The Acceptability, Feasibility, Adoption, and Fidelity of the “RhodeMap To Sepsis Survival” Implementation Strategy on Inpatient Medical Wards and Its Impact on SEP-1 Bundle Compliance: A Mixed-Methods, Hybrid Type III Implementation Study

By

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Preface and Acknowledgments

This thesis reflects the intersection of my work as an internal medicine physician, hospitalist, public health student, musician, and implementation science learner. The RhodeMap to Sepsis Survival project grew out of a practical clinical problem: how to improve timely, reliable sepsis care for patients on inpatient medical wards, where there is relatively less data to inform practice compared to the Intensive Care Unit or the Emergency Department. It also reflects a broader public health question that has shaped my training: why do evidence-based practices fail to reach patients consistently, even in resource-rich health systems?

RhodeMap to Sepsis Survival combined conventional implementation strategies—education, audit and feedback, visual reminders, electronic medical record tools, and order sets—with a novel arts-based strategy through the sepsis song. The goal was not only to improve SEP-1 bundle compliance, but also to understand how clinicians experience implementation amid competing priorities, staffing constraints, electronic medical record burden, clinical uncertainty, and multidisciplinary coordination demands. This thesis is therefore both a quality improvement project and an implementation science study, focused on a problem that is clinically urgent, operationally complex, and deeply human.

I am deeply grateful to my thesis advisor, Dr. Malabika Sarker, for her guidance, structure, and steady support throughout this project. I am also very grateful to Dr. Mitchell Levy, my specialty advisor, for his expertise in sepsis, critical care, and quality improvement, and for helping me think more clearly about the clinical and policy relevance of this work. I thank Dr. Hannah Frank for her collegiality and implementation science guidance.

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Introduction

Sepsis is a life-threatening syndrome characterized by organ dysfunction due to a dysregulated host response to infection, as per the Sepsis-3 definition[1]. The transition from infection to sepsis and eventually to septic shock represents a continuum of escalating disease severity. In the U.S., approximately 1.7 million adults get hospitalized for sepsis annually, resulting in at least 350,000 deaths [2], costing the health care system 8.8% of all hospital costs[3], and over $62 billion annually [4]. Patients with sepsis transferred to the Intensive Care Unit (ICU) from wards, as opposed to from the Emergency Department (ED) seem to have a much higher mortality (40.3%) as observed by Levy et al.[5] Sepsis patients on the wards (often termed “floors” in the United States) may represent up to 50% of all sepsis cases,[6,7] however, sepsis guidelines are based primarily on evidence from the ED and ICU patients - As per a review conducted in 2015, of the 122 studies used to develop these recommendations, only one prospective clinical trial included any patients on the wards[8,9]

The understanding and care of sepsis has considerably evolved over the last four decades. While early goal-directed therapy[10] in 2001 demonstrated mortality benefit of a resuscitative protocol, Society of Critical Care Medicine Surviving Sepsis soon afterwards developed guidelines[11] for early identification and provision of time sensitive treatment as part of bundled care. The Centers for Medicare and Medicaid Services (CMS) subsequently introduced Severe Sepsis/Septic Shock Early Management (SEP-1) Bundle in 2015[12] as a standardized approach to early sepsis management, a pay-for-reporting measure as part of Hospital Inpatient Quality Reporting (IQR) program, also establishing a standard of care. SEP-1 bundle compliance within the required time frame has been found to be associated with improved outcomes (including length of stay, readmission rates and mortality) in patients with Severe Sepsis and Septic Shock[13–16] and can also be influenced by performance improvement programs in the hospital[17,18].

Despite these guidelines, providers' compliance with SEP-1 remains suboptimal and varies widely, with national bundle adherence rates reported as low as 21.5%[5], 36.1%[19] in New York State, and a more recent national average reported by CMS at 64%[20]. Barriers to SEP-1 bundle compliance include difficulty with timely diagnosis, lack of staff training, insufficient audit and feedback, poor teamwork and communication, concerns about using bundles in certain patients[21,22]. Facilitators include confidence in knowledge and skills, beliefs in overall benefits of the bundle, beliefs that identification and management of septic patients fell within everyone's role, and that regular use of the bundle made it easier to remember[22]. Quality improvement (QI) initiatives, such as electronic health record (EHR)-based sepsis alerts, sepsis order sets, and provider education, have shown promise in improving compliance[23]. However, further efforts are needed to bridge gaps in guideline adherence, understand factors affecting adherence and ensure optimal patient outcomes, especially on medical wards

Many Quality Improvement (QI) interventions and implementation strategies have been introduced to enhance adherence to SEP-1 guidelines, yet gaps in compliance persist, particularly among non-ICU, non-ED providers on inpatient wards. Identifying and addressing barriers at multiple levels using an implementation science framework, such as the Exploration, Preparation, Implementation, Sustainment (EPIS) framework[24], can enhance the effectiveness and generalizability of QI initiatives. Despite the availability of numerous Evidence-Based Interventions (EBIs), major health gains remain unrealized due to gaps in their widespread and effective implementation. Successfully implementing already existing EBIs, like the SEP-1 bundle, could dramatically reduce mortality across diseases, often yielding greater impact than even developing new treatments alone[25–28].

This study uses a Hybrid Type III implementation-effectiveness design[29] to (i) test the impact of the implementation strategy called "RhodeMap to Sepsis Survival" (RMTSS) on medical providers' SEP-1 bundle compliance on sepsis patients admitted to inpatient medical wards (aim-1; quantitative), (ii) describe the acceptability, feasibility, adoption and fidelity of RMTSS

(aim-2; qualitative), while observing in-hospital mortality (aim-3; quantitative). Aim 1 and 2 were the primary/implementation outcomes and aim 3 was a secondary/clinical outcome. In this study, RMTSS is the implementation strategy, and the SEP-1 bundle is the clinical intervention. We used a mixed-methods approach, EPIS implementation science framework, Proctor's Implementation Outcomes30, and were guided by StaRI Checklist[31] (Table 6) for reporting implementation studies.

Hybrid type III Implementation-Effectiveness designs are suitable when existing evidence-based practices (EBPs) and/or guideline-recommended practices are being implemented. Additionally, this design is also recommended when there is concern that implementation and effectiveness of an EBP may be impacted during implementation in a new setting. This allows simultaneous testing of an implementation strategy (RMTSS) and observing information on the clinical intervention (SEP-1 compliance) and related outcomes (hospital mortality)[29].

A mixed-methods approach was used so we can triangulate quantitative and qualitative data to better understand the complex hospital ward setting in which sepsis care occurs. Qualitative data from providers helps to understand implementation outcomes better.

Background: SEP-1 Bundle Compliance and Implementation Strategies on Medical Wards

The evidence supporting SEP-1 bundle's impact on mortality is heterogeneous. The most recent systematic review by Ford et al in 2025[32] found "no moderate- or high- level evidence to support that compliance with or implementation of SEP-1 was associated with sepsis mortality" and stated that "CMS should reconsider the addition of SEP-1 to the Hospital VBP Program" (VBP: Value-Based Purchasing). It included 17 studies, all of which were observational and with high risk of bias. Among 12 studies assessing SEP-1 compliance and mortality, 5 showed statistically

significant benefit, and 7 did not- each with important limitations. Meta-analysis was not performed due to considerable methodological heterogeneity among studies.

However, dismissing protocolized sepsis care based on these observational studies would be premature. The heterogeneity reflects methodological challenges rather than failure of the concept of protocolized care itself. For example, the Rhee et al. (2021) study, which found no mortality improvement, did not actually track SEP-1 compliance rates in hospitals—it examined only the impact of 2015 CMS reporting mandates without measuring adherence to the SEP-1 bundle in hospitals and reported population level sepsis outcomes[33]. This distinction is critical: reporting mandates do not automatically translate into improved care delivery, which is precisely why implementation science has developed to address the "know-do gap" in healthcare. Additionally, the New York State experience showed that comprehensive implementation—including standardized protocols, education campaigns, and mandated public reporting—achieved 3.2% absolute mortality reduction compared to control states[34]. This suggests the implementation strategy as well, not merely the bundle itself, may determine effectiveness.

When sepsis outcomes fail to improve, it may be due to three distinct reasons: lack of benefit from protocolized sepsis care in general, limited intrinsic effectiveness of the SEP-1 bundle itself, or poor adherence to the bundle/protocolized care. Each of these represents a fundamentally different problem, requiring separate study designs to evaluate and distinct strategies to address. Compelling evidence to make any of these claims with a high degree of confidence does not yet exist.

Moreover, depending on the location of sepsis onset (Emergency Department, Intensive Care Unit or Medical Wards/Floors), there may be differences in effectiveness of SEP-1 bundles or it's individual elements. Baghdadi et al.[35] demonstrated that SEP-1's impact differs between community-onset and hospital-onset sepsis. For hospital-onset sepsis on medical wards, only broad-spectrum antibiotics were associated with mortality reduction (absolute difference -

5.20%), while other bundle components showed no benefit[35]. Additionally, Hospital onset sepsis also has lower SEP-1 adherence[36,37].

The IDSA upon reviewing this evidence, has recommended limiting mandatory SEP-1 compliance to septic shock only, advocating for SEP-1 to remain in clinical guidelines while removing it from national quality measures for sepsis without shock[38]. However, in a financially constrained, profit-driven healthcare system, hospitals are designed to be responsive to market forces, which do not consistently align with patients' needs. In this already suboptimal context, regulatory frameworks remain essential to guide care delivery. Accordingly, the solution may not be to abandon protocolized sepsis care or SEP-1 entirely, but rather to refine and optimize it through rigorous implementation science, integrating implementation outcomes alongside traditional clinical outcomes.

Quality improvement programs consistently demonstrate improved sepsis bundle compliance. A meta-analysis by Damiani et al. (2015)[18] of 50 observational studies found that performance improvement programs were associated with increased compliance with the complete 6-hour bundle (OR 4.12, 95% CI 2.95-5.76) and mortality reduction (OR 0.66, 95% CI 0.61-0.72). Importantly, the specific components appeared less critical than having a comprehensive program that included sepsis screening and metrics[39].

In the United Kingdom, "Sepsis Six"[40,41] is a simplified, National Health Service (NHS)-facing adaptation of the SEP-1 bundle built for inpatient wards. An Italian study by Monti et al.[42] demonstrated effectiveness specifically in non-ICU settings (in ED and medical wards), showing that a QI program combining educational and organizational interventions increased compliance with the simplified "Sepsis Six" bundle from 46.2% to 57.9% (p 0.001). Leisman et al.[43] found that automated EHR alerts with real-time feedback increased bundle-adherent orders from 21.1% to 29.6% (p=0.0003). However, the effectiveness of QI programs appears context-dependent—Rhee et al. (2021) found that passive SEP-1 implementation across 114 US hospitals showed no mortality improvement, perhaps pointing towards a difference between

comprehensive, quality improvement programs versus passive compliance with reporting mandates[33]. Overall, it seems implementation and quality improvement efforts can be successful in improving adherence to protocolized sepsis care and also perhaps in improving mortality.

Several implementation strategies have demonstrated effectiveness. Multifaceted interventions combining education, organizational changes, and audit-feedback systems consistently outperform single-component interventions[18,44]. Strategies that have improved bundle compliance include EMR-embedded best practice advisories, automated real time monitoring & paging alerts[43], nursing-led protocols[45], state-mandated protocols with public reporting[15,34], dedicated Sepsis-Response Teams[46] and multidisciplinary and multifaceted bedside huddle (also called "Code Sepsis")[47–50] . The studies for performance of "Code Sepsis" have been mixed with some demonstrating improved outcomes including mortality[45,51–54] while others not demonstrating it[55–58]. The balance of these mixed results was assessed to be in favor of implementation of this strategy by authors of the 2026 Surviving Sepsis Campaign Guidelines suggesting using a "code sepsis" or "sepsis huddle" protocol over not using such a protocol[48].

Van Zanten et al. (2014)[59] reported that a Dutch national program implementing sepsis screening and bundle protocols across 52 ICUs achieved improved bundle adherence and 5.8% absolute mortality reduction over 3.5 years—critically, mortality reduction occurred only in participating ICUs that actively screened and applied bundles.

Of note, almost all the above studies were conducted in the Emergency Department or the ICU. Their conclusions may not be generalizable to the hospital ward or 'floor' settings where workflow, resources, staffing (including nurse: patient ratios) and monitoring intensity is intentionally different by design.

Understanding barriers is essential for designing effective implementation strategies. Baghdadi et al. (2020)[37] demonstrated that hospital-onset sepsis has only 12.2% overall SEP-1 compliance, with ward-onset sepsis 32% less likely to receive SEP-1-adherent care than ICU-onset sepsis (RR 0.68, p=0.004).

Rhee et al. (2025) reported on barriers related to patient characteristics and found that patients receiving SEP-1 non-compliant care had significantly more complex presentations: higher rates of septic shock (42.0% vs 31.9%), nonfebrile presentations (53.3% vs 36.1%), and concurrent noninfectious illnesses (54.9% vs 45.1%). The most common care delivery-related reasons for bundle failure were not administering required fluids (31.0%), not repeating lactate (19.6%), and delayed antibiotics (16.5%)—with only the latter strongly associated with mortality[60]. Critically, SEP-1 compliance was associated with lower crude mortality, but this association disappeared after adjusting for clinical complexity (AOR 1.08, 95% CI 0.61-1.91).

Additional barriers include diagnostic uncertainty (33% or more of patients initially diagnosed with sepsis have noninfectious conditions)[61], time-sensitive execution challenges (lactate measurements within mandated windows only 32% of the time on wards versus 79% in EDs)[62], and contextual challenges of SEP-1 "time zero" for inpatients[37].

Facilitators include adequate nurse staffing[63,64]—each additional patient per nurse increases 30-day mortality by 9% (OR 1.09)—multifaceted QI programs combining screening, education, and metrics, simplified bundles adapted for ward settings[42], and institutional cultures emphasizing continuous quality improvement rather than punitive compliance monitoring[18,39,63]. The evidence collectively suggests that improving SEP-1 compliance on medical wards requires addressing fundamental workflow barriers, ensuring adequate staffing, and adapting protocols to ward-specific contexts. Implementation science frameworks assessing acceptability, feasibility, adoption, and fidelity—such as the "RhodeMap to Sepsis Survival"—are essential for translating evidence into sustainable practice change.

Methods

The Intervention and Implementation Strategy

Keeping terminology consistent with StaRI guidelines, the '*intervention'* in this study is the SEP-1 sepsis bundle, an evidence-based clinical quality measure comprising time-sensitive diagnostic and therapeutic elements (e.g., lactate measurement, blood cultures, antibiotics, and fluid resuscitation) designed to standardize early sepsis management and improve patient outcomes.

