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"Advances in Early Detection and Management of Pediatric Sepsis in Pediatric Emergency Departments: Systematic review"

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Abstract

Background: Pediatric sepsis remains a critical cause of morbidity and mortality in emergency departments (ED) worldwide. Early detection and the prompt initiation of treatment—particularly the timely administration of antibiotics—are essential to improving outcomes in this vulnerable population.

Objective: This systematic review synthesizes evidence from 25 studies conducted across diverse geographic and healthcare settings to assess the effectiveness of early detection strategies and management interventions for pediatric sepsis in ED environments.

Methods: A comprehensive literature search was conducted using multiple databases and other relevant sources. Studies were included if they evaluated early diagnostic and therapeutic interventions, such as sepsis bundles, point-of-care (POC) diagnostic tools, nurse-led response systems, and goal-directed therapy protocols. Data extraction and quality assessment were performed according to established systematic review guidelines.

Results: The evidence consistently demonstrated that early recognition and rapid initiation of treatment resulted in reduced mortality, improved compliance with sepsis management guidelines, and a decreased length of hospital stay. The studies reviewed highlighted the importance of digital triage tools and targeted educational interventions in mitigating delays in treatment and overcoming socioeconomic and resource-based disparities.

Conclusion: The implementation of standardized sepsis bundles, goal-directed therapies, and technological innovations in ED settings significantly enhances pediatric sepsis outcomes. Future research should prioritize equity-focused health interventions and context-specific adaptations to sustain improvements in global pediatric sepsis care.

Introduction

Sepsis remains a leading cause of morbidity and mortality in pediatric populations worldwide, particularly in emergency department (ED) settings where time-sensitive interventions are critical. Pediatric sepsis presents uniquely due to variable physiological responses in children, often complicating timely diagnosis and management (Randolph & McCulloh, 2014). Globally, the burden of pediatric sepsis continues to grow, disproportionately affecting low- and middle-income countries (LMICs) where resource constraints delay appropriate care (Rudd et al., 2020). The rapid progression of pediatric sepsis and its association with high mortality necessitate robust, early recognition and standardized treatment approaches.

Numerous studies have underscored the importance of early detection and timely antibiotic administration in improving outcomes for pediatric sepsis. For instance, delays in antimicrobial therapy have been directly linked to increased mortality and prolonged organ dysfunction in children (Weiss et al., 2014). The use of goal-directed therapy and triage systems in emergency departments has demonstrated improved outcomes in both high-income and resource-limited settings (Cruz et al., 2011; Haines et al., 2022). Such systems often rely on evidence-based protocols and risk stratification tools to streamline decision-making in critical windows.

Despite advancements, adherence to sepsis guidelines remains inconsistent. Studies suggest that institutional barriers, inadequate training, and resource limitations often hinder the effective

implementation of the Surviving Sepsis Campaign (SSC) guidelines, particularly in pediatric populations (Evans et al., 2021; Ranjit & Kissoon, 2021). Furthermore, disparities in socioeconomic status have been shown to influence access to timely care, resulting in higher morbidity and mortality among children from lower-income communities (Phelps et al., 2023). These inequities underscore the need for adaptable, context-specific strategies that prioritize equity in pediatric sepsis management.

Technological innovations, such as point-of-care (POC) diagnostic tools and smart triage systems, are emerging as vital assets in improving early sepsis detection. These tools enhance clinicians' ability to rapidly identify septic children, facilitating timely interventions even in under-resourced environments (Oeschger et al., 2019; Haines et al., 2022). At the same time, educational interventions targeting healthcare professionals have been shown to significantly increase compliance with pediatric sepsis bundles and reduce length of stay (Paul et al., 2014; Raj et al., 2019). As digital health continues to evolve, integration of such tools into emergency workflows is becoming increasingly viable.

Given the urgent nature of pediatric sepsis and the evolving landscape of emergency medicine, it is imperative to synthesize current evidence on early detection and management strategies. This systematic review evaluates 25 studies across diverse healthcare settings to examine interventions that improve pediatric sepsis recognition and response in emergency departments. Through a critical analysis of interventions, outcomes, and implementation challenges, this review aims to inform clinical practice and policy to ultimately improve survival and recovery in pediatric patients with sepsis.

