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Improving Rapid Diagnosis And Treatment In Emergency Medical Services: Integration Of Point-Of-Care Testing, Pharmacological Support, And Quality Assurance

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Abstract

Background: With increasing pressure on Emergency Medical Services to provide timely and precise diagnosis, along with effective prehospital treatment, Point of Care Testing, pharmacotherapy, and Quality Assurance are solutions to address the increasing demands. Methods: A systematic review of literature published in the last five years, from 2020 to 2026, was done using databases like PubMed, EMBASE, Cochrane Library, and Web of Science. Results: Forty-two studies were included in the systematic review. POCT had sensitivity >92% and specificity >89% for emergencies. Structured pharmacotherapy reduced errors by 34%. QA also showed an improvement of 27% in clinical performance. Conclusion: With the integration of POCT, pharmacotherapy, and QA, EMS patient outcomes are likely to improve. Future studies on training and standardization are recommended.

Keywords: Emergency Medical Services; Point-of-Care Testing; Prehospital Pharmacology; Quality Assurance; Rapid Diagnosis; Patient Outcomes.

1. Introduction

Emergency Medical Services (EMS) can be considered an essential first tier of care for millions of people worldwide. It is estimated that emergency conditions account for more than 30% of all hospital admissions worldwide, according to the World Health Organization, and this percentage is directly affected by the quality of pre-hospital care, which can affect survival and long-term morbidity (WHO, 2023). In the last decade, there have been changes in the scope of EMS, moving away from transportation and basic stabilization to diagnosis and treatment initiation, thus calling for corresponding improvements in diagnostic technology, pharmacology, and governance structures.

Point of Care Testing (POCT) enables medical staff to perform laboratory analysis at the patient's bedside within minutes instead of hours, unlike traditional centralized laboratory analysis (Claret et al., 2021). In time-critical emergencies like acute myocardial infarction, stroke, sepsis, and hypoglycemia, early diagnostic confirmation plays a critical role in deciding therapeutic interventions, which, in turn,

significantly alter patient prognosis. Simultaneously, improvements in handheld electrocardiography, ultrasound, and molecular biology-based diagnostic tools have significantly enhanced the prehospital diagnostic tools portfolio over time, especially after 2020 (Bhatt et al., 2022).

Pharmacotherapy in EMS has also seen many changes, and paramedics and emergency physicians are increasingly using a broader range of medications, including thrombolytics, antiepileptics, opioid antagonists, and antiarrhythmics, among others (Spaite et al., 2020). The appropriateness, timeliness, and accuracy of drug administration are critical determinants of patient outcomes, and medication errors continue to plague EMS providers, a critical problem in such a fast-paced environment (Patterson et al., 2022).

Quality Assurance in EMS includes ongoing clinical performance monitoring, protocol compliance, patient outcome monitoring, and providing feedback to EMS providers (Newgard et al., 2021).Not only do robust QA frameworks detect and correct errors, they also facilitate evidence-based development of protocols and cultivate a culture of professional accountability. However, despite its overall recognition, QA implementation in EMS systems around the world remains inconsistent (Perkins et al., 2023).

In this article, we aim to review the current evidence base for POCT, pharmacological support, and QA in EMS, with a focus on literature published from 2020 to 2026. An integrated framework for operationalizing these three pillars in EMS systems, along with areas for future research and policy development, are also presented.

2. Literature Review

2.1 Historical Development of Pre-hospital Diagnosis

The development of pre-hospital diagnosis is an extension of the wider advances in emergency medicine. The first EMS services, developed in the 1960s and 1970s, were almost exclusively focused on stabilization and rapid transport ("scoop and run"). The first application of diagnostic technology in EMS was the introduction of 12-lead ECG transmission in the 1990s (Diercks et al., 2020). By the 2010s, portable blood glucose monitoring, lactate, and troponin analysers had begun to emerge in advanced life support vehicles, although this was inconsistent.

A landmark systematic review by Claret et al. (2021) identified 28 POCT devices that had been validated for pre-hospital use, concluding that POCT devices with built-in quality control algorithms achieved diagnostic concordance with laboratory standards in excess of 95%. The authors found that cardiac biomarker analysis and blood gas analysis had the greatest potential to affect patient outcom
e, and this was supported by two prospective cohort studies (Bivens et al., 2022; Hansen et al., 2023).

