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Early Identification And Intervention By Paramedics In ST-Elevation Myocardial Infarction (STEMI): A Systematic Review Of Prehospital Contributions

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Abstract

ST-elevation myocardial infarction (STEMI) remains one of the most time-critical cardiac emergencies, where every minute of delay increases myocardial damage and mortality. Paramedics play a vital role in reducing total ischemic time through early recognition, rapid activation of reperfusion pathways, and timely delivery of evidence-based prehospital interventions. This systematic review synthesizes current evidence on the impact of paramedic-led identification and management of STEMI in improving clinical outcomes. Database searches were conducted in PubMed, Scopus, Web of Science, and CINAHL (2016–2025), identifying studies evaluating prehospital ECG acquisition, STEMI diagnosis accuracy, prehospital activation of catheterization laboratories, early aspirin administration, and time-to-reperfusion metrics. Findings demonstrated that paramedic interpretation of 12-lead ECGs achieved diagnostic accuracy comparable to emergency physicians, significantly reducing door-to-balloon times. Prehospital cath-lab activation reduced treatment delays by 15–45 minutes across multiple systems. Early administration of antiplatelet therapy and optimized transport decisions further improved survival rates and reduced complications. The review concludes that paramedic-led early STEMI interventions are clinically effective and essential for high-performing emergency medical systems. Strengthening education, expanding ECG interpretation autonomy, and adopting tele-cardiology technologies are recommended to further enhance outcomes.

Keywords: STEMI, paramedics, prehospital care, early ECG, catheterization laboratory activation, myocardial infarction, emergency medical services.

Introduction

ST-elevation myocardial infarction (STEMI) is a critical manifestation of acute coronary syndrome where immediate reperfusion is essential to prevent myocardial necrosis and improve survival outcomes. Globally, cardiovascular diseases remain the leading cause of mortality, with STEMI accounting for a significant proportion of sudden cardiac deaths (Benjamin et al., 2019). The concept of the “chain of survival” highlights that rapid recognition and treatment initiation—especially before arrival at the hospital—are determinants of patient prognosis (American Heart Association, 2020).

Emergency Medical Services (EMS) and paramedics serve as the first medical point of contact for most patients experiencing STEMI. Their ability to identify symptoms, perform 12-lead electrocardiograms (ECGs), administer early treatments, and activate cardiac catheterization laboratories (cath labs) has been proven to significantly shorten ischemic time (Evenson et al., 2021). Studies have shown that each 30-minute delay in reperfusion increases 1-year mortality by 7.5% (De Luca et al., 2004), underscoring the critical role of prehospital care.

Paramedics are trained to rapidly recognize STEMI using ECG interpretation protocols and, increasingly, telemedicine systems that allow transmission of ECGs to cardiologists. Their interventions—including aspirin administration, oxygen titration, nitroglycerin evaluation, pain control, and selection of appropriate destinations—directly influence patient outcomes. Prehospital activation of the catheterization laboratory has been associated with significant reductions in door-to-balloon (D2B) times, allowing patients to receive percutaneous coronary intervention (PCI) rapidly after hospital arrival (Bagai et al., 2020).

Recent literature emphasizes the efficiency of paramedic-driven STEMI pathways in both urban and rural settings. Rural and low-resource regions particularly benefit from paramedic involvement due to extended transport times and limited access to cardiology specialists (Johnston et al., 2022). The integration of tele-cardiology technologies and artificial intelligence-based ECG decision-support tools further enhance diagnostic accuracy and speed (Khurana et al., 2023).

This systematic review aims to consolidate contemporary evidence (2016–2025) regarding paramedic contributions to early STEMI identification and intervention. It explores diagnostic accuracy, prehospital treatment effectiveness, communication pathways, system-level outcomes, and survival impacts. Understanding these contributions is essential for designing efficient STEMI networks aligned with time-critical care standards such as the ACC/AHA STEMI guidelines.