Methodology

To conduct this systematic review, we employed a comprehensive search strategy encompassing electronic databases such as PubMed/MEDLINE, Embase, Scopus, Web of Science, and Google Scholar (for grey literature), as well as ACAM (Advanced Clinical and Medical Journal, 2023, Vol. 10, Issues 1869 & 1870). The search covered studies from January 2011 until April 2025 and was last updated on May 9, 2025. We used a combination of keywords and Medical Subject Headings (MeSH terms) including "Pediatric Sepsis," "Childhood Sepsis," "Neonatal Sepsis," "Emergency Department," "ED," "Acute Care," "Early Detection," "Sepsis Bundles," "Point of Care," "Rapid Diagnosis," and "Guidelines Adherence." Boolean operators were applied to refine the search and ensure comprehensiveness.

The selection of studies followed a two-step process. Initially, titles and abstracts of all identified records (n = 1,532) were independently screened by two reviewers to identify potentially relevant articles. After removing duplicates, 1,214 unique studies remained, and 1,165 were excluded during the initial screening for lack of relevance. Subsequently, full-text articles (n = 49) were retrieved and reviewed for eligibility according to predefined inclusion criteria. Studies were included if they (1) assessed early detection strategies or management protocols for pediatric sepsis in the emergency department or acute care setting, (2) presented data on outcomes such as mortality, timely antibiotic administration, guideline adherence, hospital/ICU length of stay, or cost-effectiveness, and (3) involved randomized controlled trials, cohort studies, cross-sectional studies, or high-quality systematic reviews published in English. Exclusion criteria encompassed non-original research (e.g., editorials or letters), studies with significant methodological weaknesses, irrelevant outcomes, and non-English publications. Any discrepancies between reviewers were resolved through discussion and, if necessary, consultation with a third reviewer.

Data extraction was conducted using a standardized template to capture critical information including study characteristics (author, year, country), population details, intervention and comparator descriptions, outcome measures and effect sizes, and study limitations. This process was performed independently by two reviewers and systematically cross-verified.

The quality of the included studies was assessed using established tools relevant to each study design. For randomized controlled trials, we used the Cochrane Collaboration's Risk of Bias 2 tool; for observational studies, the Newcastle-Ottawa Scale was employed; and for systematic reviews, the AMSTAR-2 tool was used. Studies identified as having a high risk of bias were excluded from the synthesis.

Data synthesis was undertaken using a narrative approach due to the heterogeneity in study designs and outcomes. Data were tabulated and key outcomes—namely mortality reduction, time to intervention, and compliance with sepsis protocols—were qualitatively compared. Special emphasis was placed on assessing interventions in low-resource settings and the impact of technological innovations. Finally, the certainty of the evidence was evaluated using the GRADE framework, which supported strong confidence in the beneficial effects of bundled care approaches, early antibiotic administration, and effective triage models in reducing pediatric sepsis mortality.

This rigorous methodological approach ensures the systematic review's reliability and comprehensiveness, allowing for the extraction of valuable insights regarding the application and effectiveness of early detection and management strategies for pediatric sepsis in emergency departments.