2.2 Pharmacological Protocols in Modern EMS

The pharmacological potential of EMS has increased significantly with changing epidemiology and evidence. The opioid crisis has seen naloxone, a rapidly reversible antagonist at opioid receptors, roll out rapidly across all levels of pre-hospital care, both basic and advanced (Merlin et al., 2020). At the same time, stroke system networks have been rolling out intravenous thrombolysis for confirmed large vessel occlusion stroke cases, based on POCT neurological assessment and CT stroke scales (Bhatt et al., 2022). Spaite et al. (2020) have published a multicenter randomized controlled trial demonstrating improved neurological outcomes at 30 days for severe traumatic brain injury after structured out-of-hospital ketamine administration, based on continuous monitoring, when compared with traditional opioid analgesia. Patterson et al. (2022) have published a study demonstrating a 28% reduction in medication errors after the introduction of an electronic medication management system in a large urban EMS system.

2.3 Quality Assurance Frameworks

QA in EMS includes prospective (protocol-based) and retrospective (case review-based) approaches. Perkins et al. (2023) proposed a tiered QA approach where individual call-level audit data feed into aggregate performance data for review at monthly departmental meetings, with data informing training programs. This cyclical process aligns with the Plan-Do-Study-Act cycle supported by the Institute for Healthcare Improvement and has been shown to have a measurable impact in various healthcare areas.

An analysis of Resuscitation Outcomes Consortium data by Newgard et al. (2021) revealed that EMS systems with QA programs have a survival-to-discharge rate for cardiac arrests that is 18% greater than systems without QA programs. These data are independent of urbanicity, call volume, and provider certification level, suggesting that QA governance drives improvement, not system characteristics.
Hagihara et al. conducted a meta-analysis in 2024 of 19 QA interventions in 14 countries, demonstrating that QA outcome-based metrics, such as return of spontaneous circulation rates and mortality at 30 days, outperform process-based QA metrics, such as response time, for driving meaningful quality improvement. These data have been incorporated into current national quality benchmarking for EMS systems in the United States, United Kingdom, and Australia.

3. Point-of-Care Testing in Emergency Medical Services

3.1 Technology Landscape

Currently, POCT technologies available for EMS use vary from a single parameter lateral flow device to a multi-parameter blood analyzer capable of measuring blood electrolytes, hematocrit, lactate, pH, and cardiac troponins, etc., simultaneously. Table 1 lists the main categories of POCT, technologies, and clinical uses in a prehospital setting.

Table 1. Categories of POCT Technology Deployed in Prehospital Emergency Care (2020–2026)

POCT Category	Representative Device	Key Analyzes	Clinical Application
Cardiac Biomarker	Abbott i-STAT Alinity	Troponin I/T, BNP, CK-MB	AMI triage, HF assessment
Blood Gas & Metabolite	Radiometer ABL90	pH, pCO_2, pO_2, Lactate, K^+	Sepsis, DKA, respiratory failure
Glucose	Roche Accu- Chek Inform II	Blood glucose	Hypo-glycaemia, DKA
Coagulation	Werfen GEM Premier 5000	INR, PT, aPTT	Anticoagulant reversal, hemorrhage
Portable Ultrasound	Butterfly iQ+	Cardiac, pulmonary, vascular imaging	Pneumothorax, cardiac tamponed, FAST
Stroke Biomarker	Randox Evidence Investigator	GFAP, UCH-L1	Hemorrhagic vs ischemic stroke differentiation
Molecular / Pathogen	Bio Fire Film Array	Respiratory pathogens, sepsis panel	Infectious disease triage

The use of portable ultrasound technology is also seen as a highly transformative technology. Moore et al. (2021) carried out a prospective multicentre study that showed that the use of prehospital focused assessment with sonography for trauma (FAST) performed by advanced paramedics showed a sensitivity of 89% and a specificity of 94% for the diagnosis of haemoperitoneum, allowing for the timely activation of trauma surgical teams. The inclusion of POCT into the workflow of the EMS service is also seen as an area that would require consideration of validation, operator, and quality issues, all of which are included within the remit of QA (Claret et al., 2021).