The '*implementation strategy'* in this study is the RhodeMap to Sepsis Survival (RMTSS), a multifaceted package of 6 implementation techniques—including education, audit and feedback, clinical decision support tools, visual prompts, and arts-based interventions (e.g., a sepsis song)—designed to improve provider adoption, fidelity, and completion of the SEP-1 bundle in routine inpatient care.

<u>The Intervention: 'SEP-1 Bundle'</u>

In our study, we used the implementation strategy package "RhodeMap to Sepsis Survival" (RMTSS) to improve medical providers' compliance with the intervention called the Severe Sepsis and Septic Shock Early Management (SEP-1) Bundle.

Once a patient meets the criteria for severe sepsis[65] (suspected infection, ≥2 systemic inflammatory response syndrome (SIRS) criteria, and acute organ dysfunction), the SEP-1 bundle requires physicians to complete blood draws for lactate and blood cultures (obtained *prior* to antibiotic administration), antibiotic administration and Intravenous (IV) fluid administration (with at least 30 mL/kg of crystalloid fluids for patients with hypotension) within 3 hours of recognition of sepsis. Clinicians are further required to repeat lactate (if the initial lactate was greater than 2.0 mmol/L), initiate vasopressors, and document a repeat volume and

perfusion assessment within 6 hours for patients with septic shock. All criteria were kept identical to CMS criteria[65.] For the purposes of this study, only the 3 hour bundle was tracked.

The Implementation Strategy: 'RhodeMap to Sepsis Survival' (RMTSS)

The Implementation strategy RhodeMap to Sepsis Survival (RMTSS) consists of 6 components as described below. Further details are found in Figures 1a-e and Table 5. The sepsis song is attached separately as a multimedia file (digital supplementary materials; https://doi.org/10.26300/qpnt-q180) and can also be accessed online[66,67].

1. *Monthly department meeting reports and feedback on group performance*
    a. The reports were presented by the first author (SD) during monthly Hospital Medicine department meetings which are mandatory for all providers in the department to attend.
    b. The reports included a monthly department/group performance on SEP-1 compliance, number of sepsis cases encountered, number of cases with all SEP-1 elements met ('success') and SEP-1 fallouts ('failures').
2. *Case reviews, discussion and SEP-1 education during monthly department meetings.*
    a. During the monthly department meetings, time was also allocated for educational materials on sepsis and the SEP-1 bundle.
3. *Sepsis and SEP-1 bundle posters with infographics* were visibly placed at all workstations.
4. *The 'Sepsis Song'*[66,67]
    a. The sepsis song was written, composed and released online specifically for this study. All providers were sent a link to listen to the song on their streaming platform of choice (Spotify[68], Apple Music[69], YouTube[70] etc) and is accessible to the public[67,71,72].

b. Constructs from Health Belief Model[73] and Social Cognitive Theory[74] were considered in writing and composition of the song. These are detailed in Table 1 and 2 and are intended to impact cognitive determinants of behavior.

5. *Electronic Medical Record (EMR) Best Practice Alerts (BPA)*
    a. This is an automated alert in the Electronic Medical Record system (EMR) of the hospital (Epic) and is triggered when ≥2 systemic inflammatory response syndrome (SIRS) criteria are met.
6. *EMR Sepsis Order Set that includes all the SEP-1 components*
    a. The order includes all the individual components of the SEP-1 bundle so providers can easily order them all in one place and not forget some components (Figure 1e).

Study Design

This quality improvement (QI) project, an implementation science study, employs a Hybrid Type III Implementation-Effectiveness design[29], with embedded mixed-methods (Big QUAN with qual).[75]

We used a mixed-methods approach, EPIS implementation science framework, Proctor's Implementation Outcomes[30], and were guided by StaRI Checklist[31] for reporting implementation studies.

Study Aims and Outcomes

The study has 3 aims:

Aim 1 (Primary outcome): To test the impact of the implementation strategy called "RhodeMap to Sepsis Survival" (RMTSS) on medical providers' SEP-1 bundle compliance on sepsis patients admitted to inpatient medical wards using quantitative methods.

Outcomes measured: Medical providers' compliance with the SEP-1 bundle was measured as a binary outcome (if provider is compliant=yes, non-compliant=no) and as a percentage in a group of providers (e.g. "40% compliance if 8 out of 20 providers successfully completed *all* elements of the SEP-1 bundle in July").

Aim 2 (Primary outcome): To describe the acceptability, feasibility, adoption and fidelity of RMTSS using qualitative methods.

Outcomes measured: Semi-structured In-Depth Interviews (IDIs) were conducted with medical providers to explore key implementation outcomes including acceptability, feasibility, adoption, and fidelity of RhodeMap To Sepsis Survival on inpatient medical wards ('floors')

Aim 3 (secondary outcome): To observe in-hospital mortality with quantitative methods.

Outcomes measured: In-hospital mortality was tracked during the study period (16-month pre-intervention period [January 2023 to April 2024] and 20-month post-intervention period [May 2024 to December 2025]) using routine clinical data.

Study context, setting and positionality statement

The study is being conducted in the Internal Medicine/Hospital Medicine department on medical wards ('floors') in an academic, tertiary care, 719-bed hospital in Rhode Island[76]. This is a non-teaching, and larger service compared to a smaller teaching service where residents are the ones physically placing most orders, including those for sepsis care like SEP-1 bundle orders. In contrast, on our service, attendings and APPs are directly responsible for placing orders. The medical providers being interviewed in the qualitative arm (aim 2) are all colleagues in the same department working at the same position as the interviewer (SD)- as Internal Medicine MD Hospitalists, except for 2 in-depth interviewees who were APPs out of 5 total APPs on the service.

The recipients of all the 6 components of RMTSS were medical providers in the internal medicine hospitalist service.

This study received no external funding. The first four components of the implementation strategy package were developed by the author (SD) as part of Master of Public Health coursework. The author (SD) holds the copyright to the song “Sepsis.”

Data collection

Quantitative Methods: Secondary data (EHR)

Routine data was extracted from the Electronic Health Record (EHR) also referred to as an Electronic Medical Record (EMR)- Epic[77] at Rhode Island Hospital and presented via “Power BI” software[78].

Provider SEP-1 bundle compliance (aim 1) was assessed in alignment with Center for Medicare and Medicaid Services (CMS) specifications, recording provider compliance to the SEP-1 bundle as a binary outcome (compliant vs. non-compliant). All elements of the SEP-1 checklist must be met to be considered ‘compliant’ and missing even one element results in a fall-out or ‘non-compliant’ case. Compliance rates pre- and post-implementation were compared.

In-hospital mortality was also accessed via Epic and Power BI during routine hospital data collection (aim 3).

Qualitative Methods: Primary data (IDIs)

We conducted semi-structured In-Depth Interviews (IDIs) with medical providers (13 attendings and 2 advanced practice providers) using an interview guide based on the Exploration, Preparation, Implementation, Sustainment (EPIS) framework to explore key implementation outcomes[30] including acceptability, feasibility, adoption, and fidelity of RhodeMap to Sepsis Survival in the non-ICU, non-ED inpatient setting[30].

The Internal Medicine Inpatient Service consists of 49 physicians and 5 Advanced

Practice Providers (APPs). Out of these 15 were selected by purposive sampling for Interviews.

Description of Framework Selected

The study is guided by the Exploration, Preparation, Implementation, Sustainment (EPIS) framework[24]. EPIS was utilized to systematically assess implementation outcomes related to SEP-1 bundle compliance across four key domains:

- Innovation Factors (e.g., feasibility and acceptability of the EMR tools or group feedback during monthly meetings and educational materials)
- Inner Context (e.g., organizational culture and resources, provider knowledge, self-efficacy)
- Outer context (e.g., service/environment policies like CMS regulations)
- Bridging Factors (e.g., community-academic partnerships)

EPIS framework guided both the qualitative data collection and the interpretation of findings. Additionally, the framework was also chosen to align and perhaps improve comparability of results, with a current ongoing sepsis study - 'Assessment of Implementation Methods in Sepsis[79,80] which is comparing the 3 hour bundle versus a 1-hour bundle and examining how an implementation strategy improves implementation compliance with the two bundles.

Study Population

Quantitative arm:

The quantitative component relied on routine data; information was collected from EMR. Secondary analysis of data collected for standard care on all patients admitted to the medical wards (non-ICU, non-ED 'floors') during the study period, who met CMS SEP-1 criteria were included. The providers caring for these patients are the primary unit of implementation and their compliance was tracked (aim 1).

For observing hospital mortality (aim 3), the patients included in the CMS sepsis denominator were included and the inclusion criteria was kept identical to CMS[65].

Qualitative arm:

The study was conducted at Rhode Island Hospital, Providence, RI, within the Internal Medicine Hospitalists' Service. Participants were recruited using purposive sampling from a pool of 49 physicians and 5 advanced practice providers (APPs). A total of 15 participants (13 physicians and 2 APPs) were included.

Participants were actively involved in inpatient care and had exposure to SEP-1 bundle implementation and RMTSS strategies.

Sampling Strategy

Sampling for Quantitative Section (aim 1 and aim 3)

The sampling was not needed as the quantitative component was based on secondary routine data. All eligible sepsis cases on the wards during the study period
that qualify as per inclusion/exclusion criteria, were included. Preintervention data (16-month period; January 2023 to April 2024) were compared to post-intervention data (20-month period; May 2024 to December 2025).

Sampling for Qualitative Section (aim 2)

The Internal Medicine Inpatient Service consists of 49 physicians and 5 APPs. Out of these, 15 were selected via purposive sampling for interviews. 2 additional physicians were approached but were unable to participate due to scheduling conflicts and being busy. Among the interviewees/health providers, 8 identified as male and 7 as female, 8 had been working with the department for 5 or more years.

Analysis

Quantitative (Statistical) Analysis:

All statistical analyses were performed using Stata version 17[81]. Categorical variables were summarized as frequencies and percentages. The primary outcome was SEP-1 compliance, defined as completion of the 3-hour SEP-1 bundle, measured at the provider level as a binary variable (compliant vs non-compliant). Pre-intervention data were collected over a 16-month period (January 2023 to April 2024) and post-intervention data were collected over a 20-month period (from May 2024 to December 2025.)

The association between the intervention and compliance was assessed using the Pearson chi-square test with one degree of freedom. Effect sizes were quantified using three complementary measures: absolute risk difference (ARD), risk ratio (RR), and number needed to treat (NNT). The risk difference represents the absolute change in compliance probability attributable to the intervention. The risk ratio quantifies the relative increase in compliance likelihood in the post-intervention group compared to the pre-intervention group. The number needed to treat was calculated as the inverse of the absolute risk difference, representing the number of patients who would need to receive the intervention for one additional patient to achieve compliance. Ninety-five percent confidence intervals were calculated for all effect size measures using the command csi in Stata. Attributable fractions were calculated to estimate the proportion of compliance attributable to the intervention, both among exposed individuals (attributable fraction in exposed) and in the total study population (attributable fraction in population).

A two-sided p-value of 0.05 was considered statistically significant.

Qualitative analysis:

This was guided by Consolidated criteria for reporting qualitative research (COREQ)[82].

Reflexivity statement:

The primary analyst (SD) acknowledged their role as clinician, colleague and investigator, which informed interpretation but was mitigated through systematic coding and adherence to verbatim data. The author SD is an internal medicine physician (MD, and currently a public health Masters' candidate) in the same department as the interviewee health providers and knew all the participants well. The health providers were made aware of the research being conducted for thesis work. The study employed a qualitative descriptive design using thematic analysis as outlined by Virginia Braun and Victoria Clarke (2006)[83] to explore healthcare providers' experiences with the implementation of the RhodeMap to Sepsis Survival (RMTSS) intervention. The qualitative component was embedded within the Hybrid Type III implementation-effectiveness study as a mixed-methods design, with a primary focus on implementation processes and outcomes.

Data collection:

Data were collected through a semi-structured interview guide accompanied by probes to elicit deeper insights. Interview questions were sequenced according to EPIS framework and divided into Outer Context, Inner Context, bridging factors and innovation factors. Consent was obtained before and at the start of the interview. All interviews were conducted one-on-one via Zoom, between October 2025 to February 2026, lasted approximately 30–45 minutes, and were audio-recorded. Verbal consent was obtained both prior to and at the beginning of each interview.

Transcription and Data Management

Interviews were transcribed using Zoom automated transcription. Transcripts were subsequently manually reviewed and corrected for accuracy by comparing against audio recordings. Backup

audio recordings via iPhone voice memos were used selectively to verify unclear segments and correct minor transcription errors.

All transcripts were de-identified prior to analysis.

Data Analysis

Data were analyzed using NVivo 15[84] (QSR International). Thematic analysis was conducted following the six phases described by Braun and Clarke[83]:

1. Familiarization with the data
2. Generation of initial codes (done in NVivo)
3. Searching for themes
4. Reviewing themes
5. Defining and naming themes
6. Producing the report

A total of 125 codes were generated inductively and iteratively from the transcripts. A codebook was exported from NVivo to Microsoft Excel. Codes were subsequently grouped into categories and organized into eight overarching themes.

Coding was performed by a single primary analyst (the researcher) with iterative refinement of codes and themes through repeated engagement with the data. An audit trail was maintained through NVivo and Microsoft Excel to document coding decisions and theme development.

Theme Development and Framework Mapping

Codes were grouped into themes based on conceptual similarity and relevance to implementation processes. The final eight themes were:

1. Workflow friction and operational overload impede SEP-1 completion
2. SEP-1 and RMTSS strategies are accepted, but adoption is variable
3. RMTSS improves awareness through multimodal reinforcement

4. Electronic medical record (EMR) tools are both facilitators and sources of friction

5. Suggestions for optimization

6. The sepsis song as a novel but variably used strategy

7. The “last mile” of execution as a distinct implementation challenge

8. Organizational culture and leadership influence

Each theme and corresponding codes were mapped to EPIS[85] domains (inner context, outer context, innovation factors and bridging factors) and Proctor implementation outcomes[30] (acceptability, adoption, feasibility, fidelity). This dual mapping enabled a structured interpretation of both determinants and outcomes of implementation.

Rigor and Trustworthiness

Methodological rigor was ensured through several strategies consistent with COREQ guidelines including use of verbatim quotes from transcripts to support themes for credibility, maintenance of an audit trail, iterative comparison of codes and themes against raw data, and clear documentation of analytic framework (Braun & Clarke, EPIS, Proctor) for transparency.

Dissemination Plan

The thesis will be presented at thee Sepsis Steering Committee, Rhode Island Hospital and with the Internal Medicine Inpatient Service, Department of Hospital Medicine, Rhode Island Hospital. It is also submitted for International Society for Quality in Healthcare Conference being held in Ireland, 2026.