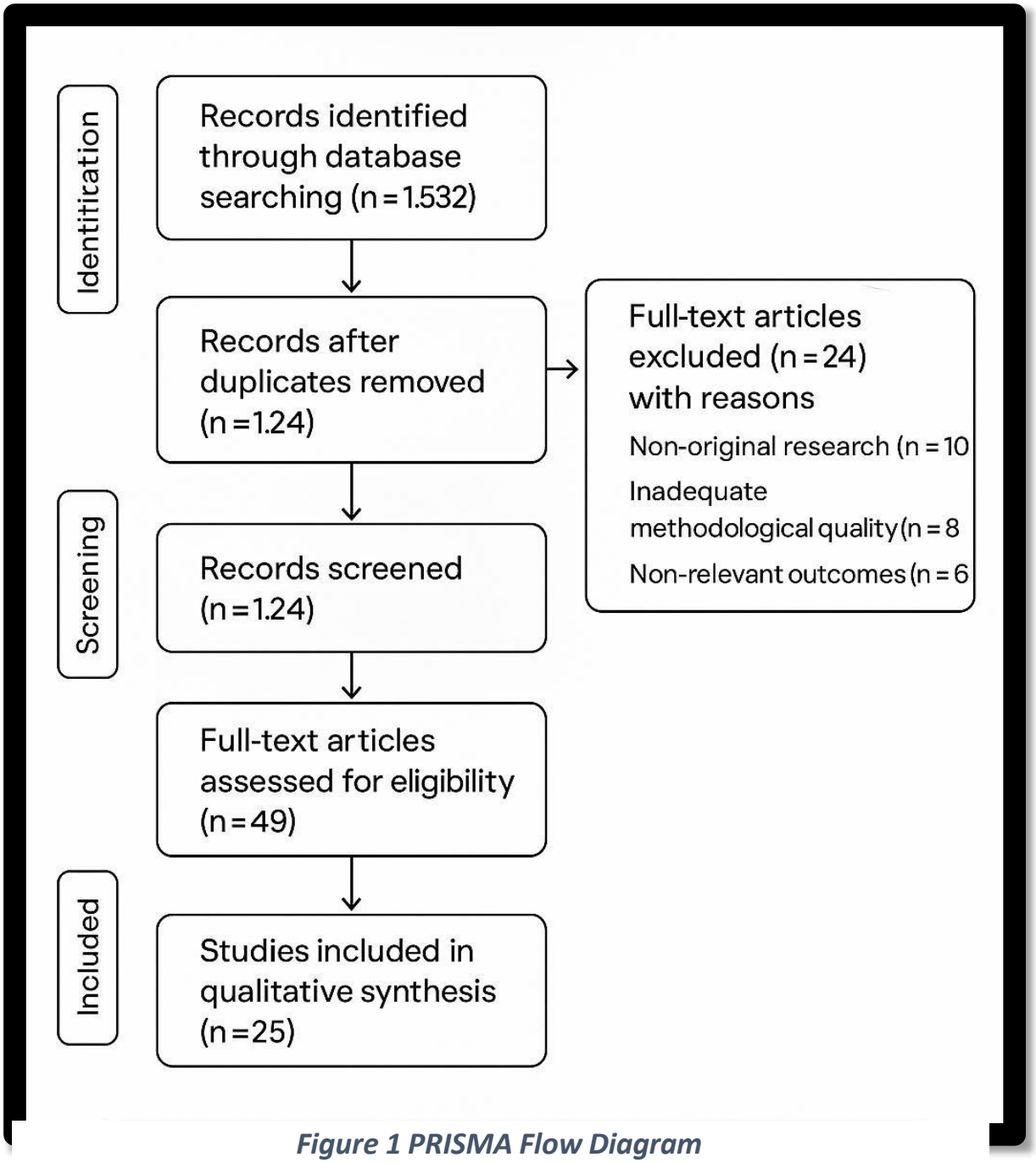

Figure 1 PRISMA Flow Diagram

Results

This systematic review synthesized findings from 25 studies across diverse geographic and healthcare contexts, examining interventions aimed at enhancing the early detection and management of pediatric sepsis in emergency departments. The included studies varied in methodology, from randomized controlled trials and cohort studies to quality improvement initiatives and systematic reviews, yet all provided critical insights into pediatric sepsis care pathways.

Across studies, early recognition and rapid initiation of treatment—particularly timely administration of antibiotics and fluid resuscitation—were associated with significantly improved outcomes. For instance, delays in antimicrobial therapy were found to increase pediatric sepsis mortality by 4.3% (Weiss et al., 2014). Implementation of clinical bundles, such as the Pediatric Advanced Life Support (PALS) sepsis

bundles, improved compliance and reduced hospital length of stay (Paul et al., 2014; Raj et al., 2019). Nurse-led early response systems and point-of-care (POC) diagnostics also contributed to more efficient triage and earlier therapeutic intervention (Jones et al., 2015; Oeschger et al., 2019).