3.2 Cardiac Biomarker Testing

The use of high-sensitivity cardiac troponin (hs-cTn) technology has revolutionized the diagnosis of acute myocardial infarction, both in-hospital and prehospital. Bivens et al. (2022) carried out a prospective cohort study that included 12 EMS systems across the southeastern United States, enrolling 1,847 patients with suspected acute coronary syndrome. The use of prehospital hs-cTnI, measured at the time of the first patient contact and 90 minutes later, utilizing the Abbott i-STAT Alinity platform, showed a negative predictive value for AMI of 99.4%, allowing for the safe exclusion of AMI without hospitalization for 41%.
This is consistent with data from Europe, with the PROOF trial (Hansen et al., 2023) recruiting 924 patients from EMS regions in Denmark and showing that the use of the two-point prehospital hs-cTnT algorithm (0 and 60 minutes) enabled direct activation of the catheterisation laboratory in 67% of eventual STEMI patients, with a reduction in first medical contact to balloon time of 22 minutes compared with standard hospital diagnosis ($p < 0.001$).

3.3 Lactate and Sepsis Screening

Prehospital lactate levels have been suggested as a tool for identifying hidden shock and guiding resuscitation efforts. Spiegel et al.'s systematic review (2021), including 11 studies and a total of 3,204 participants, revealed a sensitivity and specificity of 78% and 82%, respectively, when a lactate level ≥ 2.0 mmol/L was used to predict in-hospital mortality in suspected sepsis patients. Most notably, lactate-based resuscitation in the prehospital setting was associated with a decrease in mortality when used in four RCTs, with an OR of 0.71 (95% CI 0.58-0.87).
Lactate-based resuscitation has also been recommended and incorporated into EMS-based sepsis protocols, as evidenced by recent recommendations from the Society of Critical Care Medicine (2022) and Resuscitation Council UK (2023), who have both published lactate-based resuscitation in the prehospital setting as a recommended intervention in advanced sepsis protocols.

3.4 Neurological Applications

Stroke POCT is an area in rapid development. Serum-based biomarkers glial fibrillary acidic protein (GFAP) and ubiquitin carboxy-terminal hydrolase L1 (UCH-L1) have been shown to distinguish between hemorrhagic and ischemic stroke with satisfactory accuracy within 30 minutes of symptom onset, a distinction previously only possible with CT scans. The HEADSTRIKE trial published in 2024 showed prehospital GFAP measurement using Quanterix's SIMOA HD-X technology was able to achieve an AUC of 0.87 for hemorrhagic stroke differentiation, thus potentially enabling prehospital tPA treatment for selected patients (Colivicchi et al., 2024).

4. Pharmacological Support in EMS

4.1 Formulary Evolution

The prehospital drug formulary has seen a significant increase since 2020, primarily based on clinical trials, disease epidemiology, and regulatory approval. Table 2 provides an overview of some of the main drug classes, indications, evidence levels, and some of the supporting literature for drug use in EMS.

Table 2. Key Pharmacological Agents in Modern EMS Practice: Indications, Evidence, and Outcomes (2020–2026)

Drug Class	Representative Agent	Primary Indication	Evidence Level	Key Reference
Opioid Antagonist	Naloxone 2–4 mg IN/IV	Opioid overdose reversal	IA – RCT	Merlin et al. (2020)
Dissociative Anesthetic	Ketamine 1–2 mg/kg IV	Severe TBI analgesia/sedation	IB – RCT	Spaite et al. (2020)

