bundle compliance increased from 36.0% before implementation to 93.0% after implementation.

Implementation of the Sepsis Code also significantly improved important process indicators. Door-to-antibiotic time, ICU transfer time, time to lactate reporting, and time to blood culture collection were markedly reduced. Furthermore, the proportion of patients transferred to the ICU within three hours and the completeness of clinical documentation increased substantially. These improvements were accompanied by better clinical outcomes, including a reduction in in-hospital mortality from 21.0% to 9.0%, decreased requirements for mechanical ventilation and vasopressor support, shorter ICU and hospital stays, and a higher proportion of patients discharged alive.

The findings suggest that a structured, multidisciplinary sepsis activation pathway was

associated with improved adherence to evidence-based sepsis care and better clinical outcomes. The Sepsis Code may contribute to meaningful reductions in morbidity, mortality, and healthcare resource utilisation. Continued staff training, reinforcement of the protocol, antimicrobial stewardship, real-time performance feedback, and periodic re-auditing are recommended to sustain and further improve the effectiveness of the Sepsis Code.

Limitations of the study: This study had several limitations. First, it was conducted as a single-centre clinical audit, which may limit the generalizability of the findings to hospitals with different patient populations, staffing patterns, infrastructure, or sepsis-management practices. Second, the before-and-after design was observational and did not include random allocation; therefore, a direct causal relationship between implementation and improved outcomes could not be established.

Third, the study may have been influenced by secular trends, including improvements in critical-care practices, staffing, laboratory services, antimicrobial availability, and increased institutional awareness of sepsis over time. Fourth, although the pre- and post-implementation groups were comparable in measured baseline variables, residual confounding from unmeasured factors such as frailty, infection severity, antimicrobial resistance, source-control timing, treatment limitations, and clinician experience could not be excluded.

Fifth, some data were obtained retrospectively from medical records and were therefore dependent on the accuracy and completeness of documentation. Missing or inaccurately recorded intervention times may have introduced information bias. Sixth, the study assessed whether bundle elements were completed but did not comprehensively evaluate the appropriateness of antibiotic selection, dosage, subsequent de-escalation, fluid responsiveness, total fluid balance, or adverse effects of treatment.

Seventh, clinical outcomes such as ICU admission and length of stay may have been influenced by ICU bed availability, discharge policies, institutional workflows, and non-clinical administrative factors. Eighth, the study assessed in-hospital outcomes only and did not evaluate 28-day or 90-day mortality, readmission, long-term functional status, quality of life, or post-sepsis complications. Finally, possible unintended consequences of , including false-positive activation, unnecessary antibiotic exposure, antimicrobial resistance, fluid overload, workload burden, and alert fatigue, were not assessed.

Exclusion of records with incomplete key data may also have introduced selection bias if excluded patients differed systematically from those included in the analysis.

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