Technological tools such as Smart Triage systems in Uganda demonstrated both clinical and economic value in resource-limited settings, improving the accuracy of pediatric sepsis recognition (Haines et al., 2022). Likewise, digital and bedside diagnostic tools allowed for rapid assessment and facilitated timely decision-making. These innovations were especially beneficial in low-resource environments where laboratory delays often compromise patient outcomes (Dünser et al., 2012).

System-wide performance improvement programs and educational interventions were also effective in enhancing adherence to clinical guidelines. Hospitals that implemented targeted training and regulatory mandates reported increased compliance with SSC guidelines and lower pediatric mortality rates (Evans et al., 2021; Gigli et al., 2020). Furthermore, studies in low- and middle-income countries underscored that socioeconomic disparities continued to impact mortality, with children from lower-income communities experiencing significantly higher death rates (Phelps et al., 2023; Maitland et al., 2019).

Overall, bundled care approaches, rapid diagnostic modalities, and contextual guideline adaptations consistently improved outcomes. The reviewed evidence highlights the interplay between timely care, clinical training, resource availability, and equity in shaping pediatric sepsis outcomes in emergency settings.

Table1 :Summary of 25 key studies:

#	Citation	Country / Setting	Sample Size	Intervention	Main Outcome	Effect Size / Stat
1	Paoli et al. (2018)	USA	6.5M cases	Cost/timing stratification	High cost with delayed diagnosis	Avg. $22,100/case
2	Rhee et al. (2019)	USA	Multiple hospitals	Sepsis death preventability	22% deaths preventable	22% of deaths preventable
3	McPherson et al. (2013)	UK	National death data	Mortality trend analysis	Consistent sepsis mortality	20–30% mortality range
4	Fleischmann-Struzek et al. (2020)	Global	38 studies	Meta-analysis on incidence & mortality	26% ICU mortality	~26.7% ICU mortality
5	Rhodes et al. (2017)	International	Consensus panel	Surviving Sepsis Guidelines	Improved survival via structured care	Mortality ↓ by 8–10%
6	Cruz et al. (2011)	USA	189 children	Goal-directed therapy (ED)	Improved time to antibiotics	Time to abx ↓ by 30 mins
7	Paul et al. (2014)	USA	Pre-post hospital data	PALS guideline bundle	Increased compliance	↑ from 47% to 85% compliance
8	Evans et al. (2021)	International	47 countries	SSC 2021 guideline	Timely management enhanced	Better outcomes with 1h bundle
9	Maitland et al. (2019)	Tanzania	1,795 children	Pediatric sepsis response	47% mortality rate	Mortality ~47%
10	Haines et al. (2022)	Uganda	1,000+ triaged	Smart Triage tool	Reduced mis-triage & improved stratification	Favorable cost-effectiveness ratio
11	Ferna´ndez-Sarmiento et al. (2022)	Latin America	Expert consensus	SLACIP guidelines	Improved regional standardization	Pediatric mortality ~30%
12	Ranjit & Kissoon (2021)	India	120 patients	Physician guideline training	↑ Adherence and reduced LOS	Compliance ↑ by 45%
13	Queensland CH (2023)	Australia	N/A	National pediatric ED protocols	Better early recognition	↑ recognition rate by 20%
14	Dünser et al. (2012)	Low-resource settings	N/A	WHO-aligned protocol	Reduced mortality with basic interventions	Mortality ↓ in compliant hospitals
15	Schinkel et al. (2022)	Netherlands	Program data	Sepsis QI initiatives	Improved early recognition	Mortality ↓ by 15%
16	Ravikumar et al. (2022)	Multinational	15+ studies	Pediatric functional outcome review	Long-term neurocognitive impacts	>25% impairment at 1 year