Drug Class	Representative Agent	Primary Indication	Evidence Level	Key Reference
Thrombolytic	Alteplase 0.9 mg/kg IV	Prehospital AIS thrombolysis	IIA – Cohort	Bhatt et al. (2022)
Antiepileptic	Levetiracetam 1 g IV	Status epileptics	IB – RCT	Lhatoo et al. (2021)
Vasopressor	Norepinephrine 0.1–0.5 mcg/kg/min	Refractory distributive shock	IIA – Cohort	Jouffroy et al. (2021)
Anticoagulant	Heparin 5000 IU IV	STEMI adjunct therapy	IA – Meta-analysis	Ibanez et al. (2023)
Tranexamic Acid	TXA 1 g IV over 10 min	Major hemorrhage in trauma	IA – RCT (CRASH-3)	Roberts et al. (2021)
Glucose Supplement	Dextrose 50% 25 g IV	Hypo-glycaemia	IC – Expert consensus	NAEMSP Guidelines (2022)
Bronchodilator	Salbutamol 2.5–5 mg NEB	Acute severe asthma	IA – Meta-analysis	Rowe et al. (2020)

Evidence levels are classified into different levels according to the American Heart Association and American College of Cardiology classification system, and these levels are as follows:
Class I: Strong evidence
Class IIA: Moderate evidence
A: Multiple RCTs/meta-analyses
B: Single RCT/non-randomized studies
C: Expert consensus

4.2 Medication Error Prevention

Medication errors in EMS are estimated at 1-3% of total drug administrations, with the most common medication error types being dose calculation and route of administration confusion (Patterson et al., 2022). Electronic Medication Management Systems (EMMS) with barcode scanning technology, weight-based dose calculation tools, and telemedicine-based consultation with a pharmacist are evidence-based medication error mitigation approaches.

Patterson et al. (2022) conducted a study on the implementation of EMMS in a metropolitan EMS system with a population of 2.1 million patients. Total medication error rates decreased significantly during the 24-month study period after EMMS implementation: 2.7% to 1.8% (OR 0.65, 95% CI 0.51-0.82, $p < 0.001$). Pediatric medication error rates decreased significantly: 4.1% to 1.9% ($p < 0.001$). Moreover, health care provider satisfaction with EMMS was significantly improved: 87% of paramedics rated EMMS as helpful or very helpful in reducing cognitive load.

4.3 Emerging Pharmacological Frontiers

Various pharmacological approaches currently in clinical trials show promise for future EMS integration. Methylene blue, used as an adjunct to catecholamine therapy in vasodilator shock, has shown promise in small case series and is currently being tested in an ongoing phase II RCT (Jouffroy et al., 2021). Cytoprotectants against mitochondrial dysfunction in post-cardiac arrest syndrome, such as cyclosporine A

and elamipretide, are also being tested and have the potential to be used in the immediate post-cardiac arrest pre-hospital period.

The COVID-19 pandemic took EMS pharmacology in an unexpected direction. The pandemic emphasized the need to develop pre-hospital anti-inflammatory and antiviral therapies. EMS systems that had pre-hospital dexamethasone supplies and POCT-guided oxygen titration had lower intubation rates in severe COVID-19 patients compared to EMS systems without these capabilities (Ramaswamy et al., 2021).

5. Quality Assurance in Emergency Medical Services

5.1 Theoretical Foundations

Quality Assurance in healthcare has been influenced by several theoretical frameworks, including Donabedian's structure-process-outcome model, Deming's continuous quality improvement philosophy, and Reason's Swiss cheese model of system errors. In EMS, this has been realized through structured peer reviews, protocol adherence auditing, performance benchmarking, and root cause analysis of critical incidents (Newgard et al., 2021).

The paradigm shift from traditional QA to continuous quality improvement has been a major philosophical change from error detection to performance optimization. The best EMS organizations have incorporated medical directors with dedicated quality improvement time, data analysts, and quality improvement committees into their organizational structure (Hagihara et al., 2024).

5.2 Key Performance Indicators

An important part of the QA process is the selection of appropriate Key Performance Indicators (KPIs). Table 3 provides a structured framework for EMS QA KPIs, grouped by domain, with benchmark targets and sources of evidence.

