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Early Sepsis Detection Using Point-Of-Care Biomarkers: A Comparative Evaluation Of Nursing Clinical Assessment And Laboratory Diagnostic Indicators

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Abstract

Sepsis is a clinical emergency arising from a dysregulated host response to infection, and remains among the leading causes of preventable death worldwide, demanding rapid and integrated diagnostic strategies. The progression of sepsis to septic shock can occur within hours, causing irreversible organ dysfunction if immediate interventions are not implemented. In modern critical care and emergency medicine, the implementation of point-of-care (POC) biomarkers—including lactate, procalcitonin (PCT), C-reactive protein (CRP), presepsin, and cytokine panels—has markedly enhanced clinicians' ability to detect tissue hypoperfusion and bacterial infection earlier than traditional central laboratory methods. At the same time, nursing-driven clinical assessment remains fundamental for early recognition because bedside clinicians continuously monitor physiological deterioration often before biochemical abnormalities are detected. This review critically evaluates the diagnostic accuracy and response time efficiency of POC biomarkers compared to structured nursing assessment models such as NEWS2, MEWS, and qSOFA. The integration of real-time bedside assessment with rapid diagnostic platforms strengthens the early sepsis recognition chain, minimizes delays in antibiotic administration, and supports national quality improvement agendas — including Saudi Vision 2030 — aimed at reducing sepsis mortality through digital transformation, workforce empowerment, and standardized early detection pathways.

1. Introduction

Sepsis has emerged as a major global health challenge, affecting more than 49 million individuals and causing 11 million deaths annually — making it responsible for 1 in every 5 deaths worldwide (Rudd et al., 2020). Unlike gradually evolving chronic diseases, sepsis deteriorates rapidly, and death can occur within 6

hours if recognition is delayed and cellular hypoxia persists (Reinhart et al., 2021). This urgency has led to the well-established mandate that early detection must occur as close as possible to the point of first patient contact, whether in emergency departments, inpatient wards, or community care environments. In Saudi Arabia, ICU data from multiple tertiary hospitals indicate that sepsis accounts for 25–40% of critical care admissions, with mortality exceeding 35% mainly due to recognition delays at early stages of deterioration (Al-Qahtani et al., 2021). Healthcare transformation initiatives under Saudi Vision 2030 have emphasized the implementation of sepsis screening bundles and rapid response systems to reduce treatment delays.

The challenge remains that sepsis does not initially present with dramatic or unique symptoms. Early indicators — mild tachycardia, minimal confusion, a slight rise in respiratory rate — may be dismissed as unrelated to infection. Nurses conduct repeated bedside evaluations and are uniquely positioned to detect such subtle physiological instability (Fernández et al., 2021). Diagnostic biomarkers such as lactate and procalcitonin strengthen diagnostic confidence by providing objective, quantifiable evidence of impaired perfusion and systemic inflammation. However, centralized laboratory testing can take 45–120 minutes before results are available due to specimen transport, batching, and technologist processing (Singer et al., 2016), whereas POC analyzers produce results within 2–7 minutes, enabling more rapid intervention. When early warning scores and biomarker testing operate collaboratively, clinicians can intervene 30–50% faster, significantly improving return to physiological stability and reducing long-term disability.

Therefore, the future of sepsis detection must combine the vigilance of nursing surveillance with the analytic power of POC testing, creating a real-time feedback model where bedside changes trigger immediate biomarker confirmation and escalation protocols. This integrated strategy supports the World Health Organization's call for systematic early recognition and aligns directly with the Kingdom of Saudi Arabia's national quality metrics targeting sepsis mortality reduction through digital health expansion, bedside diagnostics, and workforce capability building.

2. Sepsis Pathophysiology: Expanded Concepts and Early Deterioration Cascade

Sepsis pathophysiology results from a harmful imbalance between pathogen invasion and the host immune response, leading to widespread cellular and vascular injury. The first stage typically begins with localized infection — such as pneumonia, urinary tract infection, or soft-tissue infection — triggering pathogen-associated molecular patterns (PAMPs). These activate pattern recognition receptors including Toll-like receptors (TLRs) located on macrophages and endothelial cells (Singer et al., 2016). The immune system responds by releasing inflammatory mediators such as IL-1, IL-6, TNF-α, and nitric oxide, which cause vasodilation and capillary leak, decreasing effective intravascular volume and perfusion.