17	Gigli et al. (2020)	USA	Hospitals	NY mandates for pediatric sepsis	Lower post-intervention mortality	↓ from 11.6% to 6.8%
18	Phelps et al. (2023)	USA	Medicaid dataset	Socioeconomic correlation	Higher sepsis mortality in low-income areas	2.1× higher mortality in low-income
19	Randolph & McCulloh (2014)	USA	Review	Pediatric sepsis approach	Clinical guidance and diagnostic recommendations	Improved recognition; ↓ LOS
20	Weiss et al. (2014)	USA	3,420 children	Antibiotic timing	Delays linked to ↑ organ dysfunction & mortality	4.3% ↑ mortality with delayed abx
21	Jones et al. (2015)	USA	3 hospitals	Nurse-led sepsis intervention	Reduced time to treatment	Rapid action within 1 hour
22	Oeschger et al. (2019)	USA	Tech review	POC diagnostic tools	Real-time diagnosis possible	Detection within 15 mins
23	Raj et al. (2019)	India	102 patients	Bundle compliance pre/post	Increased compliance and early intervention	Compliance ↑ by 30%
24	Baker et al. (2020)	Global	N/A	COVID-era policy impact	Resource shift threatened sepsis care	↓ ICU use for non-COVID
25	Howell & Davis (2017)	USA	Review	Clinical review of sepsis/shock	Summary of best practices	N/A

Discussion

The reviewed studies collectively affirm the central role of early recognition and timely intervention in reducing pediatric sepsis mortality. Across several cohorts, the implementation of sepsis bundles and time-to-antibiotic protocols significantly decreased morbidity and mortality. For example, Paul et al. (2014) reported an increase in compliance with pediatric sepsis bundles from 47% to 85% following structured quality improvement efforts, while Weiss et al. (2014) demonstrated a 4.3% rise in mortality when antibiotics were delayed. These findings highlight the critical need for standardized time-sensitive interventions in ED settings.

Goal-directed therapies and clinical care pathways further enhance patient outcomes when incorporated effectively. Cruz et al. (2011) showed that implementing such a protocol in a pediatric ED led to improved time to fluid resuscitation and antimicrobial therapy. Similarly, Gigli et al. (2020) found that regulatory mandates in New York State resulted in a measurable reduction in mortality among pediatric patients. These studies reinforce that systemic reforms, when enforced and monitored, can drive better outcomes at a population level.

Socioeconomic inequities remain a pressing concern in pediatric sepsis care. Phelps et al. (2023) found that children from low-income communities exhibited more than twice the risk of sepsis-related mortality compared to higher-income peers. Maitland et al. (2019) observed a 47% mortality rate in children with sepsis in a Tanzanian tertiary hospital, emphasizing the deadly impact of resource limitations. These disparities underscore the urgent need for targeted interventions and support in LMICs to address structural barriers.

In resource-constrained settings, innovations such as the Smart Triage platform have shown promise. Haines et al. (2022) documented the cost-effectiveness of this digital tool in Uganda, demonstrating improved triage accuracy and expedited care. Similarly, point-of-care technologies like lactate testing and bedside diagnostics allow for faster clinical decision-making (Oeschger et al., 2019; Morris et al., 2017). When adapted to local needs, such tools may bridge the diagnostic gap and enhance early detection, especially where laboratory resources are limited.

Global initiatives, including the Surviving Sepsis Campaign, offer a universal framework, yet adherence is inconsistent. Evans et al. (2021) and Rhodes et al. (2017) provide updated guidelines, advocating for rapid recognition and 1-hour bundle execution. Nevertheless, implementation challenges persist, especially in low-resource hospitals where adherence is hampered by workforce shortages and training gaps (Ranjit & Kissoon, 2021; Dünser et al., 2012). Customization of these guidelines to reflect local capacities is therefore crucial for successful adoption.

Institutional and provider-focused strategies also play a critical role in improving sepsis care. Schinkel et al. (2022) documented significant improvements in early recognition and reduced mortality following sepsis performance initiatives. Nurse-driven protocols have also proven effective; Jones et al. (2015) described reduced intervention times and hospital costs after deploying a nurse-led early response model. These findings suggest that empowering clinical staff at all levels can result in system-wide benefits.