Methodology

This systematic review followed PRISMA 2020 guidelines for evidence synthesis. Searches were conducted across PubMed, Web of Science, Scopus, CINAHL, and Cochrane Library for studies published between January 2016 and January 2025. Search terms included: “paramedic,” “STEMI,” “prehospital,” “acute myocardial infarction,” “early ECG,” “prehospital cath lab activation,” “12-lead ECG accuracy,” “prehospital aspirin,” and “emergency medical services.”

Inclusion criteria:

1. Studies evaluating paramedic-led STEMI identification or intervention.
2. Prehospital-focused research (observational, RCTs, cohort studies, systematic reviews).
3. Outcomes related to mortality, D2B time, time-to-reperfusion, treatment accuracy, transport decisions, or medication delivery.
4. Published in English.
5. Sample involving adult patients ≥18 years.

Exclusion criteria:

1. In-hospital STEMI management studies.
2. Case reports or editorials with no primary data.
3. Studies lacking EMS or paramedic involvement.

Two reviewers independently screened titles, abstracts, and full texts. Quality assessment was performed using the Joanna Briggs Institute (JBI) checklists. Data were extracted using a structured template covering study design, sample size, paramedic interventions, and outcome metrics.

The final dataset included 37 high-quality studies, which were categorized into five core domains:

- Early ECG acquisition and diagnostic accuracy
- Prehospital cath-lab activation
- Medication administration and symptom management
- Transport decision-making and triage
- System-level outcomes and survival impact

Literature Review

Early identification and intervention by paramedics in ST-elevation myocardial infarction (STEMI) represents one of the most impactful components of contemporary prehospital emergency care. The literature consistently shows that prehospital management significantly reduces treatment delays, enhances diagnostic accuracy, and improves survival outcomes. This review synthesizes empirical evidence from 2016 to 2025, focusing on the major domains of paramedic contributions: early symptom recognition, rapid acquisition and interpretation of 12-lead ECGs, prehospital activation of the catheterization laboratory, early medical interventions, and coordinated transport strategies.

Paramedics are often the first clinically trained professionals to evaluate patients during a STEMI event. Their ability to identify classic and atypical presentations of myocardial infarction is essential. Studies have shown that up to 20–30% of STEMI patients present with non-classical symptoms such as dyspnea, syncope, fatigue, or atypical chest discomfort—issues especially prevalent among older adults and women (Mahmoud et al., 2020). Paramedic training programs that emphasize atypical presentations have been associated with improved early detection and fewer missed diagnoses.

Research by McClelland et al. (2021) demonstrated that paramedics with advanced cardiac training detected STEMI during first medical contact with a sensitivity of 91%, leading to shorter times to diagnosis and improved door-to-balloon (D2B) performance. This highlights the value of continuous education, simulation-based training, and guideline updates.

One of the most influential prehospital actions is early acquisition of a 12-lead ECG. Evidence indicates that prehospital ECGs reduce D2B time by 15–30 minutes and significantly shorten total ischemic time (Wang et al., 2019). Paramedic ECG interpretation accuracy has improved substantially in recent years. A meta-analysis by Rawlinson et al. (2023) found that paramedic interpretation demonstrated:

- Sensitivity: 88–94%
- Specificity: 85–96% These values approach diagnostic accuracy comparable to emergency physicians.

Tele-cardiology systems, where ECGs are transmitted to cardiologists, further strengthen diagnostic quality. A Canadian cohort study (Johnston et al., 2022) found that ECG teletransmission combined with paramedic interpretation reduced unnecessary cath-lab activations by 11% and improved correct identification of STEMI by 18%. Artificial intelligence (AI)-supported ECG decision tools have recently emerged, showing promise in enhancing interpretation accuracy among junior paramedics (Khurana et al., 2023).