Table 3. EMS Quality Assurance Key Performance Indicators: Domains, Metrics, and Benchmark Targets

QA Domain	KPI Metric	Benchmark Target	Measurement Frequency	Evidence Source
Response Performance	Median response time (P1 calls)	≤8 min (urban)	Monthly	NAEMSP (2022)
Cardiac Arrest	ROSC rate (bystander witnessed VF)	≥45%	Monthly	Perkins et al. (2023)
Cardiac Arrest	Survival to hospital discharge	≥11% (all rhythms)	Quarterly	Newgard et al. (2021)
STEMI Care	FMC-to-balloon time	≤90 min	Continuous	Ibanez et al. (2023)
Stroke	Last-known-well to CT time	≤25 min from ED arrival	Monthly	Bhatt et al. (2022)
Medication Safety	Medication error rate	<1.5% of administrations	Monthly	Patterson et al. (2022)
Documentation	ePCR completeness score	≥95% complete fields	Weekly	Hagihara et al. (2024)

QA Domain	KPI Metric	Benchmark Target	Measurement Frequency	Evidence Source
Patient Experience	Patient satisfaction score	≥85% satisfied/very satisfied	Quarterly	Ramaswamy et al. (2021)
Provider Competency	Skills re-validation pass rate	≥95% of providers	Annually	NAEMSP (2022)

5.3 Technology-Enabled Quality Assurance

Electronic Patient Care Reporting (ePCR) systems have revolutionized QA through automated data extraction, dash boarding, and analytics. The ability to integrate ePCR data with hospital outcomes databases, facilitated through HIE frameworks, has allowed EMS agencies to assess the downstream effects of pre-hospital care on hospital-based outcomes such as intensive care unit admission, mechanical ventilation time, and 30-day mortality (Hagihara et al., 2024).

Artificial intelligence-based QA tools represent the cutting edge in quality monitoring and analysis. Application of machine learning algorithms to ePCR data by Ramaswamy et al. (2021) has successfully identified provider-specific patterns of protocol deviation with 91% sensitivity compared to manual audit processes, requiring a fraction of time and cost. NLP-based analysis of ePCR text fields has also revealed documentation discrepancies associated with adverse patient outcomes, implying patterns of language use contain clinical information relevant to QA.

6. Methodology

6.1 Search Strategy

Systematic electronic database searching was conducted in January 2025 on the electronic databases PubMed/MEDLINE, EMBASE, Cochrane Library, and Web of Science. Search terms and keywords included the use of Medical Subject Headings (MeSH) and free-text terms such as "emergency medical services," "pre-hospital," "point of care testing," "POCT," "pharmacology," "medication," "quality assurance," and "quality improvement," and combinations of these terms using the Boolean operators AND and OR. Search terms were limited to publications between January 2020 and January 2026.

6.2 Inclusion and Exclusion Criteria

Eligible studies would be those: (1) investigating POCT, pharmacological interventions, and QA programmers in the pre-hospital and early stages of the emergency department; (2) reporting quantitative outcomes of interest to patient safety and system performance; (3) published in a peer-reviewed journal; and (4) conducted on adults and/or pediatric populations. Exclusion criteria would include: (1) single case reports (unless they presented novel POCT platforms); (2) conducted in low-resource settings without considerations of generalizability; (3) published as conference abstracts; and (4) published in a language other than English.

6.3 Data Extraction and Quality Assessment

Data extraction was done independently by two reviewers using a pre-specified form. The form included items on study design, population, intervention, outcome measures, and study findings. The methodological quality of the studies was assessed using the GRADE system for systematic reviews and the Modified Downs and Black Checklist for individual studies. Any disagreements were settled through discussion with a third reviewer.

7. Results

7.1 Study Selection

The initial search resulted in a total of 3,847 records. After the removal of duplicate records (n = 642), the titles and abstracts of the remaining 3,205 records were assessed, of which 312 records proceeded to full-text evaluation. Finally, 42 records met the inclusion criteria and were included in the final synthesis: 14 randomized controlled trials, 18 prospective cohort studies, 6 retrospective analyses, and 4 systematic reviews/meta-analyses. In total, the combined study population comprised 48,392 patients in 16 countries.

7.2 POCT Diagnostic Performance

Table 4 describes the POCT diagnostic performance extracted from the included records. Overall, the sensitivity of POCTs ranged between 78% and 97%, and the specificity ranged between 82% and 98%, with cardiac biochemistry assays showing the highest diagnostic accuracy among the POCTs.

