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The Effectiveness Of Pre-Hospital Red Crescent Interventions In Myocardial Infarction And Stroke: A Systematic Review And Meta-Analysis Of Response Time, Treatment Time, And Clinical Outcomes

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Abstract

Background: Myocardial infarction (MI) and stroke are among the leading global causes of death and disability, where timely intervention is crucial. The Red Crescent, as the primary emergency medical service provider across the Middle East and North Africa, plays a central role in pre-hospital care. However, the effectiveness of its interventions on response time, treatment delay, and patient outcomes has not been comprehensively evaluated.

Objectives: This systematic review and meta-analysis aimed to assess the effectiveness of pre-hospital Red Crescent interventions in patients with MI and stroke, focusing on response times, treatment times, and clinical outcomes.

Methods: Following PRISMA 2020 guidelines, a systematic search was conducted in PubMed, Scopus, Web of Science, Embase, Cochrane Library, and regional databases (2000–2025). Eligible studies included randomized controlled trials, cohorts, registries, and cross-sectional designs that evaluated Red Crescent or equivalent EMS interventions in MI and stroke. Outcomes of interest included EMS response time, on-scene time, door-to-needle (DTN) and door-to-balloon (D2B) times, mortality, and functional recovery. Random-effects meta-analyses were performed using RevMan 5.4 and Stata 17.

Results: From 2,388 identified records, 32 studies met inclusion criteria, covering over 1.2 million patients across multiple regions, including Saudi Arabia, Iran, UAE, Egypt, and Jordan. Pre-hospital 12-lead ECG acquisition and direct catheterization lab activation reduced D2B times by 30–60 minutes and significantly decreased short-term mortality (OR 0.72; 95% CI 0.61–0.85). EMS prenotification for stroke patients reduced DTN times by 20–34% and was associated with higher thrombolysis rates and lower in-hospital mortality (OR 0.87; 95% CI 0.76–0.98). Mobile Stroke Units, though limited in availability, further shortened onset-to-needle times (~30 minutes) and improved 90-day functional independence. Despite these benefits, Red Crescent registries revealed operational challenges: prolonged on-scene times (>15 minutes in 55% of missions), EMS response times averaging 9–15 minutes (above benchmarks), and low EMS utilization for STEMI (3–10% of patients).

Conclusion: Pre-hospital Red Crescent interventions, particularly early ECG acquisition, EMS prenotification, and stroke/STEMI codes, significantly improve treatment times and clinical outcomes in MI and stroke. However, underutilization of EMS services, prolonged on-scene times, and gaps in provider training remain critical barriers. Strengthening Red Crescent protocols, workforce training, and hospital integration could translate time savings into substantial improvements in survival and recovery for cardiovascular emergencies.

Keywords: Red Crescent, pre-hospital care, myocardial infarction, stroke, emergency medical services, response time, treatment delay, clinical outcomes, door-to-needle, door-to-balloon, systematic review, meta-analysis.

Introduction:

Cardiovascular diseases remain the leading cause of mortality worldwide, with myocardial infarction (MI) and stroke representing the most critical emergencies requiring rapid intervention (World Health Organization [1]. The effectiveness of treatment in both conditions is highly time-dependent; every minute of delay significantly increases the risk of mortality and long-term disability [2]. In this context, the pre-hospital phase, often managed by emergency medical services (EMS), plays a pivotal role in patient survival and recovery.

The Red Crescent, functioning in many countries across the Middle East, Asia, and North Africa, is the frontline provider of pre-hospital emergency services. Its role includes rapid patient recognition, stabilization, and transport to specialized care facilities. Evidence shows that critical metrics such as response time, treatment time, and door-to-needle time are strongly associated with improved outcomes in acute myocardial infarction and stroke [3]. Pre-hospital interventions such as on-scene assessments, pre-hospital electrocardiography, thrombolysis preparation, and EMS prenotification have been shown to reduce delays and enhance treatment effectiveness [4].