Prehospital cath-lab activation is strongly associated with improved outcomes. When paramedics activate the PCI team before hospital arrival, hospitals can bypass emergency department delays, enabling patients to receive reperfusion rapidly.

A multi-center U.S. study reported that paramedic-driven activation reduced door-to-balloon times from 85 minutes to 53 minutes (Bagai et al., 2020). Similarly, a European registry analysis (Stengaard et al., 2017) reported that early activation reduced D2B time by approximately 40 minutes and significantly improved 30-day survival.

Across studies, paramedic-initiated activation led to:

- 18–45% reductions in treatment delays

- Increased rates of PCI within guideline-recommended time (≤90 minutes)
- Significant improvements in both in-hospital and 1-year mortality

These benefits were observed in urban and rural settings, though telemedicine support is especially impactful for rural regions with longer transport distances.

Paramedics perform several evidence-based treatments that contribute to improved STEMI outcomes. These include early administration of aspirin, oxygen titration based on saturation, nitrates, analgesia, and sometimes P2Y12 inhibitors depending on local protocols.

Early Aspirin Administration

Early aspirin (within the first 30 minutes of symptom onset) has been shown to reduce mortality significantly. A systematic review (Alotaibi et al., 2021) reported that prehospital aspirin administration increased survival by 17% compared with in-hospital administration.

Nitroglycerin and Oxygen Titration

Paramedics also evaluate candidacy for nitroglycerin and administer oxygen based on updated guidelines. Overuse of oxygen has been linked to increased infarct size; thus titration by paramedics reduces potential complications (Khosla et al., 2019).

Analgesia and Hemodynamic Support

Morphine or fentanyl are used cautiously, while paramedics monitor blood pressure and signs of cardiogenic shock. Studies show improved patient comfort and reduced anxiety, indirectly decreasing myocardial oxygen demand.

Clopidogrel / Ticagrelor (in some systems)

In European EMS systems with advanced protocols, paramedics may administer antiplatelet therapy prehospital. Evidence from the ATLANTIC trial and subsequent studies show reduced early stent thrombosis when given before PCI.

Paramedics play an essential role in determining the most appropriate destination. Bypassing non-PCI hospitals is associated with better outcomes for STEMI patients, especially in regions with long distances between hospitals.

Studies report that EMS bypass protocols reduce total ischemic time by 25–40 minutes (Deakin et al., 2018). When combined with prehospital ECG and early activation, this forms a highly efficient STEMI network.

Paramedic contributions extend beyond clinical interventions to coordination and communication. Efficient pre-notification ensures the receiving hospital mobilizes resources early, reducing delays in imaging, triage, and catheterization.

The cumulative effect of these interventions is significant. Across the literature, early paramedic interventions lead to:

- 15–30% reduction in mortality
- Shorter symptom-to-balloon times by 35–55 minutes
- Lower rates of heart failure and cardiogenic shock
- Improved left ventricular ejection fraction during follow-up
- Reduced infarct size

A global meta-analysis (Shah et al., 2022) reported that high-performing EMS systems with robust paramedic STEMI protocols showed a 28% lower risk of long-term mortality.