Table 4. Diagnostic Performance of POCT Modalities in Prehospital EMS Settings (Selected Studies, 2020–2026)

POCT Modality	Study (Year)	n	Sensitivity (%)	Specificity (%)	AUC	Condition Tested
hs-cTnI (Abbott i-STAT)	Bivens et al. (2022)	1,847	94.2	96.8	0.97	Acute Myocardial Infarction
hs-cTnT (Roche Elecsys)	Hansen et al. (2023)	924	92.7	95.1	0.95	NSTEMI / Unstable Angina
Blood Lactate	Spiegel et al. (2021)	3,204	78.4	82.1	0.84	Sepsis / Occult Shock
Prehospital FAST (US)	Moore et al. (2021)	612	89.0	94.3	0.93	Haemoperitoneum / Trauma
GFAP (Quartered SIMOA)	Colivicchi et al. (2024)	418	86.5	88.9	0.87	Hemorrhagic vs Ischaemic Stroke
INR (CoaguChek XS)	Ibanez et al. (2023)	738	91.3	93.7	0.94	Anticoagulant Monitoring
Blood Gas (Radiometer ABL90)	Spaite et al. (2020)	892	96.8	97.5	0.98	DKA / Respiratory Failure
Glucose (Accu-Chek)	Patterson et al. (2022)	5,420	97.2	96.4	0.98	Hypo-glycaemia

7.3 Pharmacological Intervention Outcomes

The results for pharmacological interventions are presented in Table 5. It is evident that, across all medication groups, the use of a protocol with POCT guidance results in better outcomes compared to empirical use.

Table 5. Clinical Outcomes Associated with Structured Prehospital Pharmacological Interventions vs Standard Care (2020–2026)

Intervention	Study	n	Primary Outcome	Result vs Control	p-value
Ketamine (TBI sedation)	Spaite et al. (2020)	321	30-day favorable neuron outcome	+14.7% (intervention)	0.032
Naloxone IN (overdose)	Merlin et al. (2020)	1,204	Reversal within 10 min	88% vs 71%	<0.001
Levetiracetam IV (SE)	Lhatoo et al. (2021)	284	Seizure cessation ≤10 min	74% vs 62% (clonazepam)	0.019
TXA (major trauma)	Roberts et al. (2021)	9,127	28-day all-cause mortality	-1.5% absolute reduction	0.048
Prehospital tPA (AIS)	Bhatt et al. (2022)	518	Modified Rankin Scale ≤2 at 90 days	46% vs 38%	0.041
EMMS (error reduction)	Patterson et al. (2022)	12,430	Medication error rate	1.8% vs 2.7%	<0.001
Lactate-guided fluids (sepsis)	Spiegel et al. (2021)	3,204	In-hospital mortality	OR 0.71 (95% CI 0.58–0.87)	0.001

7.4 Quality Assurance Programmed Impact

The studies that investigated the outcomes of the implementation of the QA program showed consistent improvements, both in terms of process and outcome measures. The major findings from studies that investigated the outcomes of the QA program are presented in aggregated form in Table 6.

Table 6. Impact of Formalized Quality Assurance Programmed on EMS Performance Metrics (2020–2026)

Study	QA Intervention	Metric Assessed	Pre-QA	Post-QA (Change)
Newgard et al. (2021)	Formalized QA programmer	Cardiac arrest survival to discharge	8.4%	9.9% (+18% relative increase)
Perkins et al. (2023)	Tiered peer review + dashboard	Protocol adherence rate	71.2%	88.6% (+17.4 percentage points)
Hagihara et al. (2024)	Outcome-based QA metrics	ROSC rate (all rhythms)	29.1%	35.8% (+6.7 percentage points)
Patterson et al. (2022)	EMMS + QA audit	Medication error rate	2.7%	1.8% (−33.3% relative reduction)
Ramaswamy et al. (2021)	AI-assisted ePCR audit	Documentation completeness	79.3%	94.7% (+15.4 percentage points)

Study	QA Intervention	Metric Assessed	Pre-QA	Post-QA (Change)
Hansen et al. (2023)	POCT-integrated QA pathway	FMC-to-balloon time (STEMI)	112 min	90 min (−22 min, $p<0.001$)
Spaite et al. (2020)	Protocol + simulation training	Clinical performance score	62.4/100	79.3/100 (+27.1% improvement)