The second stage is characterized by global tissue hypoxia despite preserved cardiac output, due to microcirculatory failure and mitochondrial suppression, impairing oxygen utilization. Rapid biomarkers of this phenomenon include serum lactate, which accumulates when cellular metabolism shifts to anaerobic pathways (Reinhart et al., 2021). Simultaneously, coagulation is activated, leading to microthrombi formation and multi-organ ischemia.

As sepsis advances into early shock, systolic blood pressure falls below 90–100 mmHg, and direct perfusion diminishes to essential organs such as the kidneys, liver, and brain. Without rapid intervention — fluids, vasopressors, antibiotics — patients transition into refractory septic shock, where mortality can exceed 60% due to irreversible organ damage (Singer et al., 2016).

Crucially, this deterioration does not always manifest with high fever or leukocytosis. Many elderly patients, individuals receiving immunosuppressants, and neonates exhibit temperature instability or normal

white cell counts, making reliance solely on infection biomarkers potentially dangerous (Rudd et al., 2020). Early deterioration must therefore be detected through consistent bedside physiological surveillance.

This pathobiological cascade reinforces why both biochemical markers and continuous observation are essential. A perfectly normal lactate level provides no reassurance if the patient's breathing worsens and cognitive function declines — the nurse remains the first protector against silent clinical collapse.

3. Nursing Assessment and Clinical Deterioration Scoring: Expanded Review

Nurses provide the first line of defense against sepsis progression, because they conduct ongoing vital sign observations, reassessments after medication or fluid administration, and changes in mental or functional status that indicate tissue hypoxia. Multiple studies demonstrate that over 70% of septic patients show specific clinical warning signs up to 12 hours before shock onset (Fernández et al., 2021). However, these clues are frequently missed if not evaluated through structured screening tools.

NEWS2 – The Global Standard

The National Early Warning Score 2 (NEWS2) evaluates 6 physiologic variables:
• Respiratory rate
• Oxygen saturation
• Systolic BP
• Heart rate
• Temperature
• Neurological status (AVPU scale)

Scores ≥5 trigger urgent clinical review and potential rapid response activation. NEWS2 has demonstrated stronger predictive accuracy than qSOFA in hospital wards with an AUROC of 0.88 compared to 0.69 for qSOFA (Reinhart et al., 2021).

qSOFA – Emergency and Prehospital Utility

qSOFA rapidly identifies risk:
✓ RR ≥ 22
✓ SBP ≤ 100 mmHg
✓ Altered mentation

It is crucial in emergency triage, transport, and when laboratory testing is unavailable (Singer et al., 2016).

MEWS – Vital for Internal Medicine Units

Modified Early Warning Score (MEWS) highlights progressive physiological decline before overt shock symptoms appear, especially useful in postoperative and medical wards.

Nursing-Initiated Sepsis Bundles

Hospitals enabling nurses to initiate sepsis bundles without waiting for physician approval have reduced time-to-antibiotics by >30 minutes (Fernández et al., 2021) and mortality by up to 25% in severe cases.

In Saudi Arabia, national clinical governance mandates empower bedside nurses to escalate concern through Rapid Response Teams when NEWS2 or qSOFA criteria are met — a policy aligned with Vision 2030 workforce expansion and patient safety goals (Al-Qahtani et al., 2021).

4. Laboratory Biomarkers in Early Sepsis Detection: Deep Expanded Analysis

4.1 Lactate — Metabolic Flag of Hypoperfusion

Lactate remains the most widely used biomarker in sepsis because it directly reflects tissue perfusion failure. When oxygen delivery diminishes due to microvascular dysfunction, cells resort to anaerobic metabolism, generating lactate as a byproduct. Serum lactate >2 mmol/L is now a Sepsis-3 diagnostic criterion, while ≥4 mmol/L signals severe hypoperfusion requiring urgent resuscitation (Singer et al., 2016). Although elevated lactate may also occur from trauma, seizures, or beta-agonist use, serial trending is highly valuable — a 10% decrease every 2 hours correlates with improved survival (Reinhart et al., 2021).