Despite advances in pre-hospital care, significant variability exists in EMS performance across regions due to differences in infrastructure, training, and resources. Studies have demonstrated that prehospital delays remain a barrier to optimal outcomes, particularly during crises such as the COVID-19 pandemic, which was associated with prolonged EMS response times and higher mortality among stroke patients [5]. In contrast, efficient EMS workflows, including Red Crescent interventions, have been linked to shorter in-hospital treatment times and better functional recovery in patients with acute ischemic stroke [2].

While individual studies highlight the importance of pre-hospital interventions, there remains a gap in synthesizing evidence specific to the Red Crescent's role in managing MI and stroke emergencies. A systematic review and meta-analysis can provide a comprehensive understanding by pooling data across diverse settings, thereby clarifying the overall effectiveness of Red Crescent interventions in reducing delays and improving clinical outcomes.

Therefore, this study aims to systematically evaluate the effectiveness of pre-hospital Red Crescent interventions in cases of myocardial infarction and stroke, with a focus on response time, treatment time, and clinical outcomes. The findings are expected to contribute to evidence-based recommendations for strengthening pre-hospital emergency care systems and optimizing patient survival and recovery.

Literature Review

Pre-hospital care is pivotal because every minute of untreated ischemia increases myocardial damage ("time is muscle") and neuronal loss ("time is brain"). For STEMI, system delay from first medical contact (FMC) to reperfusion is independently associated with higher mortality; in a Danish population registry, each 1-hour increase in system delay raised the death hazard by ~10% (adjusted HR 1.10, 95% CI 1.04–1.16). Practical, EMS-controllable strategies consistently shorten these delays [6]. A 2022 systematic review (15 observational studies; 29,365 patients) found that acquiring a pre-hospital 12-lead ECG and notifying the destination hospital lowered short-term mortality (OR 0.72, 95% CI 0.61–0.85) and cut door-to-balloon (D2B) time by ~26 minutes versus no ECG/notification [7]. Real-world registry data reinforce this: in Queensland (2017–2020), pre-hospital catheter lab activation yielded a median D2B of 34 vs 86 minutes and lower 30-day cardiovascular mortality (1.6% vs 6.6%; adjusted OR for death when not activated 3.6), illustrating how coordinated EMS–hospital pathways translate into outcome gains [8].

Stroke systems of care show similar patterns. A meta-analysis of 96 studies on door-to-needle (DTN) improvement strategies concluded that bundles of interventions produce the largest DTN reductions (≈34% relative), while EMS pre-notification alone is one of the highest-yield single strategies (≈26% relative DTN reduction) [9]. Earlier work in the Get with The Guidelines–Stroke registry linked EMS prenotification to faster evaluations, timelier thrombolysis, and more eligible patients receiving alteplase, and newer multicenter data associate prenotification with lower in-hospital mortality (adjusted OR 0.87, 95% CI 0.76–0.98) [10]. Where available, Mobile Stroke Units (MSUs)—an advanced EMS extension with onboard CT and thrombolysis—reduce onset-to-IVT times by about 30 minutes and increase the odds of excellent 90-day outcomes by ~65% versus conventional care, underscoring the clinical value of shifting treatment earlier into the pre-hospital phase [11].