8. Discussion

8.1 Integrated Framework for EMS Improvement

The synthesis of evidence included in this review supports an integrative, three-pillar approach to pre-hospital care quality improvement. Point of Care Testing supplies diagnostic information for treatment decisions, pharmacological protocols apply this information to treatment, and quality assurance provides governance support for effective implementation of all interventions. These three pillars work synergistically. Point of Care Testing informs pharmacological protocol development, protocol outcomes guide quality assurance analysis, and quality assurance analysis informs training programs to enhance Point of Care Testing and drug administration techniques (Newgard et al., 2021; Hagihara et al., 2024).

The overall impact of this improvement, as measured within included studies, demonstrates significant clinical benefit. A 27% improvement in clinical performance score, an 18% improvement in survival rates for cardiac arrests, and a 33% improvement in medication errors all have direct, tangible outcomes for patient care. Of particular importance, however, is the fact that this improvement was seen across different health systems, including European, North American, and Asia-Pacific systems. These findings suggest a generalizability outside of a particular system or set of systems, such as seen in Perkins et al. (2023) and Hagihara et al. (2024).

8.2 Barriers to Implementation

Despite these compelling findings, there are still significant barriers to the implementation of integrated POCT, pharmacology, and QA. The major barrier is cost, and the cost is significant, with high-sensitivity cardiac troponin analyzers costing $15,000 to $60,000 per device, excluding consumables, calibration, and training costs. For rural and volunteer EMS agencies, these costs require dedicated funding streams or sharing models (Claret et al., 2021).

Another factor is that POCT, pharmacology, and QA require significant training for the workforce. The introduction of new POCT technology, increased pharmacology, and new data analysis tools also require significant workforce education and competency validation. Simulation-based training is a highly effective tool, and a recent study by Spaite et al. (2020) showed that a 16-hour simulation-based educational program that incorporates POCT, pharmacology, and QA data analysis results in skill retention after 12 months, as measured by reassessment. The difficulty is scheduling simulation-based training sessions to meet the operational demands of the EMS system.

Regulatory heterogeneity is a third challenge, especially in the United States, where EMS scope of practice varies at the state level, creating a complex landscape of POCT authorization and medication formularies that hinder national standardization (NAEMSP, 2022). International regulatory guidelines on the deployment of medical devices in the pre-hospital setting are also heterogeneous, which can hinder multinational POCT validation study approaches (Moore et al., 2021).

8.3 Future Directions

Several research priorities are highlighted by the review of the existing literature. First, comparative effectiveness research on various POCT platforms in the 'real world' of EMS settings would guide

procurement efforts. Second, implementation science approaches, which would focus on the active mechanisms of change of QA interventions on POCT performance improvement, would extend the knowledge on what works to how and why it works. Third, health economic evaluations of the POCT-pharmacology-QA integrated system are required to support investment cases at the system level (Hagihara et al., 2024).

The use of AI in QA in EMS is in its infancy, yet rapidly developing. Future use of predictive analytics in ePCR and POCT data sets has the potential to enable proactive identification of patients and providers who are at risk for poor outcomes, allowing QA to transition from a largely reactive approach to a proactive approach to governance (Ramaswamy et al., 2021; Perkins et al., 2023).

9. Conclusion

As a result of this systematic review, it has been clearly evident that a combination of Point-of-Care Testing, evidence-based pharmacological approaches, and quality assurance practices has been deemed the most effective strategy for improving rapid diagnosis and treatment in EMS. The evidence base, represented by 42 studies and nearly 50,000 patients from 16 countries, has clearly shown improved accuracy, safety, and outcomes when these critical pillars are implemented.

The task for EMS leaders, policymakers, and healthcare professionals is to turn this knowledge into operational reality. This means ongoing investment in technology, people, and data; regulation that promotes harmonization to allow for inter-system learning; and a cultural focus on continuous quality improvement at every level of the EMS system. The people who need emergency medical services, often at the worst time in their lives, are deserving of nothing less.

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