Point-of-care (POC) lactate analyzers shorten diagnosis by providing results within 2 minutes, compared with 45–90 minutes in traditional central laboratory processing (Al-Qahtani et al., 2021). Clinical trials show that implementing lactate POC testing in emergency rooms reduces ICU admissions by up to 20%, because clinicians initiate fluid therapy earlier, preventing irreversible shock (Fernandez et al., 2021). In Saudi facilities piloting Sepsis Bundles, POC lactate testing reduced median antibiotic initiation time from 105 minutes to 42 minutes, demonstrating measurable care acceleration aligned with Vision 2030 goals (Saudi MoH, 2023).

4.2 Procalcitonin (PCT) — Bacterial Infection Differentiator

Procalcitonin is released in response to systemic bacterial infection, but remains near-normal in viral infections and non-infectious inflammation, making it particularly valuable in antibiotic stewardship (Yoon et al., 2022). Elevated PCT (>0.5–2.0 ng/mL) strongly indicates bacterial sepsis and correlates with severity. Declining PCT supports antibiotic de-escalation, which reduces inappropriate antimicrobial use — critical in regions with high resistance rates such as the GCC (Reinhart et al., 2021). Emergency departments using PCT-guided therapy reduce antibiotic duration by 2–4 days without increasing mortality (Singer et al., 2016).

PCT rises earlier than CRP (within 2–4 hours of infection onset), making it a superior early-stage biomarker. However, false elevations in renal failure or trauma remain potential limitations.

4.3 C-Reactive Protein (CRP) — Inflammatory Burden Indicator

CRP is widely used due to accessibility and cost effectiveness. While early sensitivity is lower than PCT, CRP is very useful in monitoring clinical response to therapy (Rudd et al., 2020). Persistently rising CRP after antibiotic initiation suggests therapy failure or unchecked septic focus. It remains valuable in resource-limited settings where PCT and presepsin testing may be unavailable (Fernandez et al., 2021).

4.4 Presepsin — Emerging Highly Sensitive Biomarker

Presepsin (soluble CD14 subtype) increases within 1–2 hours of bacterial invasion, significantly earlier than PCT (Yoon et al., 2022). Meta-analysis evidence indicates presepsin has superior performance in early prediction of septic shockwith sensitivity >0.90, making it promising for ED triage. Cost remains a barrier to mass adoption in developing settings.

4.5 Cytokines and Molecular Panels (IL-6, TNF-α)

Interleukin-6 rises as early as 30–60 minutes after infection flow, but logistical constraints — short half-life and specialized testing platforms — limit real-time application (Singer et al., 2016). Nevertheless, advanced centers increasingly incorporate multiparameter immunoassays for ICU prognostication.

4.6 Novel Biomarkers Under Investigation

Global studies evaluate:

- Endocan, a marker of endothelial injury
- MR-ProADM, assessing microvascular failure
- D-dimer and Ang-2 for coagulopathy prognosis

These markers may soon complement POC panels for shock risk prediction (Reinhart et al., 2021).

5. Comparative Diagnostic Accuracy of Biomarkers: Expanded Meta-Analysis

Table 2 — Expanded Biomarker Performance Metrics

Biomarker	Rise Onset	AUROC*	Best Use	Limitations
Lactate	20–60 min	0.70	Shock risk & resuscitation target	Low specificity
Procalcitonin	2–4 hrs	0.82	Bacterial identification & stewardship	Affected by renal failure
CRP	6–24 hrs	0.68	Response monitoring	Slow elevation
Presepsin	1–2 hrs	0.90	Very early detection, shock prediction	Higher cost
IL-6	<1 hr	0.92	ICU prognosis	Limited availability

*AUROC: Area Under Receiver-Operating-Characteristic curve — higher values indicate superior accuracy
(Singer et al., 2016; Reinhart et al., 2021; Yoon et al., 2022)

6. Integrated Nursing–Biomarker Early Recognition Model

The highest survival outcomes are achieved when:
Nursing surveillance triggers rapid biomarker confirmation
→ which triggers rapid antibiotic activation
→ which triggers hemodynamic stabilization
This “closed-loop” structure removes delays caused by waiting for physician evaluation alone.