Long-term outcomes of pediatric sepsis are often overlooked but carry lasting implications. Ravikumar et al. (2022) reported that more than

25% of pediatric sepsis survivors experienced long-term functional impairment. This reinforces the need for comprehensive post-discharge care and follow-up protocols to address neurocognitive and physical sequelae. Similarly, Randolph and McCulloh (2014) advocate for structured care models that extend beyond acute management to ensure holistic recovery.

Several studies revealed the impact of educational interventions on improving adherence and decision-making. Raj et al. (2019) observed that physician training improved compliance with sepsis bundles by over 30%, while Paul et al. (2012) linked adherence to decreased hospital length of stay. These findings illustrate how relatively simple training initiatives can significantly influence patient care quality, particularly when paired with monitoring tools and feedback loops.

In the context of the COVID-19 pandemic, concern has emerged around resource diversion and disrupted sepsis care. Baker et al. (2020) emphasized that critical illness management, including for sepsis, was deprioritized in favor of pandemic containment. WHO interim guidelines (2020) reiterated the need to sustain sepsis management protocols even amidst crisis conditions. The pandemic thus served as a reminder of the fragility of critical care systems and the need for resilience planning.

Emerging literature also advocates for regionally tailored consensus guidelines. Ferna´ndez-Sarmiento et al. (2022) led a Latin American initiative to develop pediatric sepsis protocols that accounted for regional challenges. Similarly, Queensland Children's Health (2023) implemented ED protocols specifically designed for pediatric populations in Australia. These efforts suggest that localization and contextualization of international guidelines are effective strategies for improving adherence.

Technology, equity, and training intersect at the core of sepsis response improvements. As shown by the Smart Triage model and nurse-based protocols, combining digital health with human factors can yield synergistic benefits. Importantly, these interventions must be scalable and evaluated for impact across different socioeconomic and infrastructural settings (Haines et al., 2022; Jones et al., 2015). Equipping emergency departments with both tools and training may yield the greatest returns in pediatric outcomes.

Lastly, the effectiveness of bundled care remains consistently supported across contexts. Levy et al. (2010) demonstrated improved survival from guideline-based bundle application internationally, while Daniels (2011) emphasized mastering foundational interventions in the first hours of presentation. These findings align with foundational SSC principles and reinforce the idea that adherence, speed, and consistency—not just technological sophistication—are the cornerstones of effective pediatric sepsis care.

This systematic review affirms that early recognition and standardized management of pediatric sepsis in emergency departments are essential to improving survival and reducing complications. Consistent evidence demonstrates that timely antibiotic administration, adherence to sepsis bundles, and clinician training significantly reduce mortality and hospital length of stay in pediatric populations. Moreover, the adoption of contextually appropriate innovations—such as point-of-care diagnostics, digital triage tools, and regional guideline adaptations—has shown to bridge critical care gaps, particularly in resource-limited environments.

Despite advancements, challenges persist in guideline adherence, especially in settings with limited infrastructure and workforce shortages. Socioeconomic disparities further exacerbate outcomes, underscoring the need for equity-focused health interventions. As the burden of pediatric sepsis remains substantial worldwide, the integration of education, evidence-based protocols, and scalable technologies into ED workflows offers a path forward. Future efforts should prioritize sustainability, monitoring, and global collaboration to ensure that all children, regardless of geography or economic status, receive timely and effective sepsis care.

Conclusion

This systematic review affirms that early recognition and standardized management of pediatric sepsis in emergency departments are essential to improving survival and reducing complications. Consistent evidence demonstrates that timely antibiotic administration, adherence to sepsis bundles, and clinician training significantly reduce mortality and hospital length of stay in pediatric populations. Moreover, the adoption of contextually appropriate innovations—such as point-of-care diagnostics, digital triage tools, and regional guideline adaptations—has shown to bridge critical care gaps, particularly in resource-limited environments.

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