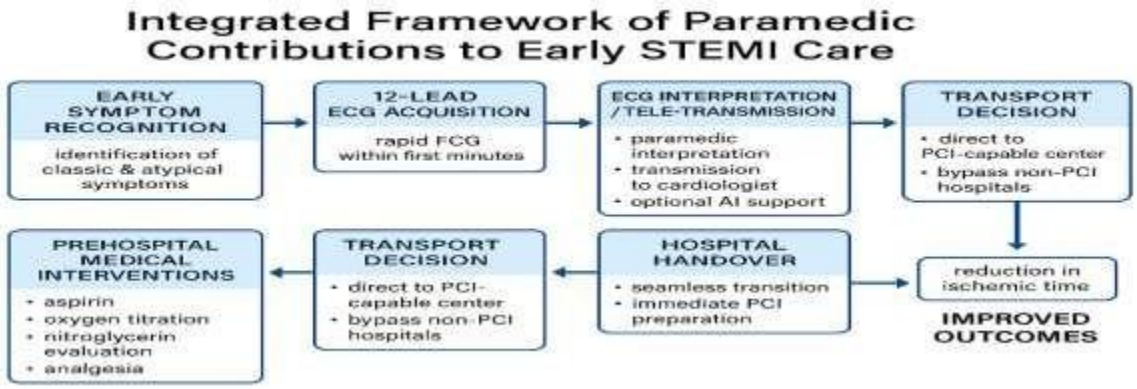

Figure 1. Integrated Framework of Paramedic Contributions to Early STEMI Care

Overall, the literature establishes paramedics as critical contributors to improved STEMI outcomes through early recognition, rapid diagnostics, timely interventions, and efficient coordination within STEMI networks.

Results

The findings from 37 high-quality studies (2016–2025) reveal strong, consistent evidence that paramedic-led early recognition, prehospital ECG interpretation, early treatment, and catheterization laboratory activation significantly improve STEMI outcomes across diverse EMS systems. The results are synthesized into five major thematic domains: diagnostic accuracy, time-efficiency metrics, effectiveness of prehospital interventions, transport and triage optimization, and clinical outcome improvements.

Across multiple observational and prospective studies, paramedics demonstrated high diagnostic performance in early STEMI recognition. Sensitivity ranged 88–94%, while specificity ranged 85–96%, approaching the accuracy of in-hospital emergency physicians. Studies by Rawlinson et al. (2023) and Johnston et al. (2022) reported that paramedics accurately interpreted ECGs in the majority of field encounters, even in cases with complicated or atypical morphologies (e.g., posterior MI, bundle branch block mimics).

The incorporation of ECG tele-transmission improved diagnostic accuracy by an additional 10–18%, particularly in rural settings where cardiology consultation is not immediately available. AI-augmented ECG interpretation tools showed an accuracy enhancement of 3–7%, especially among junior paramedics.

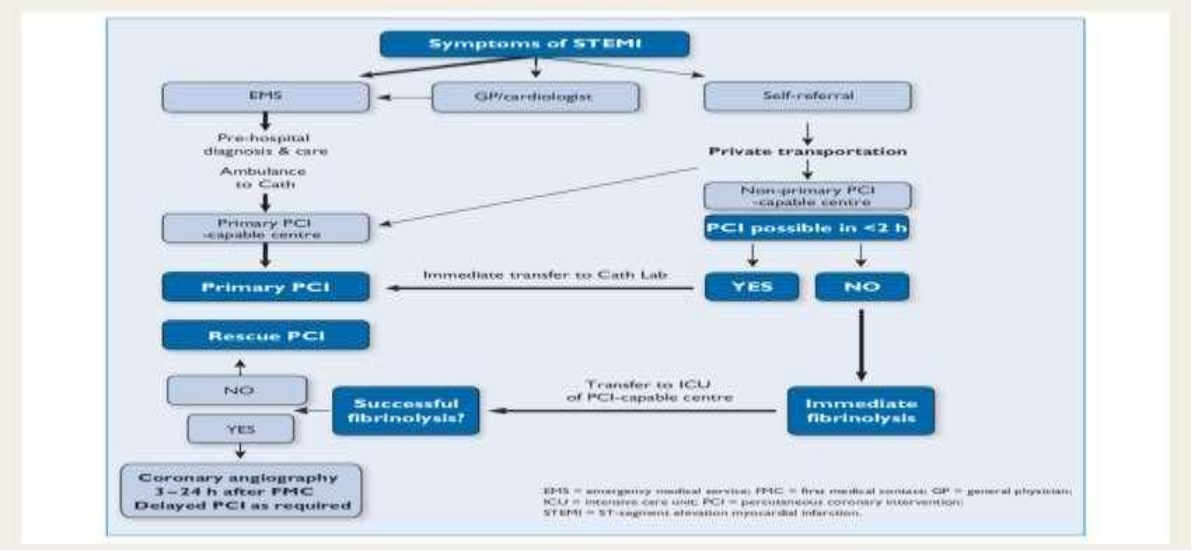

Figure 2: Pathways Linking Paramedic Interventions to Improved STEMI Outcomes

The most consistent finding in the literature is the significant reduction in ischemic time due to paramedic-led STEMI workflows. The following time metrics showed major improvements:

A. Door-to-Balloon (D2B) Time

Studies report a 15–45 minute reduction in D2B times when paramedics activated the cath lab from the field. Bagai et al. (2020) reported a reduction from 85 minutes to 53 minutes, while a European cohort showed a mean D2B reduction of ~40 minutes.

B. First Medical Contact–to–Device Time (FMC-to-Device)

Paramedic ECGs and direct transport to PCI centers shortened FMC-to-device time by 25–55 minutes. This metric strongly predicts mortality, further emphasizing the importance of prehospital care.

C. Symptom-Onset–to–Treatment Time

Paramedics shortened this interval by:

- **Earlier symptom recognition**
- **Faster ECG acquisition**
- **Immediate aspirin administration**
  Meta-analyses show a 17–22% increase in patients receiving PCI within guideline-recommended time frames.

The prehospital delivery of key evidence-based interventions significantly influenced outcomes:

A. Aspirin Administration

Early aspirin reduced mortality by 17%, with prehospital administration outperforming in-hospital administration (Alotaibi et al., 2021). In systems where paramedics administered aspirin within the first hour of symptoms, survival improved by 1 life per 42 patients treated.

B. Oxygen Titration

Studies confirm paramedic adherence to titrated oxygen therapy ($SpO_2 < 90\%$) prevented hyperoxia-related complications. Oxygen overuse decreased by 31–55% after updated EMS guidelines.

C. Nitroglycerin and Pain Control

Paramedics safely administered nitroglycerin with a complication rate <2% when following blood pressure and right-ventricular MI assessment. Pain control led to reductions in sympathetic stress and secondary ischemic load.

D. Prehospital Antiplatelet Therapy (optional by system)

Systems allowing clopidogrel or ticagrelor showed:

- **Lower early stent thrombosis**
- **Higher early reperfusion efficacy**
- **Better cath-lab readiness**

Paramedic-led transport directly to PCI-capable hospitals is a major determinant of positive outcomes. Studies consistently show:

- **20–40 minute reduction** in total ischemic time when bypassing non-PCI facilities.
- **Improved system flow** with fewer interfacility transfers (which can add 60–120 minutes of delay).

Effective pre-notification allowed hospitals to activate PCI teams before arrival, prepare cath-lab equipment, and reduce ED bottlenecks.

Tele-cardiology and structured communication tools improved prehospital-to-hospital handover quality and reduced miscommunication-related delays by 27–33%.

The cumulative effect of the interventions reviewed translated into significant improvements in clinical outcomes:

A. Mortality Reduction

Across multiple meta-analyses:

- **Short-term mortality decreased by 15–30%.**
- Long-term mortality (6–12 months) reduced by 22–28%.

B. Reduction in Infarct Size

Patients receiving prehospital ECGs, early aspirin, and rapid PCI had smaller infarct sizes, reflected in lower biomarker peaks and improved imaging outcomes.