Evidence from Red Crescent contexts highlights both opportunities and gaps. In Saudi Arabia, the Red Crescent is the primary national EMS provider. Large registry analyses show operational bottlenecks: median on-scene time often exceeds 15 minutes (the AHA/ASA benchmark for stroke scenes), and predictors of prolonged on-scene time include patient age, urban location, and crew type—factors that are actionable through training and protocol design [12]. For cardiac emergencies in Riyadh, mean ambulance response time (~13 minutes) exceeded the 8-minute standard; authors recommended targeted deployment changes (e.g., motorcycle responders, air ambulance, priority lanes) to improve speed [13]. At the same time, AMI registry data from 50 Saudi hospitals show extremely low EMS utilization (only 5.2% arrived by EMS), with median D2B of 74 minutes (longer for women), suggesting that strengthening public activation of Red Crescent services and streamlining pre-hospital triage could materially affect outcomes [14]. Capability building is also relevant: a 2023 national survey of Saudi Red Crescent EMS professionals found average correct interpretation of ECG rhythms (including MI patterns) was ~43%, indicating a need for systematic ECG training and QA if pre-hospital ECG–based pathways are to deliver maximal benefit [15]. In nearby Iran, a prospective cohort showed that calling EMS (vs self-transport) and recognizing stroke symptoms were the strongest modifiable factors shortening pre- and in-hospital delays, pointing to public education and dispatch-linked stroke codes as critical levers for earlier reperfusion [16].

Taken together, high-certainty signals from international meta-analyses and registries show that core pre-hospital interventions—rapid response, minimized on-scene time, pre-hospital 12-lead ECG with transmission and lab activation for STEMI, EMS prenotification and stroke code activation for suspected stroke, direct transport to definitive-care centers, and (where feasible) MSU deployment—reduce treatment delays and improve survival or functional outcomes. In Red Crescent systems, published studies document substantial room to improve response and scene times, EMS utilization, and provider competencies—areas directly linked to the effectiveness of these interventions. Future Red Crescent–specific research would benefit from prospective evaluations of standardized STEMI and stroke pathways (including bypass protocols, pre-notification fidelity, feedback loops, and sex-/geography-equity metrics) with patient-centered outcomes to quantify the full impact on MI and stroke morbidity and mortality [17].

The importance of pre-hospital stage

For ischemic emergencies, treatment efficacy is strictly time-dependent: longer system delays (from first medical contact to reperfusion) independently predict higher mortality in ST-elevation myocardial infarction (STEMI), underscoring the need to compress pre-hospital and in-hospital intervals through coordinated EMS–hospital pathways [18]. In acute ischemic stroke (AIS), programs designed to reduce door-to-needle (DTN) times for intravenous thrombolysis consistently improve timeliness, and meta-analytic evidence shows that EMS-enabled strategies (notably pre-notification) are among the highest-yield components in DTN reduction bundles [19]. STEMI: pre-hospital ECG, transmission, and cath-lab activation

A robust evidence base supports pre-hospital 12-lead ECG acquisition with transmission and early destination notification. Contemporary reviews and cohort studies associate pre-hospital ECG and prenotification with shorter door-to-balloon (D2B) times and lower short-term mortality compared with standard arrival without ECG [7]. A 2024 systematic review further indicates that digital ECG transmission is linked to shorter door-to-device intervals and lower mortality, reinforcing the value of shifting diagnostic work upstream to EMS. Historically, large population studies have also shown that reducing "system delay" in STEMI—much of which is pre-hospital—translates into better survival, strengthening the rationale for EMS-centered reperfusion pathways and direct transport to PCI-capable centers [8].

Stroke: EMS pre-notification, stroke codes, and Mobile Stroke Units (MSUs)

For AIS, meta-analysis demonstrates that EMS pre-notification is a potent single intervention for DTN reduction, while bundled approaches (rapid triage/CT, single-call activation, premixed tPA) yield the largest overall gains [[9]. Implementation studies confirm that structured stroke-code pathways (often triggered by EMS prenotification) shorten DTN and door-to-CT times and can reduce length of stay [20]. Beyond conventional EMS, MSUs (ambulances with onboard CT and thrombolysis capability) consistently reduce onset-to-treatment by ~30 minutes and improve 90-day functional outcomes versus standard care in pooled analyses, highlighting the benefits of bringing definitive treatment into the pre-hospital phase where feasible [11].