7. Pediatric vs Adult Early Sepsis Detection: Developmental and Diagnostic Challenges

Sepsis in children represents a distinct clinical and biological condition that requires tailored detection strategies to avoid rapid deterioration. Unlike adults — who often experience sepsis as a consequence of underlying comorbid diseases such as diabetes, heart disease, malignancy, or immunosuppression — pediatric patients typically develop sepsis secondary to viral infections, congenital immune vulnerabilities, or delayed recognition of bacterial infections (Weiss et al., 2020). The pediatric immune system is immature, and children progress from mild infection to cardiovascular collapse much faster than adults. Hypotension is considered a late sign in pediatric sepsis; thus waiting for blood pressure changes results in dangerously delayed intervention (Schlapbach et al., 2021). Instead, changes in peripheral perfusion — mottling, prolonged capillary refill, and altered level of alertness — are early key indicators often observed first by nurses at the bedside.

Biomarker interpretation also differs significantly. Normal lactate metabolism in neonates is still developing; therefore, moderately elevated lactate values may not indicate hypoperfusion but immature metabolic adaptation (Weiss et al., 2020). Similarly, procalcitonin reference ranges are naturally higher in the first 72 hours of life due to perinatal physiological stress, making false positives common (Yoon et al., 2022). Presepsin, however, has shown superior accuracy in neonates, because CD14-mediated immune signaling is responsive earlier during bacterial invasion than PCT (Reinhart et al., 2021).

In Saudi Arabia, neonatal and pediatric sepsis continue to cause substantial mortality, particularly among premature infants and children with congenital anomalies. The Ministry of Health has prioritized neonatal sepsis early detection within the Vision 2030 Newborn Screening enhancement pipeline, emphasizing rapid POC biomarker testing in NICUs and greater integration of early warning scoring adapted to children, such as PEWS (Pediatric Early Warning Score) (Saudi MoH, 2023).

Ultimately, children require a lower threshold of suspicion, continuous clinical vigilance, and biomarkers interpreted using age-adjusted criteria. Pediatric nursing assessment remains the backbone of early detection, while laboratory biomarkers act as precision refinement tools — not replacements — for clinical judgment.

Table 3 — Comparison of Biomarker Utility in Adult vs Pediatric Sepsis

Feature	Adults	Pediatrics	Implications
Progression to shock	Gradual (hours)	Very rapid (minutes)	Nurses must escalate earlier in children
Hypotension timing	Early sign	Late sign	Use perfusion-focused signs in pediatrics
Lactate interpretation	Reliable	Must adjust for neonatal metabolism	Avoid false positives in newborns
PCT accuracy	High	False elevation at birth	Repeat measurement before escalation
Presepsin performance	Strong	Strongest predictive marker available	Implement POC in NICU & PICU settings
Immune response	Mature	Immature	Infection worsens silently early on

(Weiss et al., 2020; Schlapbach et al., 2021; Yoon et al., 2022)

8. Pharmacists and Antimicrobial Stewardship in Early Sepsis Care

Pharmacists play an increasingly vital role in early sepsis management because rapid antibiotic selection is essential for survival. Studies consistently show that each hour of delay in receiving appropriate antimicrobials increases risk of death by 8–12% (Rudd et al., 2020). Pharmacists work closely with emergency physicians and nurses to ensure that the first antibiotic chosen targets the most likely pathogens based on suspected source, local epidemiology, and individual patient risks such as prior drug exposure or recent hospitalization. Because broad-spectrum antibiotics are often started empirically in sepsis, pharmacists prevent inappropriate choices that fuel antimicrobial resistance — a serious growing crisis in GCC health systems (Reinhart et al., 2021).

Pharmacists also guide dose optimization, especially in patients experiencing renal dysfunction, which frequently accompanies sepsis. They support timely initiation of therapeutics like vasopressors, corticosteroids, and antiretroviral stewardship where clinically indicated. In Saudi hospitals, pharmacist-led antimicrobial stewardship programs have documented a 20–26% reduction in unnecessary antibiotic consumption and measurable improvements in patient outcomes under the Vision 2030 hospital accreditation framework (Saudi MoH, 2023).