Ethical Considerations

The study was conducted as part of a quality improvement and research initiative and received appropriate institutional review. Participants provided informed consent, and all data were de-identified to ensure confidentiality.

Fidelity and Adaptation

RMTSS components 1–3 were delivered throughout the post-intervention period for 20 months (May 2024 to December 2025); components 4–6 were only delivered for the last 6 months (added in July 2025 until December 2025). This is depicted in Figure 3. Fidelity to provider receipt was not systematically measured. No formal adaptations to SEP-1 criteria were made.

Results

Study Population

This study employed a Hybrid Type III effectiveness-implementation design, which primarily tests an implementation strategy while observing and gathering information on the clinical intervention's impact on relevant outcomes. A total of 147 patients with sepsis managed in the non-ICU, non-ED inpatient medical ward ("floor") setting were included in the analysis, comprising 55 patients in the 16-month pre-intervention period (January 2023 to April 2024) and 92 patients in the 20-month post-intervention period (May 2024 to December 2025).

Aim 1: Impact of RMTSS on SEP-1 Bundle Compliance (Primary Implementation Outcome)

SEP-1 bundle compliance rates increased significantly following implementation of the RhodeMap To Sepsis Survival (RMTSS) strategy. In the pre-intervention period, 12 of 55 patient encounters (21.8%) achieved SEP-1 bundle compliance, compared with 35 of 92 patient encounters (38.0%) in the post-intervention period. This difference was statistically significant ($\chi^2 = 4.17$, df = 1, $p = 0.041$).

The absolute risk difference was 16.2 percentage points (95% CI: 1.5% to 31.0%), indicating a clinically meaningful improvement in compliance (Figure 4a). The risk ratio was 1.74 (95% CI:

0.99 to 3.07), suggesting that patient encounters in the post-intervention period were 74% more likely to achieve SEP-1 bundle compliance compared with those in the pre-intervention period. The number needed to treat was 7 (95% CI: 4 to 68), indicating that for every 7 patient encounters managed under the RMTSS protocol, one additional encounter achieved full SEP-1 bundle compliance.

Individual bundle component metrics also demonstrated improvements across multiple domains in the post-intervention period compared with the pre-intervention period (Figure 4b). Initial lactate pass rate increased from 53% to 68%. Blood culture pass rate increased from 56% to 78%. Antibiotic pass rate increased from 86% to 94%. IV fluid pass rate increased from 13% to 24%.

Aim 2: Acceptability, Feasibility, Adoption, and Fidelity of RMTSS

Overview

Fifteen clinicians (13 physicians and 2 advanced practice providers) participated in semi-structured interviews exploring the implementation of the RhodeMap to Sepsis Survival (RMTSS) intervention. A total of 125 codes were generated and organized into eight themes. Selective codes belonging to each theme are detailed in Table 4. Also included in the table are columns linking the codes to their corresponding EPIS domains[85] and Proctor Implementation Outcomes[30].

Themes:

1. Workflow friction and operational overload impede SEP-1 completion

Participants consistently described the clinical environment as cognitively and operationally demanding, with competing priorities and interruptions undermining SEP-1 completion. Providers emphasized the burden of multiple simultaneous alerts and tasks:

“besides sepsis triggers, there are so many other triggers that are competing with physicians' attention as well… it's not only the sepsis triggers that affect me, all those triggers affect me.” (Health provider 4)

Interruptions—particularly through electronic communication—disrupted workflow continuity: “they are deterrents and attention sinks.” (Health provider 3). “Secure chats” refers to a secure texting application built into the hospital EMR that is available on smartphones as well.

“when you have constant disruptions, it kind of sometimes derails your train of thought, or your flow of work.” (Health provider 2)

Participants also highlighted cognitive overload and environmental stimulation:

“you do have that stimulation… that excess stimulation from everywhere else. That may make you make mistakes along the way.” (Health provider 1)

Structural constraints such as staffing shortages further impaired timely bundle completion:

“our staffing… 100% affects how timely the sepsis protocol is given.” (Health provider 3)

Collectively, these findings indicate that inner-context workflow complexity- especially staffing and cognitive load-related aspects- directly impacts feasibility and acceptability of SEP-1 implementation.

2. SEP-1 and RMTSS strategies are accepted, but adoption is variable

Participants generally viewed SEP-1 as beneficial and were familiar with its components. They did not generally feel that the SEP-1 bundle was cumbersome, in fact many felt it was actually helpful in delivering sepsis care:

“Yes… I would say it's helpful.” (Health provider 3)

“I'm fairly, fairly confident.” (Health provider 8)

However, adoption was not uniform. Providers described a need for clinical judgment and selective use:

“you need to weigh those pros and cons very carefully before just blindly administering a Sep 1 sepsis bundle.” (Health provider 3)

“many of the patients are chronically ill… that may limit our use of the SEP1.” (Health provider 3)

Although perceived as an “excellent tool,” variability in clinical contexts influenced adherence:

“we underutilize it, but… it is an excellent tool.” (Health provider 2)

This theme reflects high acceptability but variable adoption, shaped by clinical complexity within the inner and outer context.

3. RMTSS improves awareness through multimodal reinforcement

Participants described RMTSS as increasing awareness and prioritization of sepsis through repeated exposure, feedback, and multimodal educational strategies, keeping sepsis salient:

“when we talk about this thing every month… it just makes these things important.” (Health provider 4)

“having it… being talked about helps… this makes it sort of front and center in our conversations.” (Health provider 14)

Visual tools and infographics were particularly effective:

“I am a very visual learner… it's definitely the infographic.” (Health provider 12)

“it does bring it to the forefront.” (Health provider 4)

Feedback and performance tracking further reinforced behavior:

“having… the numbers… we at least know how we are doing.” (Health provider 15)

Participants also noted that awareness translated into action:

“any way that you're getting the information is going to increase awareness, and hopefully compliance.” (Health provider 12)

These findings highlight some important possible mechanisms through which multiple complementary strategies work to improve adoption, acceptability, feasibility and fidelity.

4. EMR tools are both facilitators and sources of friction

Electronic medical record (EMR) tools were described as both enabling and constraining implementation. On one hand, they were considered indispensable and were considered to improve efficiency and information access:

“you can find out exactly what's happening with the patient… a lot quicker than it would be without the EMR.” (Health provider 1)

“being able to place orders and have results within moments is really exceptional.” (Health provider 12)

Alerts were seen as crucial prompts:

“definitely getting the trigger and alert is helpful.” (Health provider 4)

However, excessive alerts led to fatigue:

“there's a component of alert fatigue… which makes me pay less attention.” (Health provider 8)

“I think it's death by a thousand clicks.” (Health provider 8)

While it was recognized that order sets enabled completeness in compliance with all elements of the SEP-1 bundle:

“if I don't use the orderset, I may miss something.” (Health provider 1)

their use varied across providers:

“I haven't… been trying to use it as much as I could.” (Health provider 2)

Thus, EMR itself and RMTSS’ EMR components functioned as critical factors influencing feasibility, adoption, and fidelity—both positively and negatively- suggesting the need for more nuanced contextual tailoring.

5. Suggestions for optimization

Participants identified several opportunities to improve implementation, particularly through feedback, real-time guidance, and workflow alignment:

“maybe reasonable to reach out to those providers who have a lower compliance score.” (Health provider 1)

A lack of real-time tracking and guidance was a key limitation:

“there's no really good way to see whether or not the patient has completed… all the steps.” (Health provider 8)

Workflow misalignment was also highlighted:

“it's not the exact same workflow every single time… I had to put in the relevant bundle elements manually.” (Health provider 9)

The psychological impact of aesthetic choices of the infographic poster was also highlighted by one physician, since the printouts were black and white

“would be more helpful if it was colorful… strategic location of… where do you put those posters.” (Health provider 4)

These findings emphasize the importance of tailoring implementation strategies within the inner context improve feasibility and adoption.

6. The sepsis song as a novel but variably used implementation strategy

The sepsis song emerged as a unique educational tool that enhanced engagement and awareness:

“the song definitely did help.” (Health provider 4)

Participants described its cognitive benefits:

“putting anything to music helps you put it in your brain in a different place… and access it differently.” (Health provider 8)

It was also perceived as engaging and emotionally resonant:

“it definitely makes you more aware.” (Health provider 4)

“it opens a smile… makes them think.” (Health provider 7)

Some participants highlighted its role in teaching:

“it's another way of learning… some people learn visually, musically.” (Health provider 12)

However, its use in real-time clinical practice was limited:

“I don't recall the song or think about the song at all.” (Health provider 7)

Additionally, the delivery was suboptimal: " it's not being heard so often" (Health provider 4)

This theme reflects high acceptability but variable adoption, characteristic of innovative educational interventions.

7. The “last mile” of execution is a distinct implementation problem

A key barrier identified was the gap between ordering interventions and their timely execution:

“you would see that the lactate's been ordered, but it's not being drawn… fluids… given after the… 3 to 6 hour period.” (Health provider 1)

Participants emphasized the complexity of coordinating multiple team members:

“it requires a small army to get this done in a timely fashion.” (Health provider 3)

These findings illustrate that some outcomes may be constrained not by knowledge or initial action, but by downstream or parallel execution within complex care systems, highlighting a distinct “last mile” implementation challenge.

8. Organizational culture and leadership influence

Participants identified organizational prioritization as a key facilitator of implementation:

“Do you feel that sepsis is a visible organizational priority…? … Absolutely.” (Health provider 1)

“I think yours is the number one most visible.” (Health provider 9)

Institutional emphasis, leadership support and visibility reinforced engagement and awareness, suggesting that organizational culture within the inner context promotes adoption and acceptability.

Summary of Qualitative Findings (Aim-2)

Overall, implementation of SEP-1 and the impact of RMTSS strategies are shaped by a dynamic interplay between:

- Inner context factors (workflow complexity, cognitive load, staffing)
- Innovation factors (education, feedback, EMR tools, multimodal reinforcement)
- Organizational prioritization

While acceptability of interventions was high, feasibility and fidelity were frequently constrained, particularly by workflow fragmentation and execution challenges. Innovative strategies such as the sepsis song demonstrated strong engagement but variable translation into clinical practice.

Aim 3: Hospital Mortality (Secondary Clinical Outcome)

Consistent with Hybrid Type III methodology, hospital mortality was assessed as a secondary, observational outcome to gather preliminary information on the clinical intervention's impact. The study was not designed or powered to detect statistically significant differences in mortality. Hospital mortality among sepsis patients on the medical wards decreased from 16.4% (9/55 patients) in the pre-intervention period to 9.8% (9/92 patients) in the post-intervention period, representing an absolute risk reduction of 6.6 percentage points (Figure 4c). As anticipated for a Hybrid Type III design, this difference did not reach statistical significance ($\chi^2 = 1.39$, df = 1, $p = 0.238$).

The risk ratio for mortality was 0.60 (95% CI: 0.25 to 1.41), indicating a 40% relative reduction in mortality risk. The observed NNT to prevent one death was 15 patients. It is important to interpret this mortality NNT within the context of the Hybrid Type III design. Unlike the compliance NNT (which reflects the direct effect of the RMTSS implementation strategy), the mortality NNT represents an indirect, downstream effect of the implementation strategy, mediated through improved SEP-1 bundle compliance. The hypothesized causal pathway is:

RMTSS implementation strategy → Improved SEP-1 compliance → Reduced Mortality

This mortality NNT of 15 should therefore be interpreted as hypothesis-generating evidence suggesting that implementation strategies improving sepsis bundle compliance may translate to meaningful reductions in mortality. However, because the clinical outcome was observational rather than the primary powered endpoint, and because the effect is mediated through an intermediate outcome (compliance), this finding requires confirmation in adequately powered effectiveness studies and as such should not be interpreted causally.

Discussion

This Hybrid Type III implementation–effectiveness study evaluated the impact of a multifaceted implementation strategy—RhodeMap to Sepsis Survival (RMTSS)—on delivery of the SEP-1 bundle in a non-ICU inpatient medical ward setting. Consistent with StaRI guidance, we distinguish between the implementation strategy (RMTSS) and the clinical intervention (SEP-1 bundle) and interpret findings across both strands.

Implementation of RMTSS was associated with a statistically significant and clinically meaningful improvement in SEP-1 compliance (aim 1), with improvements across multiple bundle components. A reduction in hospital mortality (aim-3) was observed but did not reach statistical significance, consistent with the study's Hybrid Type III design and limited power for clinical outcomes. However, this contributes to the debate of the benefits of the SEP-1 bundle, especially on medical wards. The findings point to an evidence gap regarding which bundle components, time targets and implementation approaches produce the greatest clinical benefit. The ongoing AIMS trial[86–88] is one such study that is looking at 1-hour versus 3-hour SEP-1 bundles in the ED setting with hospital mortality as the primary clinical outcome and bundle fidelity as a co-primary implementation outcome. However, because AIMS is ED-based,

additional implementation–effectiveness studies are needed in non-ED, non-ICU medical ward settings, where recognition of sepsis, patient mix, workflows, staffing patterns, and bundle execution barriers may differ substantially.

The qualitative findings (aim-2) showed that while SEP-1 and RMTSS strategies were broadly acceptable to clinicians, feasibility and fidelity were constrained by workflow fragmentation, cognitive overload, staffing limitations, and execution challenges, including in the “last mile” between order placement and intervention completion. Taken together, these mixed-methods findings suggest that RMTSS improved compliance primarily by increasing awareness, achieving salience, institutional support and reinforcing behavior, but its overall effectiveness was moderated by structural and cognitive constraints within the clinical environment. Similar findings have been observed in qualitative studies both in the United States, as well as with the use of Sepsis Six in the United Kingdom. Tarrant et al.[89] in their ethnographic study in 2016 noted that sepsis care protocols are not a simple sequence of steps, but rather a ‘complex trajectory’ requiring implementation efforts to not just focus on individual behavior change, but to pay attention to coordination of workflow and address “interruptions and operational failures that obstruct task completion”. Hayes et al.[87] in their process evaluation for the ongoing AIMS[86,88] study on sepsis in US Emergency Departments also noted heavy workloads, competing priorities, high staff turnover rates and Epic (EHR) issues as barriers to SEP-1 bundle compliance.

A central insight from this study is that SEP-1 compliance is fundamentally a systems-level challenge rather than a knowledge deficit. Even in a resource-rich academic medical center, clinicians operate within complex, high-interruption environments where multiple time-sensitive tasks compete for attention. Execution of SEP-1 requires coordinated action across physicians, nurses, laboratory staff, and pharmacy, transforming what appears to be a checklist into a distributed, multi-actor process.

