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ORIGINAL ARTICLE

Nurse-Led Interventions on Door-to-Balloon Time in ST-Segment Elevation Myocardial Infarction: A Systematic Review and Meta-Analysis

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Abstract: **Introduction:** Door-to-balloon (D2B) time has become a widely accepted indicator of the quality and efficiency of ST-segment elevation myocardial infarction (STEMI) care. This systematic review and meta-analysis evaluated the effectiveness of nurse-led emergency care interventions in reducing D2B time among patients with STEMI undergoing primary percutaneous coronary intervention (PCI). **Methods:** In this systematic review and meta-analysis, quasi-experimental and cohort studies of adult patients with STEMI undergoing primary PCI in emergency settings that compared nurse-led interventions with standard care or pre-intervention practice were included. We searched eight databases (Scopus, Embase, Cochrane Library, Web of Science, PubMed, Google Scholar, ClinicalTrials.gov, and ProQuest) from inception to June 2026. Random-effects meta-analysis was performed. **Results:** Fourteen studies were included; of these, 10 (1,472 patients) provided sufficient data for meta-analysis, while four were summarized narratively. Nurse-led interventions significantly reduced D2B time, with a pooled mean difference of −40.26 minutes (95% confidence interval (CI): −54.36 to −26.46; p<0.001). Heterogeneity was substantial (I^2 = 92%). Subgroup analyses showed consistent benefits across intervention types and risk of bias. No significant mortality benefit was observed, although mortality outcomes were inconsistently reported. The certainty of evidence was low. **Conclusions:** Nurse-led interventions were associated with clinically meaningful D2B time reduction, though evidence certainty was low and effects varied across settings. Implementation should target local bottlenecks within multidisciplinary STEMI systems.

Keywords: ST Elevation Myocardial Infarction; Percutaneous Coronary Intervention; Emergency Nursing; Triage; Systematic Review; Meta-Analysis

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1. Introduction

Acute myocardial infarction (AMI) remains a leading cause of mortality and morbidity worldwide despite significant advances in cardiovascular care (1). Among the spectrum of acute coronary syndromes, ST-segment elevation myocardial infarction (STEMI) represents the most time-sensitive clinical emergency because it is caused by complete occlusion of a coronary artery, resulting in rapid myocardial ischemia and irreversible tissue necrosis if reperfusion is delayed (2). Since the extent of myocardial damage is directly related to the duration of coronary occlusion, timely restoration of coronary blood flow is the cornerstone of STEMI management (3). Primary percutaneous coronary intervention (PCI) is the preferred reperfusion strategy when performed promptly by experienced teams (4). Compared with fibrinolytic therapy, timely primary PCI is associated with lower mortality, fewer recurrent ischemic events, and improved long-term clinical outcomes (5). Consequently, door-to-balloon (D2B) time, the interval between hospital arrival and first balloon inflation or stent deployment during PCI, has become a widely accepted indicator of the quality and efficiency of STEMI care (6). Current international guidelines recommend achieving a D2B time of 90 minutes or less, and this benchmark is routinely used to evaluate hospital performance and guide quality improvement initiatives (2).

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Substantial efforts have been devoted to reducing D2B time through improvements in STEMI systems of care. Evidence supports several effective strategies, including prehospital electrocardiogram (ECG) acquisition and transmission, direct activation of the catheterization laboratory by emergency physicians, streamlined communication pathways, and regionalized STEMI networks (7). These interventions have contributed to significant reductions in treatment delays across many health care settings (8).

Within these multidisciplinary systems, nurses play a central role in coordinating the rapid assessment and management of patients with STEMI. As frontline health care professionals, nurses are frequently responsible for early patient assessment, prompt ECG acquisition, initiation of standardized STEMI protocols, preparation of patients for primary PCI, communication among multidisciplinary teams, and coordination of transfer to the catheterization laboratory (9, 10). Their involvement across multiple stages of the reperfusion pathway positions them to influence treatment efficiency and minimize delays before coronary reperfusion (11). Namdar et al. demonstrated that a nurse-coordinated STEMI code protocol significantly reduced D2B time from 113.5 to 79.3 minutes (12). In addition, nurses play an essential role in facilitating prehospital ECG transmission, activating emergency reperfusion pathways, and coordinating multidisciplinary communication, thereby supporting more efficient clinical workflows (13, 14). However, the broader evidence base remains limited and fragmented by methodological heterogeneity, with few rigorous trials and considerable variation in intervention design and outcome reporting (15). In addition, while previous systematic reviews

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have examined several aspects of STEMI management, including antioxidant therapy (16), prevention of contrast-induced nephropathy (17), pharmacoinvasive management (18), regional STEMI networks (19), and revascularization strategies (20), none has specifically evaluated the effectiveness of nurse-led interventions on D2B time.