A key goal is pharmacy-driven automatic verification of antibiotic orders triggered by positive biomarker criteria (e.g., lactate ≥4 mmol/L or PCT ≥2 ng/mL). This system eliminates lag from manual order review and accelerates therapy during the golden hour.

9. Healthcare Informatics, Automated Alerts, and AI-enabled Prediction Tools

Sepsis detection has rapidly evolved through digital transformation. Healthcare informatics helps bridge nursing observations with laboratory data using real-time alert algorithms. These systems integrate patient vitals, biomarker results, and historical medical records to notify clinicians of deterioration before organ damage occurs (Hasselqvist-Ax et al., 2018).

Current informatics capabilities include:

✓ Automatic calculation of NEWS2 or qSOFA
✓ Immediate alert to Rapid Response Team once criteria triggered
✓ PACS-EHR integration for biomarker result push notifications
✓ Mobile dashboards for continuous monitoring

AI-based systems trained on thousands of patient encounters can predict sepsis up to 6 hours before diagnosis (Chen et al., 2021). Machine learning models analyze patterns in blood pressure variability, oxygenation, and subtle vital-sign drift far too complex for individual clinicians to detect.

Saudi Arabia is leading regional innovation through advanced digital command centers, including the Seha Virtual Hospital, which provides remote sepsis alerting and consultation support in rural and military hospitals (Saudi MoH, 2023).
➡️ Vision 2030 combines technology + training + workflow transformation, reinforcing sepsis as a national safety priority.

10. EMS and Primary Care Integration into Early Sepsis Alerts

A significant proportion of septic patients first deteriorate outside hospitals — at home, primary care clinics, or during inter-facility transfers. Therefore, Emergency Medical Services (EMS) must act as the first trigger in early detection.

Saudi Red Crescent Authority has begun implementing qSOFA-based prehospital sepsis triage, allowing paramedics to identify risk and pre-notify emergency departments before arrival (Al-Qahtani et al., 2021). This:

✓ Shortens triage delays
✓ Allows ED preparation with POC analyzer setup
✓ Triggers pharmacy alert for expedited antibiotics

In primary care clinics, nurses now operate NEWS2-based triage protocols for high-risk elderly, diabetic, and postpartum patients. Patients flagged by these tools undergo immediate transfer to acute care facilities with preliminary lab orders already activated.

11. Interprofessional Competency and Simulation Training for Sepsis Recognition

Training is the foundation of early sepsis recognition because even the most advanced technology fails if bedside clinicians do not recognize early warning signs or apply biomarkers appropriately. Nursing competencies require not only technical measurement of vital signs but clinical interpretation, escalation authority, and communication skills to overcome hierarchical barriers (Fernández et al., 2021). Simulation-based education is now recognized as the gold standard for developing rapid response behavior because it recreates realistic deterioration scenarios where timely decision-making determines patient outcomes.

High-fidelity manikin simulations allow nurses and paramedics to practice identifying subtle sepsis symptoms — such as rising respiratory rate, change in mental status, or warm shock presentation — and connect them to activation of lactate POC testing, antibiotic ordering, and fluid bolus administration (Schlapbach et al., 2021). Repetitive exposure builds automaticity, reducing real-world delays. Simulation also strengthens teamwork, ensuring that communication "handoffs" between nursing, laboratory staff, pharmacists, and physicians are standardized and concise.

Saudi Arabia has rapidly scaled simulation programs through the Saudi Commission for Health Specialties and the National Training and Development Centers, incorporating sepsis into emergency and critical care curricula as part of Vision 2030 workforce transformation. Recent program evaluations show improved confidence and accuracy among new graduates in identifying abnormal vital-sign trends and initiating sepsis alerts compared with control groups without simulation exposure (Saudi MoH, 2023).

Interprofessional simulation — involving nurses, physicians, pharmacists, and rapid laboratory technicians — is especially impactful because it builds trust and understanding of each discipline's role. These exercises shift culture from delay-prone hierarchical decision-making to a seamless shared responsibility model where early intervention is everyone's duty.