The identification of a distinct “last mile” implementation gap captured in interviews—where interventions are ordered but not completed within required timeframes— is noteworthy but requires objective measurement regarding what fraction of SEP-1 fallouts occur due to orders not being placed, compared to orders not being able to be executed in the required timeframe. It conceptually extends prior literature by highlighting that implementation failure may occur not only at the level of providers’ clinical decision-making but also at the level of operational execution. This suggests that fidelity in implementation research should be conceptualized beyond clinician adherence to include system-level delivery processes.

A dominant theme across qualitative findings was the role of cognitive load in shaping implementation outcomes. Clinicians described environments characterized by frequent interruptions, competing alerts, and high task density, leading to fragmentation of attention and workflow disruption- similar to existing literature[87,89] already discussed. These findings align with the concept of finite cognitive capacity described in Cognitive Load Theory[90], which has been recontextualized in complex clinical practice environments[91], where finite capacity of working memory compromises both the acquisition of clinical knowledge as well as reliable execution of cognitively demanding, multielement tasks in practice- similar to the structure of the sepsis bundle.

This provides a critical lens for interpreting the quantitative findings. While overall compliance improved, persistent gaps—particularly in some components such as fluid administration—suggest that clinicians may selectively prioritize tasks under cognitive constraints rather than uniformly applying all bundle elements. Alternatively, appropriate application of provider’s clinical judgement in a septic patient on the wards, appropriately *not* administering IV fluids, but not documenting specific fluid exception documentation requirements (required by CMS) may explain this finding as well. Our study was not able to detect or explore the reasons for missing the IV fluids component of the bundle. It is plausible that being cognitively saturated, some physicians held IV fluid administration that was indicated. Alternatively, it is also plausible that IV

fluids were appropriately held, but documenting the IV fluid exception was not done due to cognitive saturation. In Cognitive Load Theory (CLT), the model of human cognitive architecture comprises 3 components- the sensory memory, working memory (which has limited capacity) and long-term memory (which has infinite capacity). CLT identifies 3 types of cognitive loads that compete for the finite capacity of working memory. These are the *Intrinsic load* (dependent on the complexity of the task itself- like multiple elements of the SEP-1 bundle), *Extraneous load* (determined by the non-essential demands that do not contribute to the task at hand- like EHR alert fatigue, interruptive secure chats, documentation burden and poorly designed workflows) and the *Garmane load* (the deliberately made cognitive effort to organize and integrate information into long term memory, so bundle execution will become progressively easier and automated in the future). When total cognitive load (Intrinsic + Extrinsic + Germane load) exceeds the finite capacity of working memory, it leads to performance degradation. The goal of any implementation strategy should be to reduce Extraneous load (those are often unnecessary interruptions), manage Intrinsic load (e.g. make SEP-1 bundle execution as easy or 'feasible' as possible) and optimize Germane load (so people can learn RMTSS or SEP-1 bundle for example, and next time execution will be easier and more 'automated').

Our findings of cognitive workload potentially impacting providers' ability to deliver care may have a possible relation to the important phenomenon of physician burnout, with recent prevalence noted to be above 40%[92]. A recent review of physician burnout[93] made strong recommendations to "Focus on the development and evaluation of interventions that reduce physician workload."

We suggest that implementation frameworks such as EPIS would benefit from explicitly incorporating cognitive mapping of clinical work, including the distribution of attentional demands, frequency and impact of interruptions (especially EMR-based to minimize, as one Health provider put it, "death by a thousand clicks"), alignment (or misalignment) between interventions and natural workflow. Such an approach would enable designs of implementation

strategies that are cognitively sustainable, rather than simply additive, thereby improving their adoption, feasibility and sustainability.

This study highlights the importance of opportunity cost in implementation—a concept well-established in health economics but not frequently operationalized in implementation science[94,95]. However, what our study conceptually draws attention to is more than just financial opportunity cost. SEP-1 implementation requires allocation of finite resources—time, attention, staffing—which inevitably introduces trade-offs. We suggest attention to three interrelated forms of opportunity cost relevant to implementation: cognitive opportunity cost (diversion of limited attentional resources by medical providers toward SEP-1 at the expense of other clinical tasks), grounded in cognitive load theory[91]; clinical opportunity cost (reduced attention to non-target conditions or competing priorities), paralleling displacement effects described in health economics[96–98]; and relational opportunity cost (diminished time for patient communication and patient-centered care), consistent with evidence that time pressure degrades the therapeutic relationship and shared decision-making[99,100].

While partial measures of these constructs exist—cognitive workload scales, time-motion studies[94], burnout metrics[93]—they have some limitations. Burnout scales and metrics are inconsistently defined,[92,93] opportunity cost definitions in health economics do not take into account the cognitive and subjective costs on the medical provider (for example, in the discussion of ‘Value Frameworks’, included are patient Quality Adjusted Life Years and financial cost, but not included are the cognitive cost on physicians or relational opportunity cost). Drossman et al[99] have articulated the idea similar to what we termed ‘relational opportunity cost’, but the proposed solutions are limited to the physician as an individual. Integration of these concepts into an implementation science framework like EPIS can enable multi-level

conceptualization, determinants and possible solutions at Inner Context or Outer Context level for example, thereby enhancing our understanding of why interventions succeed or fail. Closely related is the concept of optimal efficiency—the level of protocol adherence that maximizes net clinical benefit when accounting for cognitive, clinical, and relational costs. Implementation science increasingly recognizes that fidelity and adaptation are complementary rather than opposing imperatives, and that contextual modifications to evidence-based interventions are not inherently detrimental to outcomes[101,102]. In our study, increased adherence to the SEP-1 bundle (aim -1) was associated statistically non-significantly with inpatient mortality (aim-3). It is unclear if this association will hold a linear relation with increasing SEP-1 compliance and what the opportunity costs will be if compliance is increased to higher levels on medical wards. Schwarz et al[101] proposed "a theoretical approach, a Value Equation, to reconciling the fidelity and adaptation debate", a concept which overlaps with our suggestion. The overall 'Value Equation' could include the measures of cognitive burden, quality of life of medical providers and opportunity costs, thereby aiming for optimal efficiency rather than maximizing financial-only measures of efficiency.

We acknowledge these terms are neither operationally defined with precision, nor are empirically validated. Future studies should develop consensus on the theoretical and operational definition of these terms, prospectively measure opportunity costs alongside traditional implementation outcomes, and adopt multidisciplinary approaches—integrating cognitive science, health economics, and communication science—to determine whether incorporating these constructs into frameworks such as EPIS yields more sustainable and effective implementation.

The inclusion of a sepsis song as part of the RMTSS strategy represents a novel, low-cost, low carbon-footprint, arts-based implementation approach that may help reinforce awareness, memory, and engagement with SEP-1 bundle elements. Participants in our study described the song as memorable, emotionally engaging, and useful for increasing awareness, although its

translation into real-time clinical behavior was variable. This suggests that music may function less as a stand-alone behavior-change intervention and more as an adjunctive cognitive and cultural reinforcement strategy within a broader multifaceted implementation package.

The theoretical rationale for using music as an implementation strategy is supported by emerging cognitive neuroscience literature linking musical pleasure, reward processing, and memory. Ferreri et al. describe music as a powerful mnemonic tool whose benefits may be mediated through dopaminergic reward pathways involved in memory consolidation[103]. Their review summarizes experimental evidence showing that pleasure experienced during music listening, modulated by both dopaminergic transmission and individual sensitivity to musical reward, can enhance episodic memory for music itself and even for associated non-musical information. This is relevant to implementation because many clinical protocols, including SEP-1, require rapid retrieval of structured information under conditions of high cognitive load.

In their 2017 experimental study[104], Ferreri et al. found that music-related reward responses predicted episodic memory performance: musical excerpts rated as more rewarding were more likely to be recognized and remembered 24 hours later. Interestingly, individual differences in musical reward sensitivity, measured using the Barcelona Music Reward Questionnaire, predicted recollection performance, suggesting that the cognitive benefit of music is not uniform across individuals. This finding helps interpret the variable uptake of the sepsis song in RMTSS: some clinicians may experience music as highly salient and memorable, while others may find it less useful or not recall it during clinical care.

The mechanistic basis for this effect is strengthened by Ferreri et al. 's 2021 pharmacologic study[105], which demonstrated that dopamine modulates reward-driven music memory consolidation. In that study, participants listened to unfamiliar musical excerpts under placebo, levodopa, and risperidone conditions. The authors found that the pleasure-memory relationship was disrupted when dopaminergic signaling was blocked with risperidone, particularly among participants with lower or average musical hedonia . These findings suggest that musical

pleasure may enhance memory through dopaminergic reward mechanisms, supporting the plausibility of music as a mnemonic implementation tool.

Importantly, Cardona et al.[106] extended this work beyond memory for music itself by demonstrating that musical pleasure can enhance verbal episodic memory. In their study, participants encoded words in the context of highly pleasant music, less pleasant music, or white noise; 24 hours later, memory was tested. Participants with higher musical reward sensitivity showed improved recollection, particularly for words encoded in a highly pleasant musical context, and this effect persisted even when music was played before rather than during encoding. This finding is especially relevant to clinical implementation because the goal of the sepsis song was not musical memory per se, but improved recall of non-musical clinical content: blood cultures, lactate, antibiotics, fluids, and time-sensitive SEP-1 steps.

Within RMTSS, the sepsis song may therefore be understood as operating through several overlapping mechanisms. First, it may serve as a cue to action, consistent with the Health Belief Model[73], by prompting clinicians to recognize sepsis and recall the required response. Second, it may provide reinforcement, consistent with Social Cognitive Theory[74], through repetition, rhythm, emotional salience, and shared exposure. Third, it may act as a retrieval scaffold, using melody and rhythm to organize complex information into a more easily remembered sequence. Finally, it may contribute to a shared cultural environment in which sepsis remains visible, discussed, and memorable.

However, the qualitative findings also suggest clear limits. Participants did not consistently report using the song during real-time clinical decision-making. This is consistent with the broader finding that music-memory effects depend on musical pleasure, individual musical hedonia, context, and exposure frequency. Therefore, music-based strategies should not be interpreted as substitutes for staffing, workflow redesign, EMR optimization, audit and feedback, or reliable multidisciplinary execution. Rather, they may be best understood as low-cost, eco-

friendly adjuncts that increase salience, reinforce memory, and support awareness within a larger implementation strategy.

Taken together, these findings suggest that music may represent a promising but underdeveloped category of implementation strategy, particularly for protocols requiring rapid recall of structured steps under cognitive pressure. Future research should evaluate arts-based implementation strategies more formally, including their acceptability, exposure dose, effect on recall, inter-individual variability, and downstream impact on clinical behavior. In the context of RMTSS, the sepsis song should be interpreted as a novel, theoretically grounded, and low-cost reinforcement strategy whose value lies in complementing—not replacing—the operational and system-level changes required for reliable SEP-1 implementation.

The generalizability of these findings must be interpreted within the context of the study setting. This study was conducted in a resource-rich academic medical center with advanced EMR infrastructure, established quality improvement systems, and in many ways favorable staffing conditions. Such resources are not uniformly available across healthcare systems globally. Differences in EMR availability and cost, staffing ratios, organizational structure, quality improvement capacity may significantly influence the feasibility and effectiveness of similar implementation strategies in other settings, including community hospitals and low- and middle-income countries.

These differences have important health equity implications. Implementation strategies that depend on advanced technology, analytics personnel, or substantial institutional infrastructure may unintentionally widen gaps between well-resourced and under-resourced settings. Therefore, future work should examine which components of RMTSS are essential, which can be adapted, and which lower-cost elements—such as education, feedback, posters, and the sepsis song—may be feasible across diverse settings. These considerations underscore the importance of integrating health equity and structural context into implementation science frameworks. A growing body of implementation science scholarship, as well as medical

organizations, [107–110] consistent with this idea, have called for health equity to be a foundational- not just an optional- element of implementation science research.

Several broader factors warrant brief mention. The increasing integration of artificial intelligence into healthcare may alter cognitive workflows, potentially reducing some burdens while introducing others (e.g., verification, information overload). Similarly, the ecological impact of health infrastructure, including current efforts to integrate Artificial Intelligence, EMRs and data-intensive systems, represents an emerging area for consideration in healthcare delivery. The health care sector is responsible for 10% of greenhouse gas emissions in the US [111,112]. Given this high carbon footprint, implementation strategies that are cost (financial and environmental) effective are particularly attractive for a sustainable future of health care delivery.

While these factors were not directly evaluated in this study, they represent important contextual influences for future research and should be incorporated into Implementation frameworks.

This study has several strengths and limitations. In terms of strength, . first, it addresses SEP-1 bundle implementation in a non-ICU, non-ED inpatient ward setting, a clinically important and comparatively understudied context in sepsis care. Much of the existing literature on protocolized sepsis management is derived from emergency department and intensive care environments, where workflows, staffing ratios, monitoring intensity, and team structures differ substantially from medical wards[8,9]. By focusing on ward-based sepsis, this study contributes evidence from a setting where implementation challenges may be particularly pronounced. Second, the study uses a Hybrid Type III implementation–effectiveness design, which is well suited to evaluating an implementation strategy while observing downstream clinical outcomes. This design allowed RMTSS to be evaluated primarily as a strategy to improve SEP-1 delivery, while also generating preliminary, hypothesis-generating information about hospital mortality. Consistent with StaRI guidance, the study distinguishes the implementation strategy,

RhodeMap to Sepsis Survival, from the clinical intervention being implemented, the SEP-1 bundle.

Third, the mixed-methods design strengthens interpretation of the findings. Quantitative analysis demonstrated an improvement in SEP-1 compliance after RMTSS implementation, while qualitative interviews helped explain how and why the strategy may have worked, and where implementation barriers persisted. The qualitative component added important insight into acceptability, adoption, feasibility, and fidelity, particularly around workflow fragmentation, cognitive load, EMR-related friction, staffing limitations, and the “last mile” of execution.

Fourth, the study is theoretically grounded. EPIS provided a structure for examining inner context, outer context, innovation factors, and bridging factors, while Proctor’s implementation outcomes helped organize findings around acceptability, adoption, feasibility, and fidelity. This strengthens the conceptual clarity of the study and improves its relevance to implementation science.

Finally, RMTSS included both conventional implementation strategies, such as education, audit and feedback, visual reminders, EMR alerts, and order sets, and a novel arts-based component through the sepsis song. This combination provides a pragmatic, real-world example of how multimodal implementation strategies may increase salience and reinforce clinical behavior in complex care environments.

This study also has important limitations. First, the quantitative component used a pre–post design without randomization or a concurrent control group. As a result, causal inference is limited. Improvements in SEP-1 compliance may have been influenced by secular trends, institutional priorities, staffing changes, concurrent quality improvement efforts, changes in provider awareness, or other unmeasured contextual factors.