The present systematic review and meta-analysis aimed to synthesize the available evidence to determine the effect of nurse-led interventions on D2B time. In addition, this review sought to explore potential sources of heterogeneity across intervention types and study characteristics.

2. Methods

2.1. *Study design and setting*

This systematic review and meta-analysis followed the Cochrane Handbook for Systematic Reviews of Interventions methods guidance and is reported according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) 2020 statement (21). The protocol is registered in PROSPERO (CRD420261427758).

In this review, nurse-led interventions were defined as interventions in which nurses had a primary or clearly identifiable role, either by directly initiating STEMI protocols or by coordinating key elements of multidisciplinary care. Interventions in which nursing involvement was passive or nonspecific were not considered nurse-led.

2.2. *Search Strategy and Selection Criteria*

We searched Scopus, Embase, Cochrane Library, Web of Science, PubMed, Google Scholar, ClinicalTrials.gov, and ProQuest from inception to June 19, 2026, without initial language restrictions; however, only English-language publications were included in the final review. Strategies combined terms for door-to-balloon time, STEMI, and nursing (full strategies in supplementary table 1). For Google Scholar, study design terms were added to improve specificity due to its lack of controlled vocabulary. Reference lists of included studies and relevant reviews were also screened.

Quasi-experimental studies (before-and-after designs), nonrandomized controlled trials, prospective and retrospective cohort studies, and quality improvement initiatives were eligible. Included studies evaluated a nurse-led intervention implemented in the emergency department to reduce door-to-balloon time in STEMI patients, where the nurse was the primary interventionist or a distinctly identifiable member of the team whose role could be differentiated from other bundle components. Interventions were categorized as: (1) nurse-led triage and ECG initiation, (2) nurse-led team coordination and transfer, or (3) nurse education and training. Eligible settings were emergency departments and chest pain centers with on-site PCI capability. Comparators were standard care or pre-intervention practices. The primary outcome was door-to-balloon time, defined as minutes from hospital arrival to first balloon inflation during primary PCI. Borden et al. (2012) (22) reported two separate patient cohorts. The atypical presentation cohort was excluded because STEMI could not be confirmed in all participants; only the typical chest pain cohort was retained.

Two reviewers independently screened studies in duplicate. Disagreements were resolved by consensus or a third reviewer. Studies were excluded if D2B time was not extractable, if the study reported only post-intervention data without a pre-intervention comparator, if the intervention lacked a distinguishable nursing role, if standard deviation could not be obtained or estimated, or if the population included diagnoses other than STEMI without subgroup analysis.

2.3. *Data Extraction and Quality Assessment*

Two reviewers independently extracted data in duplicate using a piloted, standardized form. Extracted variables included study identifiers, intervention category and description, design, population, sample size, setting, data type, pre- and post-intervention door-to-balloon times, effect size metric, and risk of bias.

Two reviewers independently assessed methodological quality using the Joanna Briggs Institute (JBI) critical appraisal checklists: the JBI Checklist for Case Series (23), the JBI Checklist for Cohort Studies (24), the JBI Checklist for Analytical Cross-Sectional Studies (25), and the JBI Checklist for Quasi-Experimental Studies (26), as appropriate to each study design. Studies were assigned a JBI score and classified as low, moderate, or high risk of bias. Discrepancies in data extraction or quality assessment were resolved through discussion and consensus, with a third reviewer consulted when necessary. For each study, the JBI score was calculated as the percentage of 'yes' responses. Based on commonly adopted thresholds in previous systematic reviews (27, 28), studies were classified as low risk of bias (≥70%), moderate risk (50–69%), or high risk (<50%). These thresholds were pre-defined in our review protocol.

2.4. *Data Synthesis and Analysis*

Nurse-led interventions were categorized into three groups: triage and ECG initiation, team coordination and transfer, and education and training.