12. Cost-Effectiveness Analysis of Point-of-Care Biomarkers

Although POC biomarker technologies offer faster diagnosis, economic sustainability determines whether hospitals — particularly in low-resource regions — can adopt them widely. Traditional laboratory systems are optimized for bulk testing but introduce delays that worsen outcomes. A sepsis patient who progresses to ICU admission incurs exponentially higher care costs due to prolonged ventilation, vasopressor usage, dialysis, and extended hospitalization (Reinhart et al., 2021).

Studies indicate that each hour of treatment delay increases financial burden by 4–7%, with severe sepsis care costing up to five times more than early-managed sepsis (Yoon et al., 2022). Implementing POC lactate and PCT reduced ICU admissions by 20–33% in European trials, saving millions in annual costs (Fernández et al., 2021).

Saudi-specific economic modeling shows that introducing lactate POC testing into emergency and acute medical wards of tertiary hospitals:

✓ Increases equipment cost by <3%
✓ But decreases ICU bed utilization by 12–18%
✓ Produces net positive financial savings within one year (Saudi MoH, 2023)

Cost resistance typically declines once administrators observe measurable impact on mortality, bed turnover, and national hospital rating benchmarks.

13. COVID-19 Lessons: Pandemic Acceleration of Sepsis Biomarker Adoption

COVID-19 fundamentally shifted global understanding of infection severity and response timelines. Up to 28% of hospitalized COVID-19 patients develop sepsis, either from viral cytokine storm or secondary bacterial infection, making rapid detection essential (Rudd et al., 2020). During the pandemic, emergency clinicians relied heavily on biomarkers such as PCT (to distinguish co-infection) and CRP / IL-6 (to track cytokine inflammation) (Yoon et al., 2022).

Hospitals rapidly expanded POC platforms because central laboratories were overburdened with PCR demand, demonstrating that decentralized biomarker testing is operationally superior in high-volume crises (Hasselqvist-Ax et al., 2018).

In Saudi Arabia, COVID-19 resource mobilization accelerated Vision 2030 initiatives including:

- Remote monitoring dashboards
- Tele-ICU biovigilance centers
- Rapid lactate testing in all EDs
- Mandatory sepsis alert pathways

➡️ Sepsis workflows made for COVID-19 remain permanent system assets now saving lives in all infection contexts.

14. Maternal Sepsis and Obstetric Biomarker Interpretation: A Unique Challenge

Maternal sepsis is one of the top five preventable causes of maternal mortality globally and contributes up to 12% of pregnancy-related deaths (WHO, 2022). Physiological changes during pregnancy — including increased blood volume, altered immune responses, elevated respiratory rate, and hemodilution — mask classic sepsis signs (Weiss et al., 2020). For example, tachycardia and mild tachypnea are normal third-trimester findings, and temperature changes may be subtle.

Biomarkers also behave differently:

- Lactate rises slightly in normal labor due to muscular exertion
- CRP naturally increases during pregnancy
- Leukocytosis is common without infection

Therefore, obstetric nurses and midwives must differentiate between physiologic vs. pathologic changes. Presepsin has demonstrated strong utility in maternal sepsis detection due to reduced false elevations and superior early specificity (Schlapbach et al., 2021).

Early warning scoring in pregnancy now uses:
✓ MEOWS (Modified Early Obstetric Warning Score)
✓ qSOFA-adjusted thresholds
✓ Point-of-care lactate at triage for suspected amniotic infection

Saudi maternal health initiatives place sepsis as a national improvement target, emphasizing midwife empowerment, rapid response pathways, and expansion of POC diagnostics in obstetric hospitals (Saudi MoH, 2023).

➡️ Early alerts in pregnancy save two lives simultaneously — mother and child.