Second, the study was conducted at a single academic medical center within one hospitalist service. The findings may not be generalizable to other hospitals, particularly community

hospitals, teaching services, emergency departments, intensive care units, or health systems with different staffing models, EMR infrastructure, quality improvement capacity, or regulatory environments.

Third, fidelity to individual RMTSS components was not fully measured. For example, the study did not systematically quantify exposure to the sepsis song, frequency of poster viewing, attendance at specific educational sessions, use of the EMR order set, provider-level response to BPAs, or the extent to which each implementation component was delivered or received as intended. This limits the ability to determine which components of RMTSS were most effective.

Fourth, the qualitative analysis was conducted by a single primary analyst who was also a clinician-colleague within the same department and the developer of several RMTSS components. Although reflexivity, de-identification, verbatim quotations, and an audit trail were used to strengthen trustworthiness, the possibility of social desirability bias among health providers and interpretive bias during analysis remains.

Fifth, the study did not directly evaluate the intrinsic efficacy of the SEP-1 bundle itself. Rather, it evaluated whether a multifaceted implementation strategy improved delivery of SEP-1 in routine ward practice. This distinction is important because improved bundle compliance does not necessarily prove that the bundle, as currently specified, improves clinical outcomes for all ward-based sepsis patients.

Sixth, during the study period, several contextual factors may have influenced SEP-1 performance, including ongoing institutional attention to sepsis (Inner context), CMS considering moving SEP-1 bundle from a pay-for-reporting to pay-for-performance metric (Outer context). This would have financial implications for hospitals and hospitals would be incentivized to allocate more resources to the care of sepsis patients. Because this was a pre–post study without a concurrent control group, the independent contribution of RMTSS cannot be fully separated from these contextual influences.

This study has several implications for practice, policy, and implementation research. For clinical practice, the findings suggest that improving SEP-1 compliance on medical wards requires more than disseminating guidelines or educating clinicians. SEP-1 completion depends on coordinated action across physicians, nurses, laboratory services, pharmacy, EMR systems, and institutional workflows. Therefore, implementation strategies should address not only provider knowledge and motivation, but also staffing, task distribution, communication, alert burden, order-set usability, and real-time execution.

For health system leaders, the findings highlight the importance of designing implementation strategies that are compatible with the realities of ward-based clinical work. Interventions that add tasks to already saturated environments may improve awareness but still fail at the point of execution. Future SEP-1 improvement efforts should include mechanisms for real-time tracking of bundle completion and provider support, clearer escalation pathways, multidisciplinary accountability, and workflow redesign that reduces rather than increases cognitive burden.

For policy, this study supports a more nuanced approach to SEP-1 as a quality measure. Rather than treating SEP-1 compliance as a simple blanket marker of provider performance in any undifferentiated hospital setting, policymakers should recognize that compliance reflects both provider clinical decision-making and overall system capacity. SEP-1 should continue to evolve with generation of quality evidence and be adapted for ward-based sepsis care, with attention to the specific challenges of non-ICU, non-ED settings, including staffing, cognitive capacities, workflow, EMR infrastructure, diagnostic uncertainty, and available resources.

Ward-based sepsis measures should preserve the benefits of early recognition and timely treatment while allowing clinically appropriate individualization, particularly for complex patients in whom fluid administration, timing definitions, or diagnostic clarity may be challenging. In this context, tying SEP-1 compliance directly to pay-for-performance programs should be carefully evaluated, as financial incentives may inadequately account for differences in ward-level

resources, system capacity, and the complex multidisciplinary processes required to complete the bundle reliably.

For implementation science, this study suggests that cognitive load, opportunity cost, and the "last mile" of execution deserve greater attention in implementation frameworks. EPIS and Proctor's constructs were useful for organizing determinants and outcomes, but the findings suggest that future frameworks may benefit from more explicit attention to finite clinician cognitive capacities, workflow fragmentation, and the operational coordination required to complete time-sensitive interventions.

The sepsis song also raises an important direction for future work. Arts-based implementation strategies may be useful as low-cost, emotionally engaging, and memorable adjuncts, particularly for protocols requiring rapid recall. However, such strategies should be evaluated rigorously and ethically, with attention to exposure, acceptability, recall, behavior change, and unintended effects. They should support clinicians rather than function as substitutes for staffing, workflow redesign, or system-level investment.

Future research should further validate and adapt SEP-1 bundle specifically for hospital ward settings, including identifying which bundle elements are most strongly associated with improved outcomes in this clinical setting as opposed to ICU or the ED. RMTSS should be evaluated prospectively in larger, controlled, and preferably multi-site studies using randomization when feasible.

Future studies should also measure fidelity to individual RMTSS components including educational exposure, poster visibility, order-set use, BPA response, audit and feedback participation and sepsis song exposure. More granular, real time process measurement is needed to identify where "last-mile" process failures occur, including recognition, ordering,

documentation, laboratory completion, medication and fluid delivery and bedside administration, and multidisciplinary coordination.

Additional work should develop implementation metrics for cognitive workload, opportunity cost, alert fatigue, and workflow burden in complex clinical environments. This would require multidisciplinary collaboration between health economists, psychologists, implementation scientists and other specialties. The role of arts-based implementation strategies should also be studied, particularly their effects on recall, adoption, behavior change and sustainability.

Finally, future research should assess the sustainability, scalability, equity, and generalizability of RMTSS across other services, hospitals, and health systems, including community, safety-net, and resource-limited settings. Economic and environmental evaluations should also be incorporated to measure financial cost, staff time, opportunity cost, and the carbon footprint of implementation strategies.

Conclusion

In this mixed-methods Hybrid Type III implementation–effectiveness study, RhodeMap to Sepsis Survival was associated with improved SEP-1 bundle compliance among patients with sepsis managed on non-ICU, non-ED inpatient medical wards. The observed improvement in compliance, together with a non-significant signal toward lower hospital mortality, suggests that multifaceted implementation strategies may help close the gap between sepsis protocols and real-world clinical delivery.

However, SEP-1 implementation is not simply a matter of clinician knowledge or motivation. Reliable completion of the bundle depends on the interaction of provider cognition, EMR design, staffing, multidisciplinary coordination, organizational culture, and the operational “last mile” between ordering and completing time-sensitive care. RMTSS appeared to improve awareness,

salience, and engagement, but its effects were constrained by workflow fragmentation, cognitive load, and system-level execution barriers.

These findings support a more realistic model of implementation in acute care: one that values evidence-based protocols while recognizing the finite cognitive, relational, and operational capacity of clinicians and health systems. Future efforts to improve sepsis care on medical wards should combine protocolized care with improved workflow design, multidisciplinary execution support, EMR optimization, and careful attention to sustainability, scalability, and unintended consequences. In this context, RMTSS represents a promising, pragmatic, and theoretically grounded implementation strategy, while also illustrating the need for implementation science to move beyond asking whether clinicians comply, toward understanding whether systems are designed to make the right care feasible.