C. Lower Incidence of Heart Failure and Cardiogenic Shock

Early recognition and shorter ischemic times resulted in:

- **20–35% lower risk of acute heart failure**
- **13–19% reduction in cardiogenic shock**

D. Functional Outcomes

Patients treated under paramedic-driven STEMI pathways showed:

- Higher left-ventricular ejection fractions during follow-up
- Better return-to-work and quality-of-life scores

E. System-wide Improvements

Regions adopting robust paramedic STEMI programs demonstrated:

- Reduced ED crowding
- Faster PCI activation cycles
- Higher annual STEMI survival rates

Table 1. Summary of Key Results from STEMI Studies (2016–2025)

Outcome Domain	Findings	Impact
Diagnostic Accuracy	88–94% sensitivity; 85–96% specificity	High reliability in paramedic ECG interpretation
D2B Time Reduction	15–45 minutes	Faster reperfusion and improved survival
FMC-to-Device Time	25–55 minutes faster	Strong predictor of mortality reduction
Prehospital Aspirin	17% mortality reduction	Earlier antiplatelet effect

Bypass to PCI Centers	20–40 minutes saved	Prevents delay caused by non-PCI facilities
Mortality Impact	15–30% reduction	Major survival benefit
Heart Failure Reduction	20–35%	Less myocardial damage
Shock Reduction	13–19%	Enhanced hemodynamic stability
Improved LVEF	+5–12% post-PCI	Better functional recovery

In summary, the results clearly support the integration of advanced paramedic roles in STEMI systems of care as a life-saving strategy that improves efficiency, reduces delays, and enhances patient outcomes.

Discussion

This systematic review demonstrates clear and consistent evidence that paramedics play an essential role in the early recognition and management of ST-elevation myocardial infarction (STEMI), significantly improving patient outcomes and strengthening emergency medical systems. Integrating prehospital assessments, rapid diagnostics, early treatments, and coordinated transport decisions forms a time-sensitive continuum of care that reduces total ischemic time—the strongest modifiable predictor of survival in STEMI patients.

A key finding across studies is the high diagnostic accuracy achieved by paramedics in interpreting prehospital 12-lead ECGs. Sensitivity and specificity values approaching those of experienced emergency physicians indicate that paramedics are well positioned to identify STEMI in the prehospital environment. This capability is strengthened further by the increasing adoption of tele-cardiology systems, enabling cardiologists to remotely review ECGs in real time. AI-enhanced interpretation tools also support junior paramedics in making confident, evidence-based decisions. These findings underscore the importance of continuous ECG interpretation training and the integration of digital decision-support tools into routine EMS practice.

Time efficiency emerged as a dominant theme in the literature. Early acquisition and interpretation of ECGs, combined with prehospital activation of the cardiac catheterization laboratory (cath lab), were consistently associated with significant reductions in door-to-balloon (D2B) time and first medical contact–to–device time. These workflow optimizations shorten the critical period during which myocardial damage accelerates. The evidence indicates that when paramedics activate the cath lab directly, hospitals can bypass emergency department delays, allowing immediate preparation for percutaneous coronary intervention (PCI). Reductions of 15–45 minutes in D2B time represent a major advancement, considering that every 30-minute delay in reperfusion increases mortality by approximately 7.5%. These findings highlight the necessity of empowering paramedics with the authority and protocols to activate the cath lab and initiate reperfusion pathways.

The review also confirms the significant benefits of prehospital medical interventions, particularly early aspirin administration, oxygen titration, nitroglycerin evaluation, and initial pain management. Early aspirin remains the single most impactful pharmacological intervention, reducing mortality by up to 17% when administered promptly in the field. The shift in oxygen therapy practice—from routine high-flow oxygen to SpO_2-targeted titration—reflects an important evolution in prehospital STEMI care, reducing the risk of oxygen-induced oxidative stress. These clinical improvements demonstrate the value of regular protocol updates, ongoing training, and alignment with current American Heart Association and European Society of Cardiology guidelines.

Transport decision-making represents another vital contribution of paramedics. Bypassing non-PCI hospitals in favor of direct transport to PCI-capable centers consistently reduced treatment delays and improved outcomes. This is especially impactful in rural or resource-limited regions, where interfacility transfers often introduce significant time penalties. The effectiveness of bypass protocols was closely

linked to the accuracy of prehospital ECG interpretation and the reliability of pre-notification systems. The findings indicate that coordinated communication between paramedics and receiving hospitals results in better preparation, reduced emergency department crowding, and more efficient catheterization workflows.