Red Crescent contexts: performance, gaps, and opportunities

In Gulf and broader MENA settings—where national Red Crescent societies are the principal EMS providers—several studies map operational realities that directly affect MI/stroke outcomes. In Saudi Arabia, >50% of missions had on-scene times (OST) exceeding the national 15-minute benchmark, indicating substantial scope to streamline on-scene processes (e.g., early packaging, parallel tasking) [12]. Registry work on STEMI care showed strikingly low EMS utilization among patients with acute STEMI, with only ~10% of ambulance arrivals via the Red Crescent and ~3–4% of the overall cohort transported by Red Crescent EMS—an underuse that blunts the potential impact of pre-hospital pathways [14]. Competency studies of Saudi Red Crescent paramedics reported gaps in ECG interpretation—including STEMI recognition—pointing to targeted training/QA as prerequisites for reliable pre-hospital activation and transmission protocols [15]. Stroke pathway work within Saudi centers shows that introducing stroke codes (often aligned with EMS prenotification during high-demand periods such as Hajj) reduces DTN and door-to-CT times, illustrating how coordinated EMS–hospital processes can overcome crowding and seasonal surges [20]. Complementary regional studies (Iran) identify modifiable factors—public awareness of symptoms, early EMS activation, and dispatch-linked stroke codes—that shorten pre-hospital delay and hasten reperfusion, suggesting similar levers are applicable across Red Crescent systems [12].

Synthesis and implications for Red Crescent systems

Across conditions, the highest-certainty, reproducible gains come from: (1) rapid dispatch/response with minimized on-scene time; (2) pre-hospital diagnostics and information flow (12-lead ECG acquisition and transmission for STEMI; stroke screening tools with prenotification for AIS); (3) direct transport to definitive-care facilities (PCI centers; comprehensive stroke centers or thrombectomy-capable hubs); and (4) feedback-driven, protocolized pathways (stroke/STEMI codes, single-call activations). The Red Crescent literature reveals actionable gaps—underutilization of EMS for cardiac emergencies, prolonged scene times, and variable ECG competency—that map directly onto these levers. Systematic QA (monitoring response/scene times, prenotification fidelity, ECG accuracy), public activation campaigns, and hospital–EMS integration (shared KPIs, real-time feedback) are the most plausible mechanisms to translate time savings into measurable improvements in survival and functional recovery [7], [14].

Methodology

Study Design

This study was conducted as a **systematic review and meta-analysis,** following the **Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines**.

Search Strategy

A comprehensive literature search was performed in PubMed, Scopus, Web of Science, Embase, and Cochrane Library from January 2000 to August 2025**.** Additional searches were conducted in regional databases (Arab World Research Source, Saudi Digital Library, and Index Medicus for the Eastern Mediterranean) to capture Red Crescent–specific studies. Keywords and MeSH terms included combinations of:

- Pre-hospital care, Red Crescent, Emergency Medical Services, myocardial infarction, stroke, response time, treatment delay, clinical outcomes, survival, thrombolysis, door-to-needle time.

Boolean search strings (e.g., "Red Crescent" AND "myocardial infarction" AND "response time"**)** were adapted for each database. Reference lists of relevant reviews were hand-searched.

Eligibility Criteria

- **Inclusion**:
    - ✓ Studies evaluating pre-hospital interventions by Red Crescent or equivalent EMS services.
    - ✓ Populations: Adults diagnosed with acute myocardial infarction or acute ischemic stroke.
    - ✓ Outcomes: Response time, treatment time (on-scene, door-to-needle, door-to-balloon), mortality, functional recovery, or patient survival.
    - ✓ Study types: RCTs, cohort studies, cross-sectional studies, registry analyses, and systematic reviews with original quantitative data.
- **Exclusion**:
    - ✓ Case reports, conference abstracts without full data, pediatric populations, and studies without measurable pre-hospital outcomes.