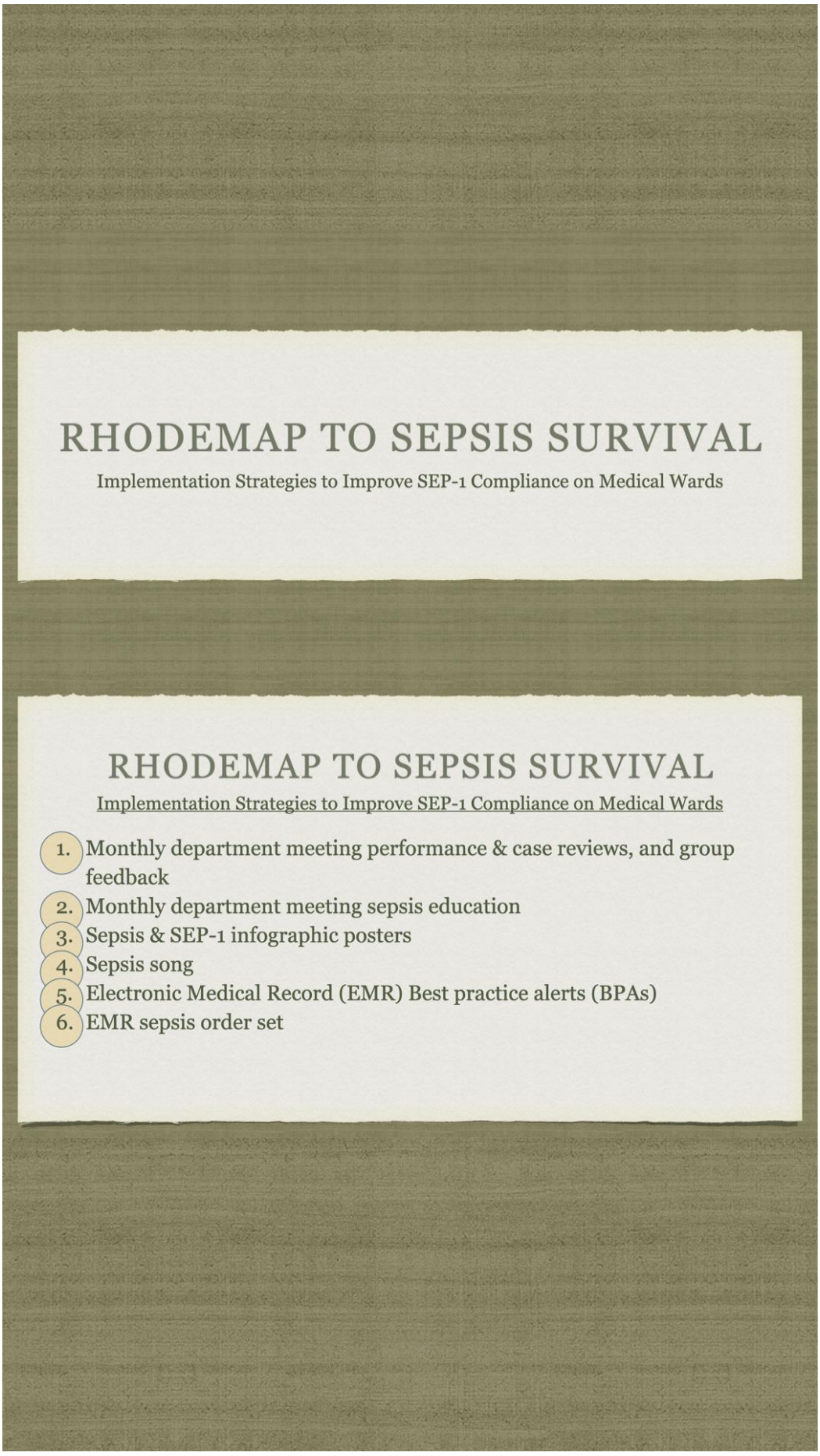


Figure 1a: RhodeMap To Sepsis Survival summary page during monthly meetings

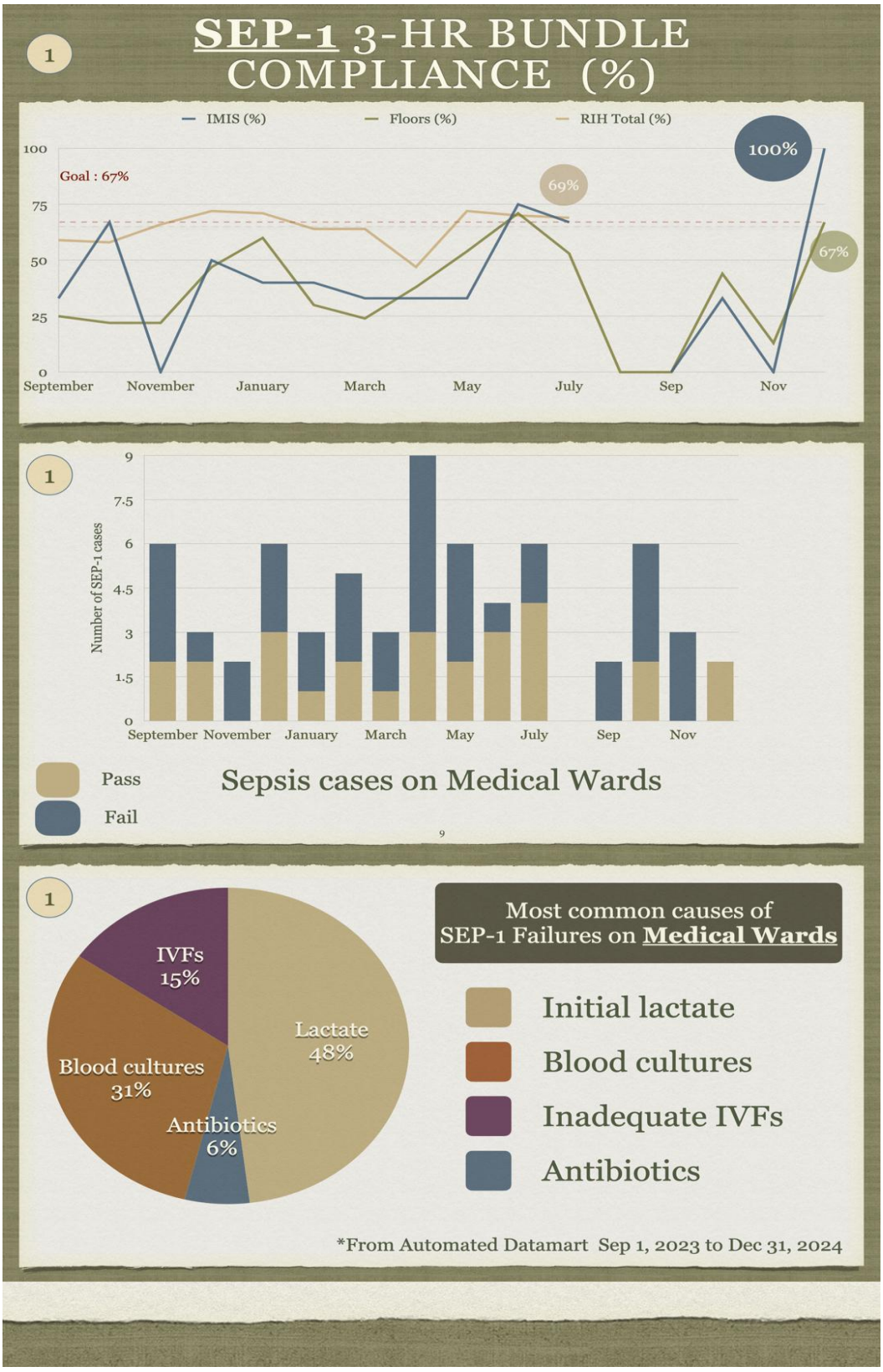


Figure 1b

Component #1 of RhodeMap To Sepsis Survival monthly meeting presentations

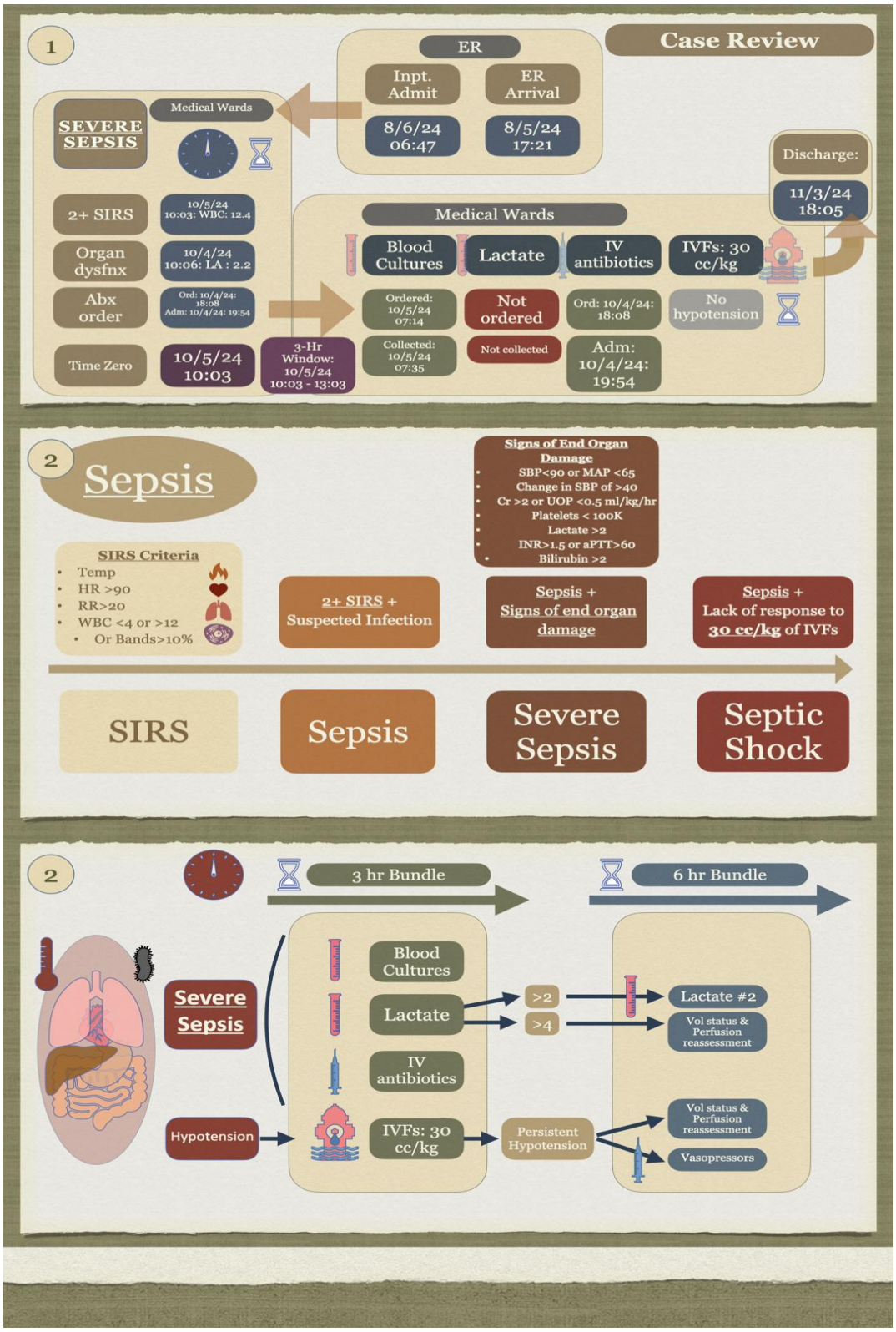


Figure 1c

Components #1 & 2 of RhodeMap To Sepsis Survival monthly meeting presentations

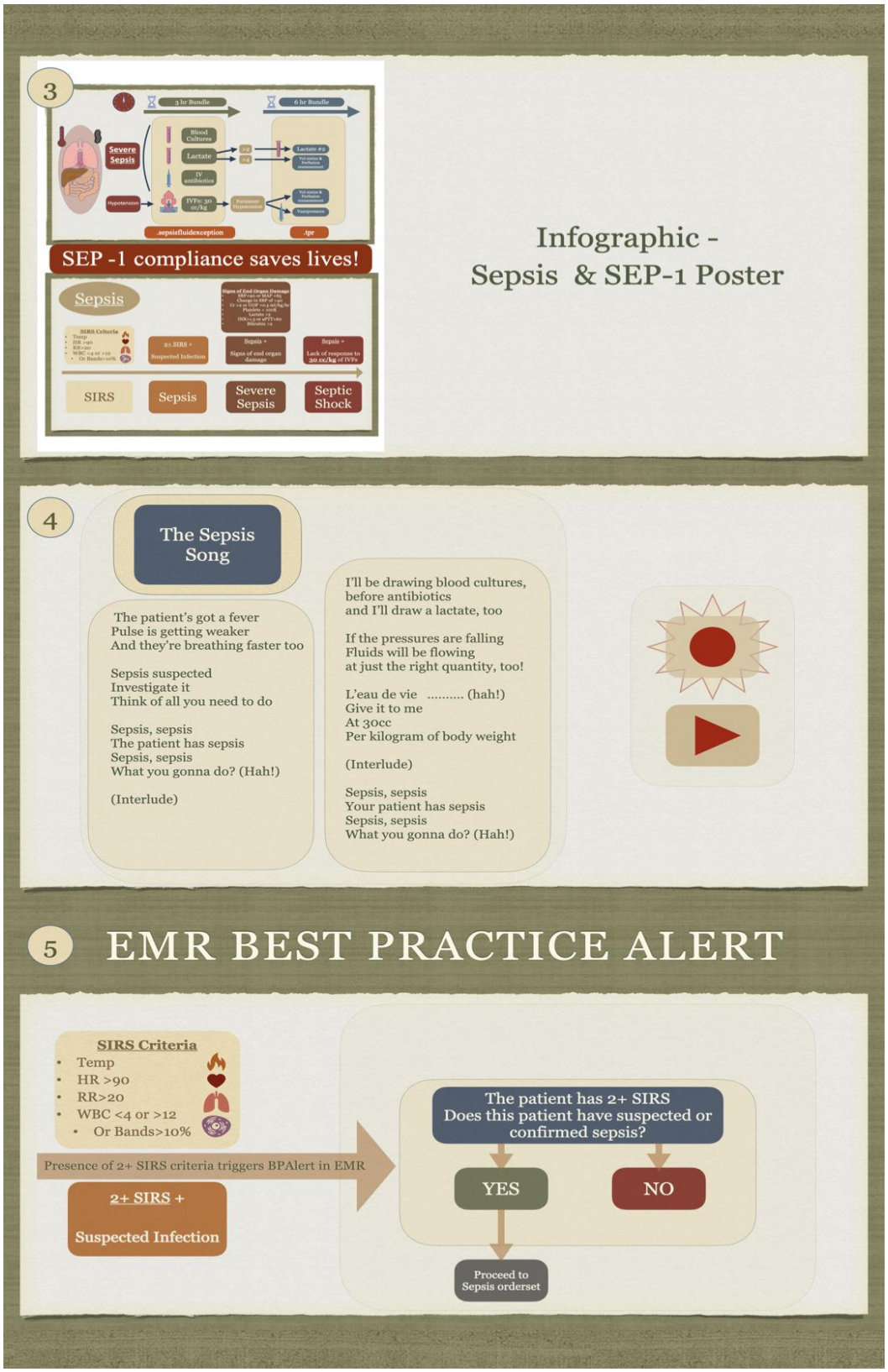


Figure 1d : Components # 3, 4 (Lyrics only) & 5 of RhodeMap To Sepsis Survival

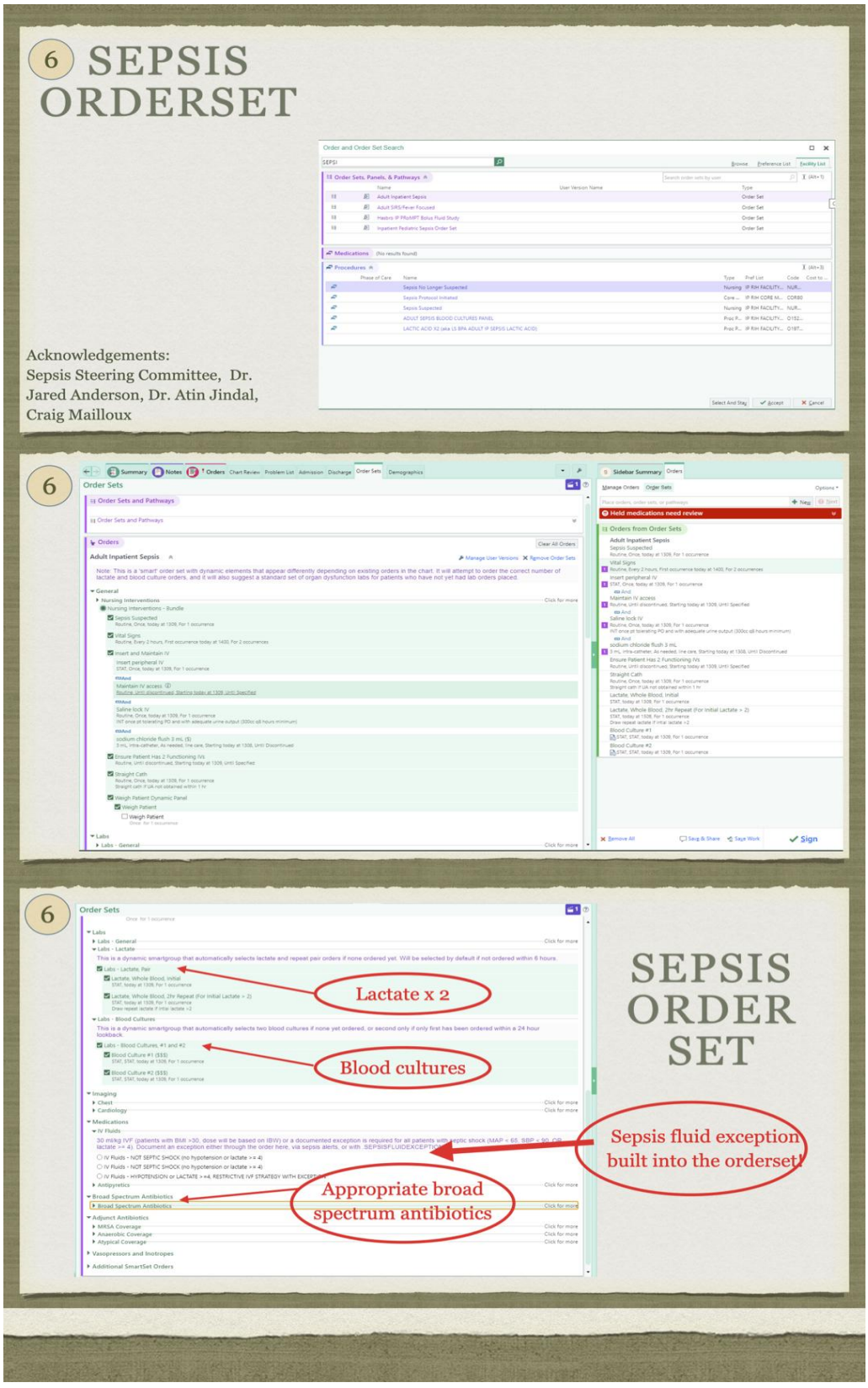


Figure 1e

Component # 6 of RhodeMap To Sepsis Survival : The sepsis order set

Health Belief Model Construct	Application in Song
Perceived Severity	Lyrics like *"The patient's got a fever… pulse is getting weaker… breathing faster too"* emphasize clinical deterioration to highlight severity of untreated sepsis.
Perceived Susceptibility	*"Sepsis suspected, investigate it"* cues providers to consider sepsis in any deteriorating patient.
Cues to Action	The repeated line *"Sepsis, sepsis, what you gonna do?"* functions as a prompt for clinical action.
Perceived Benefits	The line *"L'eau de vie"* in reference to life saving fluids is a reminder of the survival benefit of the right quantity of fluids
Information Chunking	Complex SEP-1 steps are simplified and 'chunked' together (blood cultures before antibiotics, lactate, fluids) and with repetition, intended to aid in prompt recall.

Table 1: Health Belief Model Constructs

Social Cognitive Theory Construct	Application in Song
Reinforcement	Catchy rhythm and repetition create positive reinforcement, enhancing memory and recall.
Self-Efficacy	The confidence-building tone (especially through musical tempo and call-response) encourages belief in one's ability to perform SEP-1 tasks.
Reciprocal Determinism	The song can change the clinical environment by becoming a shared cultural element (e.g., played in team huddles, posted in wards), thereby influencing norms and behavior.