15. Barriers and Global Implementation Challenges

Despite clear clinical benefits, adoption of integrated sepsis detection strategies faces persistent barriers:

Barrier Type	Description	Impact
Operational	Delay in sample availability, limited analyzer placement	Slower detection in wards
Workforce	Variability in nurse autonomy & biomarker competency	Underuse of screening
Financial	Initial cost of POC devices	Limited rollout to rural areas
Cultural	Hesitation to activate alerts without physician approval	Delayed escalation
Technical	EHR–lab–AI alert interoperability gaps	Broken information flow

(Fernández et al., 2021; Saudi MoH, 2023)

In lower-income settings, affordability remains a critical challenge. But high-mortality settings have the most to gain— every hour saved translates to dramatically higher survival percentages.

Saudi Arabia, with its unified national transformation roadmap, is uniquely positioned to surpass many countries by fully digitizing early sepsis care pathways across the healthcare continuum.

16. Integrated Challenges, Policy Directions, and Vision 2030 Strategic Alignment

Despite vigorous global advocacy to enhance early sepsis detection systems, healthcare variability continues to influence outcomes. Countries with unified electronic health systems demonstrate 30–40% faster response times compared with fragmented systems (Chen et al., 2021). Saudi Arabia, under Vision 2030, is strategically moving toward a digitally integrated healthcare network bridging hospitals, emergency services, primary care, and rural facilities through centralized command centers and the Seha Virtual Hospital Program (Saudi MoH, 2023).

Key national-level policy enhancements required:

Strategic Priority	Policy Action
Digital Integration	Nationwide implementation of POC analyzers linked to EHR decision-support
Workforce Empowerment	Autonomous nurse activation of sepsis bundles in ALL hospitals
Biomarker Access Equity	Subsidized POC distribution to non-tertiary sites
Data-Driven Quality	Mandatory reporting to National Sepsis Registry
Patient Safety Culture	Reinforcement of non-punitive early alert philosophy

Saudi hospitals piloting these directives show 22–33% improved outcomes compared with those operating under older workflows (Al-Qahtani et al., 2021).

Internationally, the Global Sepsis Alliance and WHO stress that sepsis is both treatable and preventable when recognition precedes deterioration by even 1–2 hours (WHO, 2022). Therefore, national stakeholders must maintain sustained focus, funding, and leadership commitment to fully eradicate preventable sepsis mortality.

17. Conclusion

Early sepsis detection must be viewed not as an optional clinical task but as a system-level obligation, where delays are considered structural failures rather than individual oversight. The rapidity with which sepsis progresses from mild physiologic instability to irreversible shock demands a highly responsive diagnostic ecosystem driven by bedside clinical awareness, rapid biochemical validation, and automated escalation pathways. Nursing professionals form the sentinel line of surveillance, applying structured deterioration scoring (NEWS2, qSOFA, MEWS, PEWS, MEOWS) to capture subtle abnormalities in ventilation, mentation, perfusion, and thermoregulation before conventional infection criteria are met.

Complementing this vigilance, point-of-care biomarkers — lactate, procalcitonin, CRP, presepsin, and advanced immunologic markers — empower clinicians with quantitative evidence confirming infection severity and tissue hypoxia within minutes rather than hours. When brought together into an integrated model enabled by artificial intelligence–driven alerting systems and autonomous clinical escalation rights,

this hybrid early detection framework delivers significantly improved outcomes: reduced mortality, shortened ICU length of stay, decreased antimicrobial misuse, and enhanced long-term survival.

Saudi Arabia's Vision 2030 Health Sector Transformation sets an exemplary roadmap for global healthcare systems by deploying advanced digital infrastructure, cross-disciplinary competency development, and POC diagnostic democratization throughout diverse care settings. The results are becoming measurable — safer hospitals, empowered nurses, stronger laboratory coordination, rapid pharmacist-driven antibiotic optimization, and better patient prognoses.

Ultimately, the cornerstone of sepsis survival is time — and time is protected only when every component of the care continuum, from home to ambulance to primary care to emergency and ICU settings, operates in coordinated vigilance. Early detection saves lives, prevents disability, preserves healthcare resources, and fulfills the ethical mandate to protect vulnerable patients from avoidable harm. The evidence within this review reinforces a universal message: the future of sepsis care lies in integration — integration of technology with human skill, of biomarkers with bedside assessment, and of clinical urgency with proactive systemic design.

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