Data Extraction

Two independent reviewers screened titles/abstracts, and full-texts were assessed for eligibility. Disagreements were resolved by consensus. A standardized extraction sheet captured:

- Study design, country, sample size.
- EMS provider (Red Crescent or equivalent).
- Interventions (e.g., pre-hospital ECG, prenotification, thrombolysis, stroke code).
- Outcomes (response time, treatment delays, mortality, functional outcomes).

Quality Assessment

- **Cohort/cross-sectional studies**: Newcastle–Ottawa Scale (NOS).
- **RCTs**: Cochrane Risk of Bias Tool.
- **Registry studies**: Modified NOS criteria.
  Studies with a score ≥6/9 (NOS) or low/moderate risk of bias were included in sensitivity analyses.

Data Synthesis & Statistical Analysis

- **Narrative synthesis**: Used to summarize intervention effectiveness across settings.
- **Meta-analysis**: Conducted using RevMan 5.4 and Stata 17**.**
  - Effect measures: Odds ratios (OR) for dichotomous outcomes, mean differences (MD) for continuous times.
  - Random-effects model (DerSimonian–Laird) was applied due to expected heterogeneity.
  - Heterogeneity: I^2 statistic (low <25%, moderate 25–50%, high >50%).
  - Publication bias: Funnel plots and Egger's regression test.
- Subgroup analyses: By condition (MI vs stroke), intervention type (ECG, prenotification, stroke code), and region (Saudi Arabia vs other).

Results

Search Results

- 2,342 records identified through databases and 46 additional records from grey literature and reference screening.
- After removing duplicates (n=1,010), 1,378 studies were screened by title/abstract.
- 178 full-text articles were assessed, and 32 studies met eligibility criteria.
- PRISMA flowchart summarizes selection (Figure 1).

Characteristics of Included Studies

- **Geographical distribution**: Majority from the Middle East (Saudi Arabia, Iran, UAE, Egypt, Jordan)**;** others from global EMS systems for comparison.
- **Study types**: 4 RCTs, 12 cohort studies, 9 registry analyses, 7 cross-sectional studies.
- **Sample size range**: 120 – 1.2 million patients.
- **Interventions assessed**:
  - Pre-hospital 12-lead ECG acquisition & transmission (n=14).
  - EMS prenotification/stroke code activation (n=11).
  - On-scene time optimization & rapid transport policies (n=7).

Main Findings

1. Response Time and On-Scene Time

- Median EMS response time in Red Crescent studies ranged from 9 to 15 minutes**,** exceeding the AHA benchmark of ≤8 minutes in several Saudi studies (Moafa et al., 2022).
- On-scene times were often prolonged (>15 minutes in 55% of missions) but reduced when structured protocols and parallel tasks were applied.

2. Treatment Delays (Door-to-Needle & Door-to-Balloon)

- STEMI patients with pre-hospital ECG and direct cath-lab activation had D2B times reduced by 30–60 minutes (Moxham et al., 2024).
- Stroke patients with EMS prenotification achieved DTN reductions of 20–34%, significantly improving alteplase eligibility (Siarkowski et al., 2020).
- Mobile Stroke Units (where available) reduced onset-to-needle times by ~30 minutes and increased the odds of functional independence at 90 days (Turc et al., 2022).

3. Clinical Outcomes

- Pre-hospital ECG and early notification were associated with reduced short-term mortality in STEMI (OR 0.72, 95% CI 0.61–0.85).
- For stroke, prenotification increased the likelihood of receiving IV tPA and was linked with lower in-hospital mortality (OR 0.87, 95% CI 0.76–0.98).
- Red Crescent registries revealed low EMS utilization rates (3–10% of STEMI patients), limiting the potential population impact (AlHabib et al., 2016).

4. Subgroup & Sensitivity Analyses

- Benefits of pre-hospital interventions were consistent across regions**,** though effect sizes were larger in structured EMS systems with established hospital coordination**.**
- Excluding low-quality studies did not change the direction of effects, strengthening robustness.

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