Table 2: Social Cognitive Theory Constructs

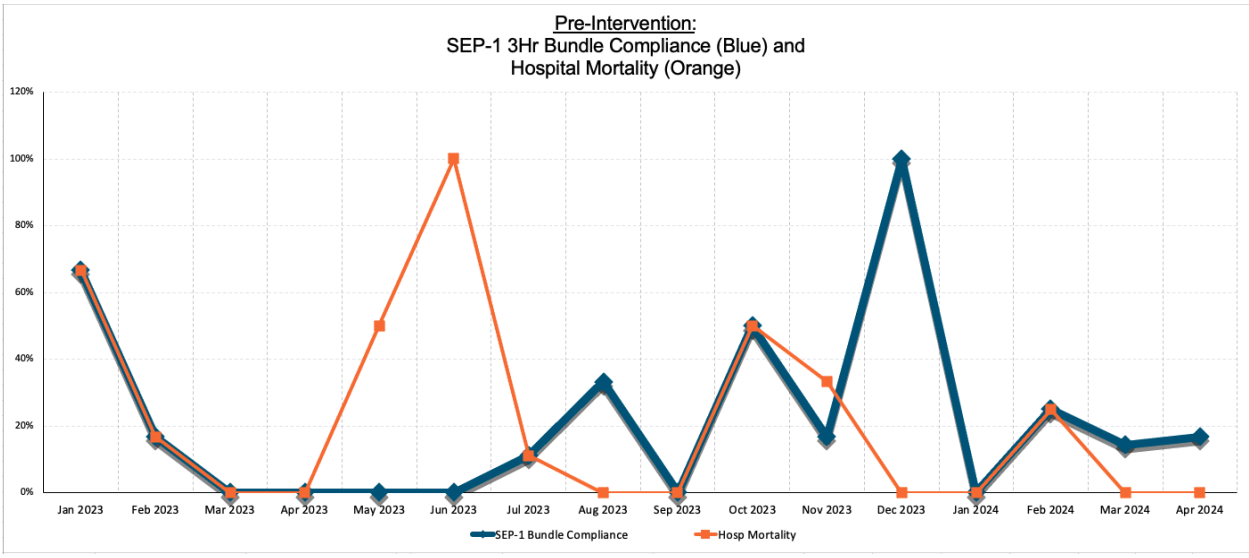


Figure 2a

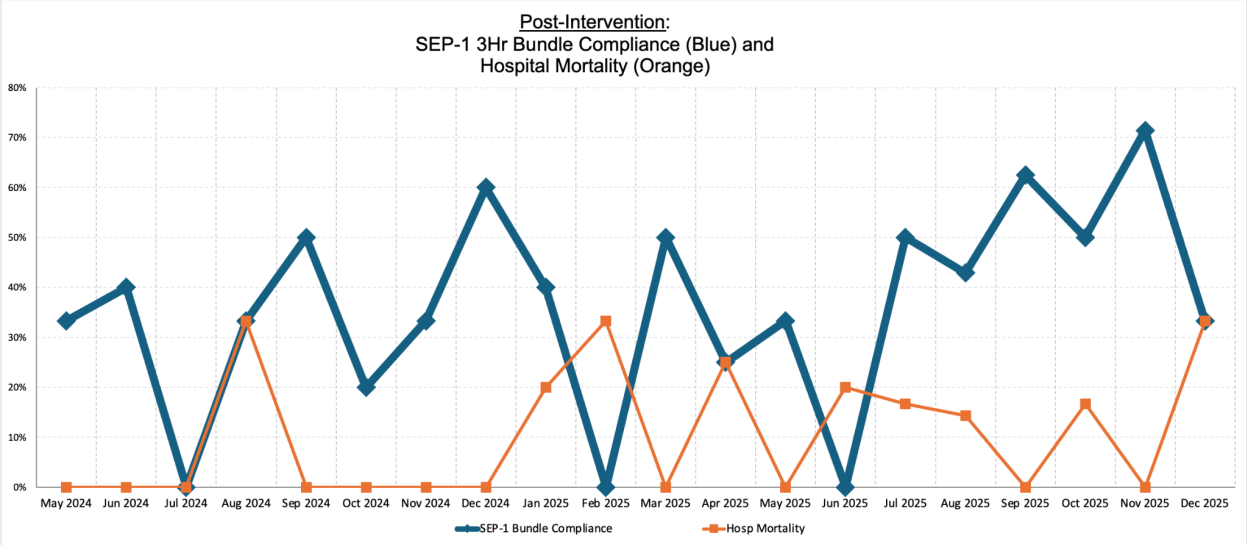


Figure 2b

PRE-Intervention

Month	SEP-1 Bundle Compliance	Hosp Mortality
Jan 2023	66.7%	66.7%
Feb 2023	16.7%	16.7%
Mar 2023	0.0%	0.0%
Apr 2023	0.0%	0.0%
May 2023	0.0%	50.0%
Jun 2023	0.0%	100.0%
Jul 2023	11.1%	11.1%
Aug 2023	33.3%	0.0%

Sep 2023	0.0%	0.0%
Oct 2023	50.0%	50.0%
Nov 2023	16.7%	33.3%
Dec 2023	100.0%	0.0%
Jan 2024	0.0%	0.0%
Feb 2024	25.0%	25.0%
Mar 2024	14.3%	0.0%
Apr 2024	16.7%	0.0%

Table 3a

POST-Intervention		
Month	**SEP-1 Bundle Compliance**	**Hosp Mortality**
May 2024	33.3%	0.0%
Jun 2024	40.0%	0.0%
Jul 2024	0.0%	0.0%
Aug 2024	33.3%	33.3%
Sep 2024	50.0%	0.0%

Oct 2024	20.0%	0.0%
Nov 2024	33.3%	0.0%
Dec 2024	60.0%	0.0%
Jan 2025	40.0%	20.0%
Feb 2025	0.0%	33.3%
Mar 2025	50.0%	0.0%
Apr 2025	25.0%	25.0%
May 2025	33.3%	0.0%
Jun 2025	0.0%	20.0%
Jul 2025	50.0%	16.7%
Aug 2025	42.9%	14.3%
Sep 2025	62.5%	0.0%
Oct 2025	50.0%	16.7%
Nov 2025	71.4%	0.0%
Dec 2025	33.3%	33.3%

Table 3b

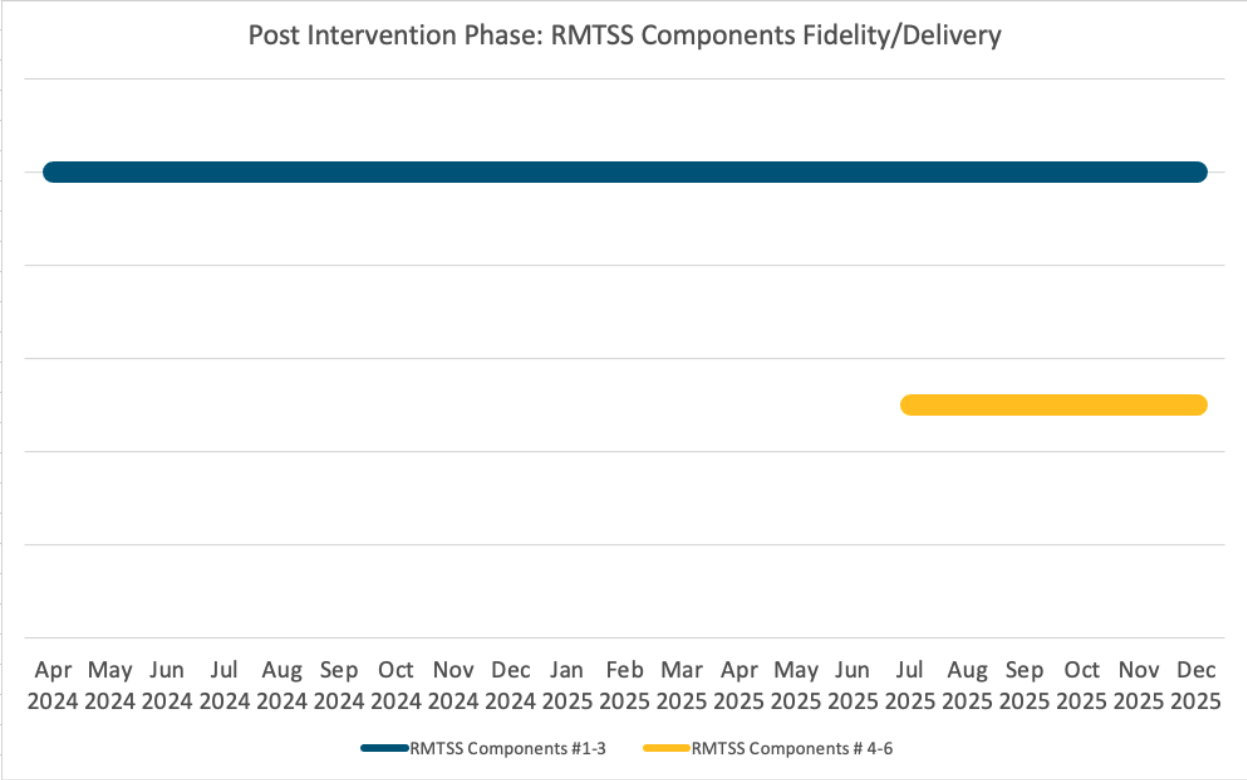


Figure 3:
Timeline of RMTSS component delivery during the post-intervention period

Components 1-3 include monthly department meeting reports and feedback on group performance, Education, and Sepsis and SEP-1 bundle Posters. **Components 4-6** include the Sepsis song, the EMR Best Practice Advisory alerts, and the Sepsis Orderset.

Theme	Representative Code	EPIS Domain	Proctor Implementation Outcomes	Illustrative Quote (Health provider #)
Workflow friction and operational overload impede SEP-1 completion	Competing priorities	Inner Context	Feasibility; Fidelity	"I think it negatively affects it because, again, it takes away from your workflow and your concentration." (Health provider 2) " besides sepsis triggers, there are so many other triggers that are competing with physicians' attention as well, right? Like, insulin triggers. like medication interaction triggers...it's not only the sepsis triggers that affects me, all those triggers affect me." (Health provider 4)
	Secure chats / interruptions	Inner Context	Feasibility	"they are deterrents and attention sinks." (Health provider 3)
	Interruptions during care	Inner Context	Feasibility; Fidelity	They greatly affect… I think, especially the secure chats, because there's… when you have constant disruptions, it kind of sometimes derails your train of thought, or your flow of work. (Health provider 2)
	Cognitive workload	Inner Context	Feasibility	" you do have that that stimulation, that excess stimulation from everywhere else. That may make you make mistakes along the way" (Health provider 1)
	Staffing limitations	Inner Context	Feasibility	" The biggest barrier is, I would say. our staffing….that… 100% affects how timely the sepsis protocol is given. " (Health provider 3)
SEP-1 itself and RMTSS strategies are generally accepted, but adoption is variable	Familiarity with SEP-1	Inner Context / Outer Context	Acceptability	"Yes" …"I would say it's helpful." (Health provider 3)
	Confidence using SEP-1 bundle	Inner Context / Outer	Acceptability; Adoption	"I'm fairly, fairly confident." (Health provider 8)

		Context		
	Variable adoption	Inner Context / Outer Context	Adoption	"you need to weigh those pros and cons very carefully before just blindly administering a Sep 1 sepsis bundle..” (Health provider 3)
	Perceived usefulness of SEP-1	Inner Context / Outer Context	Acceptability; Adoption	“I think it's excellent. I think, uh, we underutilize it, but I think it is a… An excellent tool.” (Health provider 2)
RMTSS improves awareness through multimodal reinforcement	Repetition improves retention	Inner Context/Innovation Factors	Adoption	“ when we talk about this thing every month it does prioritize, it just makes these things important..” (Health provider 4) " there is always room to improve, and that comes from the data that's always in the back of your mind" (Health provider 15)
	Awareness leads to action	Inner Context	Adoption	“ any way that you're getting the information is going to increase awareness, and hopefully compliance,.” (Health provider 12)
	Visual aids (posters) useful	Inner Context	Adoption	“The poster.. I am a very visual learner…it just makes sense to me visually. So, for me, it's definitely the infographic.” (Health provider 12) "because I see it every time I enter the room. So if I see sepsis bundle, yeah, sepsis bundle is important. So, uh, consciously or subconsciously...it does bring it to the forefront." (Health provider 4)
	Multimodal reinforcement	Innovation factors	Adoption	"Difficult to attribute the value.. to this... in terms of saying, like, hey, this one is more important than others." (Health provider 4)
	Increased awareness	Inner Context	Acceptability; Adoption	“ the conversations that we have in our monthly meetings … just having it … being talked about helps. That's it ..This makes it sort of front and center in our conversations in the department” (Health provider 14)
	Perceived fit	Innovation factors	Feasibility	"It's merged seamlessly into our workflow." (Health provider 12)

	Feedback improves performance	Inner Context/Innovation Factors	Adoption; Fidelity	“Yeah, definitely. I mean, having… the numbers, especially during meetings, we at least know the goals, we at least know how we are doing” (Health provider 15)
EMR tools are both a main facilitator and a main friction point	EMR facilitates SEP-1 compliance	Inner Context	Feasibility	“"You can find out exactly what's happening with the patient on most occasions a lot quicker than it would be without the EMR" (Health provider 1) " our EMR is like lightning fast, so… Um, being able to… Place orders and have results within moments is really exceptional." (Health provider 12)
	BPA alerts helpful	Inner Context	Acceptability, Feasibilty	“definitely getting the trigger and alert is helpful” (Health provider 4)
	Alert fatigue	Inner Context	Acceptability, Feasibilty	I think the alerts that we get… are excessive, and there's a component of alert fatigue, which makes me pay less attention to these things. (Health provider 8) "Unfortunately, if I'm being honest, um… I think it's death by a thousand clicks." (Health provider 8)
	Order set reliance	Inner Context	Feasibility	“ if I don't use the orderset, I may miss something.” (Health provider 1)
	Variable order set use	Inner Context	Adoption	“Me, personally, honestly, no, just because… I feel like I'm hypervigilant on the things that I need to order, but also, it's relatively new, so I haven't… been trying to use it as much As I could.” (Health provider 2)
Suggestions for optimization	Targeted feedback	Inner Context/Innovation Factors	Adoption	“maybe reasonable to reach out to those providers who have a lower compliance score” (Health provider 1)
	Real-time guidance	Inner Context/Innovation Factors	Feasibility	“there's no really good way to see whether or not the patient has completed the order set or ... all the steps or not.” (Health provider 8)
	Workflow	Inner	Feasibility	“it's not the exact same workflow every single time, and I often find

	integration	Context/Innovation Factors		myself implementing the bundle manually ... a sepsis alert popped up, not for me, but for the nurse… That's the problem, because it didn't show up for me, it showed up for the nurse....And I had to put in the relevant bundle elements manually." (Health provider 9)
	Make posters colored and visible	Innovation factors	Fidelity; Feasibility	"would be more helpful if it was colorful. black and white, still,it's useful, but also... strategic location of... where do you put those posters." (Health provider 4)
The sepsis song emerged as a novel but variably used implementation strategy	Sepsis song memorable	Innovation factors	Acceptability	"in terms of making providers, other people aware about these issues, the song definitely did help." (Health provider 4)
	Music improves recall	Innovation factors	Adoption	"the song itself? Yeah!... putting anything to music helps you put it in your brain in a different place, in a different way, and access it differently, so yeah." (Health provider 8)
	Engaging learning modality	Innovation factors	Acceptability	"if you add, like, cool things like song to it. if we add, like, cool things like visual to it, right? If we add cool things like that.. it definitely makes you more aware about these things.." (Health provider 4)
	Emotional connection to learning	Innovation factors	Acceptability	"it opens a smile… makes them think if they are doing it right or not." (Health provider 7)
	Novel ways of learning	Innovation factors	Acceptability	" but it is something, honestly, that we pass along to the students we teach... it's another way of learning, right? Some people learn visually, musically." (Health provider 12)
	Variable recall in practice	Innovation factors	Adoption, Fidelity	"When I have somebody with sepsis, I don't recall the song or think about the song at all." (Health provider 7); " it's not being heard so often" (Health provider 4)
The "last mile" of execution is a distinct	Execution delays despite correct orders	Inner Context	Feasibility	" on many occasions. you would see that the lactate's been ordered, but it's not being drawn you'll see that the fluids have been ordered, and they were given after the… 3 to 6 hour period" (Health

implementation problem				provider 1)
	Multidisciplinary coordination needs	Inner Context / Bridging Factors	Feasibility	“ pharmacy staff, you need to get broad-spectrum antibiotics in a timely fashion. Lab draws. It requires a small army to get this done in a timely fashion, and if you were understaffed Logically, this is just going to prolong the entire process.” (Health provider 3)
Organizational Culture & Leadership Influence	Leadership support & Institutional prioritization	Inner Context	Adoption; Acceptability	"[Interviewer]: Do you feel that sepsis is a visible organizational priority compared to other QI initiatives? [Health provider 1] : Absolutely." "Of any of them, I think yours is the number one most visible, yeah." (Health provider 9)
Table 4				