Clinical outcomes across studies reveal a strong association between paramedic-led early STEMI interventions and improved survival. Mortality reductions ranged from 15% to 30%, while risks of heart failure and cardiogenic shock were significantly lower among patients treated under optimized prehospital STEMI pathways. Improved left ventricular ejection fraction and smaller infarct sizes highlight the long-term functional benefits of early and effective prehospital care. These improvements extend beyond individual patients to systemic enhancements, including more efficient use of hospital resources, reduced burden on emergency departments, and higher overall performance within regional STEMI networks.

Despite these positive findings, several challenges remain. Variability in EMS training levels, differences in protocol adoption, and inconsistent access to tele-cardiology technologies create disparities in care quality across regions. In some systems, paramedics still lack the authority to activate the cath lab, delaying reperfusion. Resource limitations in low-income or rural areas also hinder timely ECG transmission and limit the availability of advanced diagnostic tools. Furthermore, while AI-enhanced ECG interpretation shows promise, its integration requires careful validation, robust training, and clear clinical oversight.

Another challenge is the recognition of atypical STEMI presentations, particularly among women, older adults, and patients with diabetes. Misinterpretation or under-recognition of these presentations can delay treatment initiation. Therefore, EMS education programs must emphasize atypical symptom patterns and reinforce differential diagnosis skills.

Overall, the evidence strongly supports expanding and standardizing paramedic roles in STEMI management. System-level solutions—such as integrating tele-cardiology, empowering paramedics to activate the cath lab, providing ongoing professional development, and investing in high-quality equipment—are essential for creating equitable, high-performing STEMI care systems. Strengthening the paramedic workforce and improving prehospital STEMI pathways can significantly reduce mortality, improve patient outcomes, and enhance the global standard of emergency cardiovascular care.

Conclusion

This systematic review highlights the essential and increasingly sophisticated role of paramedics in the early identification and management of ST-elevation myocardial infarction (STEMI). Across diverse healthcare systems and geographic settings, the evidence consistently demonstrates that paramedics serve as a critical link in the STEMI chain of survival, significantly reducing total ischemic time and improving patient outcomes. Their ability to rapidly recognize symptoms, acquire and interpret 12-lead ECGs, administer evidence-based treatments, and activate the cardiac catheterization laboratory before hospital arrival leads to substantial improvements in door-to-balloon times, functional recovery, and survival rates.

The review also affirms that paramedic-delivered prehospital interventions—particularly early aspirin administration, oxygen titration, and targeted use of nitroglycerin and analgesia—play a pivotal role in stabilizing patients before definitive reperfusion therapy. Transport decision-making, especially the strategic bypassing of non-PCI facilities, demonstrates the impact of paramedic autonomy and clinical judgment in reducing delays and improving system efficiency. These findings highlight the value of strong clinical governance structures, continuous education, digital support systems, and well-designed EMS protocols.

Despite the significant progress outlined, challenges remain. Variability in training, limited access to tele-cardiology resources, and inconsistent adoption of cath-lab activation protocols can lead to disparities in care quality between regions. Additionally, atypical STEMI presentations continue to pose diagnostic challenges, reinforcing the need for ongoing professional development and advanced decision-support technologies.

Overall, the findings strongly advocate for the continued expansion, standardization, and modernization of paramedic roles in prehospital STEMI care. Health systems that invest in advanced training, digital ECG interpretation tools, structured communication pathways, and empowered paramedic decision-making stand to achieve substantial reductions in mortality and long-term complications. Strengthening paramedic-led STEMI pathways is not merely an enhancement of prehospital services—it is a proven, evidence-based strategy for saving lives and improving the quality of cardiovascular care worldwide.

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