RMTSS component	Actor	Target	Action	Dose/timing	Mechanism	Expected outcome
Monthly performance feedback	SD	Hospitalists/APPs	Present compliance/fallouts	Monthly	Audit and feedback; salience	Adoption/ Fidelity
SEP-1 education	SD	Hospitalists/APPs	Case review/teaching	Monthly	Knowledge, self-efficacy	Acceptability/ Adoption
Posters	SD/QI team	Workstations/Hospitalists/APPs	Visual reminders	Continuous	Cue to action	Adoption/ Fidelity
Sepsis song	SD	Hospitalists/APPs	Music-based mnemonic	Shared online	Recall/emotional salience	Acceptability/ Awareness
BPA	Data Analyst/Tech Support Epic/EMR	Hospitalists/APPs	Alert when SIRS criteria met	Real-time	Prompting, cue to action	Recognition/ Adoption/Fidelity
Order set	Data Analyst/Tech Support Epic/EMR	Hospitalists/APPs	Bundled orders	Real-time	Reduces omission, ensures bundle completeness	Fidelity

Table 5: Implementation Strategy Description

StaRI Item	StaRI Reporting Requirement	Where Addressed in Thesis	How Addressed / Notes
1. Title	Identify the study as an implementation study and describe the methodology.	Title page	The title identifies the work as a mixed-methods Hybrid Type III implementation study evaluating RMTSS and SEP-1 bundle compliance.
2. Abstract	Identify the study as an implementation study; describe the implementation strategy, intervention, implementation outcomes, and health outcomes.	Abstract	The abstract describes RMTSS as the implementation strategy, SEP-1 as the clinical intervention, implementation outcomes including acceptability, feasibility, adoption, fidelity, and SEP-1 compliance, and hospital mortality as a secondary clinical outcome.
3. Introduction: Problem	Describe the healthcare/public health problem the intervention aims to address.	Introduction; Background section	The thesis describes sepsis burden, mortality, cost, ward-based sepsis risk, and persistent gaps in SEP-1 compliance, especially in non-ICU, non-ED inpatient settings.
4. Introduction: Rationale for implementation strategy and intervention	Provide scientific background and rationale for both the implementation strategy and intervention, including theory/framework/model.	Introduction; Background; Methods: Intervention and Implementation Strategy; Tables 1, 2, and 5	SEP-1 is described as the evidence-based clinical intervention. RMTSS is described as a multifaceted implementation strategy informed by EPIS, Proctor outcomes, Health Belief Model, Social Cognitive Theory, and sepsis QI literature.

5. Aims and objectives	Differentiate implementation objectives from intervention/health objectives.	Study Aims and Outcomes	Aim 1 evaluates RMTSS impact on SEP-1 compliance; Aim 2 describes acceptability, feasibility, adoption, and fidelity of RMTSS; Aim 3 observes hospital mortality as a secondary clinical outcome.
6. Study design	Describe design, key evaluation features, and relevant methodological reporting standards.	Study Design; Quantitative and Qualitative Methods	The study is described as a mixed-methods Hybrid Type III implementation–effectiveness study with “Big QUAN with qual” structure, guided by StaRI and COREQ.
7. Context	Describe context in which the intervention was implemented, including barriers/facilitators that may affect implementation elsewhere.	Study Context, Setting, and Positionality; Discussion; Limitations	The thesis describes a 719-bed academic tertiary care hospital, non-teaching hospitalist service, provider workflow, EMR environment, staffing constraints, CMS policy context, and organizational prioritization of sepsis.
8. Sites and populations	Describe targeted sites/personnel/resources for implementation and target population for intervention.	Study Population; Sampling Strategy; Study Context	The implementation strategy targeted hospitalists and APPs on the Internal Medicine/Hospital Medicine service. The clinical intervention targeted eligible non-ICU, non-ED ward patients meeting CMS SEP-1 criteria.
9. Description of implementation strategy and	Provide detailed description of both the implementation	Methods: The Intervention and Implementation Strategy;	SEP-1 is described as the clinical bundle. RMTSS is

intervention	strategy and intervention.	Figures 1a–1e; Table 5	described as six implementation components: feedback, education, posters, sepsis song, EMR BPA, and EMR order set. Table 5 further specifies actor, target, action, dose/timing, mechanism, and expected outcome.
10. Subgroups / nested studies	Describe subgroups recruited for additional research tasks or nested studies.	Qualitative Methods; Sampling Strategy	The qualitative interview sample is described as a purposively selected subgroup of 15 providers from a pool of 49 physicians and 5 APPs.
11. Outcomes	Define prespecified implementation and intervention outcomes and how they were assessed.	Study Aims and Outcomes; Quantitative Analysis; Qualitative Analysis	Implementation outcomes included SEP-1 compliance, acceptability, feasibility, adoption, and fidelity. Hospital mortality was assessed as a secondary clinical outcome.
12. Process evaluation	Describe process evaluation objectives and outcomes related to mechanisms through which the strategy is expected to work.	This was not part of the study and therefore not done.	N/A
13. Economic evaluation	Report methods for resource use, costs, and economic outcomes, where applicable.	This was not part of the study and therefore not done.	A formal economic evaluation was not conducted. The thesis acknowledges that cost-effectiveness, staff time, opportunity cost, and environmental cost were not formally measured and should be evaluated in future research.

14. Sample size rationale	Provide rationale for sample sizes, including calculations, pragmatic constraints, or saturation/data adequacy.	Sampling Strategy; Analysis; Limitations	Quantitative sample size was determined by all eligible cases available in routine data during the pre- and post-intervention periods. Qualitative sample included 15 providers from the IMIS clinician pool; two additional physicians were approached but unable to participate.
15. Methods of analysis	Describe analytic methods and reasons for choice.	Quantitative Analysis; Qualitative Analysis	Quantitative analysis used frequencies, percentages, Pearson chi-square testing, absolute risk difference, risk ratio, NNT, and 95% confidence intervals in Stata. Qualitative analysis used Braun and Clarke thematic analysis in NVivo 15, with EPIS and Proctor mapping.
16. Subgroup analyses	Describe any a priori subgroup analyses.	This was not part of the study and therefore not done.	N/A
17. Results: Populations	Report characteristics and proportions of recipient populations.	Results: Study Population; Qualitative Results Overview	Quantitative sample included 147 ward-based sepsis patients, with 55 pre-intervention and 92 post-intervention. Qualitative sample included 15 clinicians: 13 physicians and 2 APPs.
18. Results: Outcomes	Report implementation and intervention outcomes.	Results Aim 1; Results Aim 2; Results Aim 3	SEP-1 compliance increased from 21.8% to 38.0%. Qualitative implementation outcomes were organized into

			eight themes. Mortality decreased from 16.4% to 9.8%, but was not statistically significant (Secondary aim).
19. Results: Process data	Report process data related to the implementation strategy and its mechanisms.	This was not part of the study and therefore not done.	N/A
20. Results: Economic outcomes	Report resource use, costs, and economic outcomes, where applicable.	This was not part of the study and therefore not done.	N/A The thesis identifies economic and environmental evaluation as a future research priority.
21. Results: Subgroups	Report representativeness and outcomes of subgroups recruited for additional research tasks.	This was not part of the study and therefore not done.	N/A
22. Fidelity and adaptation	Report fidelity to the implementation strategy and intervention, and any adaptation to context.	Fidelity and Adaptation; Figure 3; Limitations	RMTSS components 1–3 were delivered across the 20-month post-intervention period; components 4–6 were delivered during the final 6 months. Provider receipt/exposure was not systematically measured. SEP-1 criteria were not formally adapted.
23. Contextual changes	Describe contextual changes that may have affected outcomes.	Limitations	The thesis notes that institutional sepsis attention and CMS consideration of SEP-1 movement from pay-for-reporting to pay-for-performance may have influenced performance,

			limiting causal attribution in the pre–post design.
24. Harms or unintended effects	Report important harms or unintended effects.	Results Aim 2; Discussion; Limitations	Qualitative findings identified possible unintended consequences including alert fatigue, cognitive overload, workflow disruption, “death by a thousand clicks,” and competing priorities; these were not prospectively quantified.
25. Discussion: Summary, strengths, limitations, comparison, conclusions	Summarize findings, strengths, limitations, comparison with other studies, conclusions, and implications.	Discussion; Strengths; Limitations; Conclusion	The Discussion integrates quantitative and qualitative findings, compares the study with sepsis implementation literature, and discusses strengths, limitations, and implications.
26. Implications: Policy, practice, research, scalability, sustainability	Discuss policy, practice, and research implications of the implementation strategy and intervention, including scalability and sustainability.	Implications and Future Directions; Conclusion	The thesis discusses implications for ward-based sepsis care, health system leadership, SEP-1 policy, implementation science, cognitive load, arts-based strategies, sustainability, scalability, equity, and environmental impact.
27. General: Approvals, registration, funding, conflicts	Include statements on regulatory approvals, governance, protocol/registration, funding, and conflicts of interest.	Ethical Considerations; Study Context and Positionality	The thesis states that the study received appropriate institutional review, participants provided informed consent, data were de-identified, and no funding was

	received. The Study was not registered

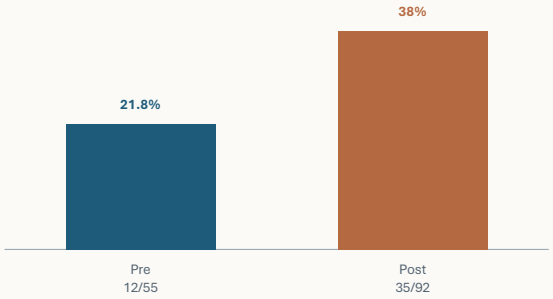
Table 6: StaRI Checklist

RESULTS

Aim 1: SEP-1 compliance improved significantly

Primary quantitative implementation outcome

3-hour SEP-1 bundle compliance



16.2%	1.74	7
Absolute increase	**Risk ratio**	**NNT**
95% CI: 1.5% to 31.0%	95% CI: 0.99 to 3.07	95% CI: 4 to 68

$\chi^2 = 4.17$, df = 1, p = 0.041

Interpretation: RMTSS was associated with a clinically meaningful improvement in bundle completion.

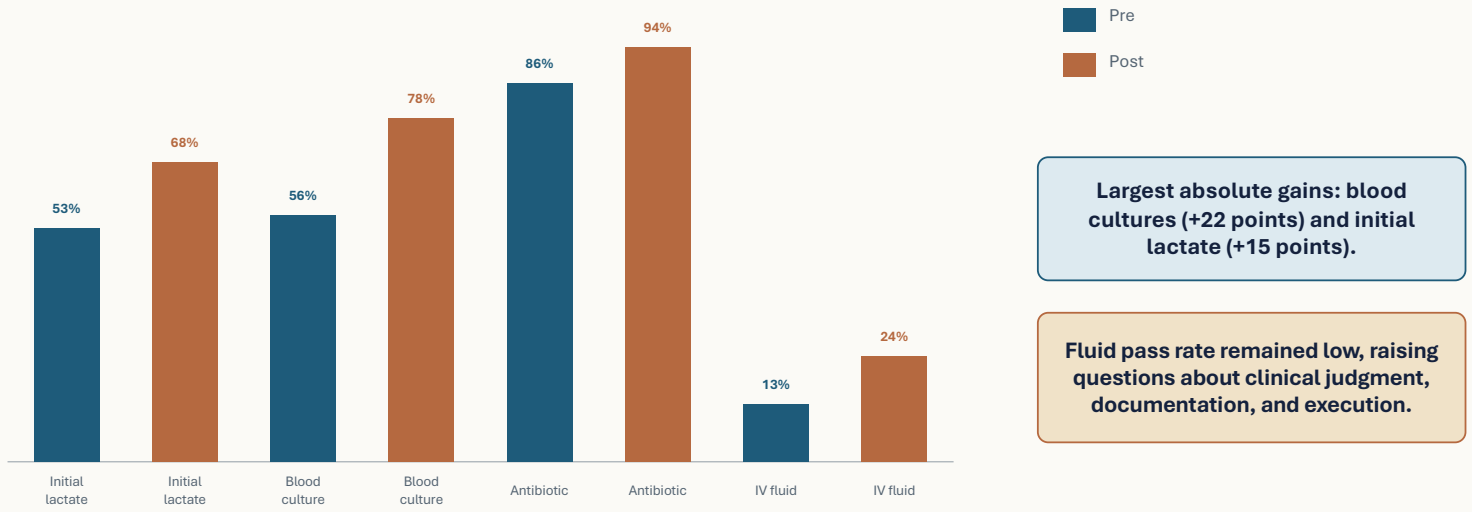
Figure 4a. Aim 1: SEP-1 compliance

RESULTS

Bundle components improved across multiple domains

The improvement was not confined to one element

Individual component pass rates



Largest absolute gains: blood cultures (+22 points) and initial lactate (+15 points).

Fluid pass rate remained low, raising questions about clinical judgment, documentation, and execution.

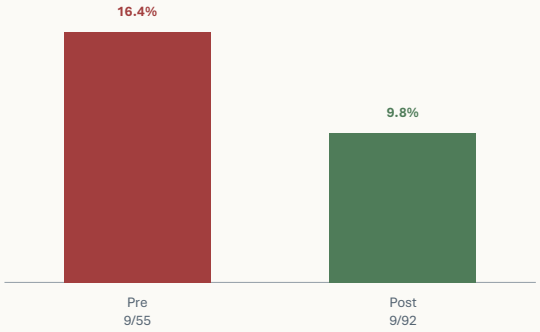
Figure 4b. Individual bundle element improvement pre- vs post- intervention

RESULTS

Aim 3: mortality signal was hypothesis-generating

Clinical outcome was secondary and not powered

In-hospital mortality



6.6%	0.60	0.238
Absolute reduction	**Risk ratio**	**p-value**
Not statistically significant	95% CI: 0.25 to 1.41	$\chi^2 = 1.39$

RMTSS → Improved SEP-1 compliance → Possible mortality impact

Interpretation: promising signal, not causal evidence.

Figure 4c: Aim-3 ; in-hospital mortality

References

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