All meta-analyses were performed using R (version 4.6.1) with the metafor package (version 5.0-1), employing random-effects models with inverse variance weighting to account for anticipated clinical and methodological heterogeneity. Pooled effect estimates were reported as mean differences (MD) with 95% confidence intervals. Statistical heterogeneity was assessed using the I^2 statistic, with values of 25%, 50%, and 75% representing low, moderate, and high heterogeneity, respectively.

A minimum of two studies was required for meta-analysis. Pre-specified subgroup analyses (using mixed-effects models with categorical moderators) were conducted for intervention type (triage/ECG vs team coordination) and study quality (low vs moderate risk of bias) to explore potential sources of heterogeneity. In addition, an exploratory post-hoc meta-regression was performed to examine whether publication year (as a continuous variable) was associated with the effect size; this analysis was not pre-specified in the protocol and was added to investigate possible temporal trends underlying the high between-study heterogeneity. Sensitivity analyses included restriction to low risk of bias studies and leave-one-out analysis to assess the influence of individual studies. Publication bias was assessed using a contour-enhanced funnel plot and Egger's regression test. In addition, the trim-and-fill method was applied to adjust for potential small-study effects by imputing missing studies and recalculating the pooled effect estimate.

2.5. *Certainty of Evidence*

The certainty of evidence was assessed using the GRADE (Grading of Recommendations, Assessment, Development, and

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Evaluation) framework. As all included studies were non-randomized designs (quasi-experimental or controlled clinical trials), the starting certainty was set as low. Evidence was evaluated across five domains for downgrading (risk of bias, inconsistency, indirectness, imprecision, and publication bias) and one domain for upgrading (large magnitude of effect). The GRADE evidence profile was generated using MAGICapp (MAGIC Evidence Ecosystem Foundation, Norway, https://app.magicapp.org/#/guideline/11444).

3. Results

3.1. *Study selection*

The systematic search identified 3,620 records across the eight databases. After removal of 503 duplicates, 3,117 titles and 182 abstracts were screened, and 43 full-text articles were assessed for eligibility. Of these, 29 were excluded (21 for the wrong intervention, 5 conference abstracts, and one each for wrong outcomes, inappropriate causal direction of the intervention/exposure, and wrong study design), leaving 14 studies that met the inclusion criteria. Ten studies provided sufficient data (means and standard deviations, or medians with interquartile ranges convertible using the method of Wan et al. (29)) to be combined in the quantitative meta-analysis, whereas four studies were summarized narratively. The study-selection process is summarized in the PRISMA 2020 flow diagram (21) (Figure 1).

3.2. *Characteristics of included studies*

The 14 included studies were published between 2007 and 2026 and were conducted across nine countries, with the largest number from the United States (n = 5), followed by Taiwan (n = 2) and one each from Australia, China, Iran, Saudi Arabia, Singapore, Spain, and the United Kingdom. Sample sizes ranged from 58 to 841 patients. The predominant design was the before-and-after (quasi-experimental) study; a single non-randomized controlled trial (Namdar 2021) and several retrospective cohort and audit designs were also included. The 14 nurse-led interventions fell into three categories: nurse-driven triage and electrocardiogram (ECG) acquisition (n = 6), nurse-led team coordination and patient transfer (n = 7), and nurse education and training (n = 1). Of these, 10 studies contributed to the quantitative meta-analysis (four Triage/ECG and six Team Coordination studies). Door-to-balloon time was reported as a mean with standard deviation in some studies and as a median with interquartile range in others. The detailed characteristics of each study are presented in Table 1. Four of the fourteen studies did not contribute to the pooled analysis: Levis 2010 (30), Berga Congost 2021 (31), and Medina 2007 (32) because a usable pre-versus-post contrast could not be derived, and Charles 2008 (33) because only a median without any measure of dispersion was reported, which precluded estimation of the variance required for pooling. These four studies were carried forward to the narrative synthesis (Section 3.10).

3.3. *Methodological quality (risk of bias)*

Methodological quality was appraised using the appropriate Joanna Briggs Institute (JBI) critical-appraisal checklists. Of the 14 studies, 4 were judged to be at low risk of bias, 8 at moderate risk, and 2 at high risk. The predominance of moderate-risk ratings reflects the largely uncontrolled before-and-after designs of the evidence base, while the four low-risk studies provided the methodologically strongest evidence. The two high-risk studies (Medina 2007 (32) and Berga Congost 2021 (31)) were quality-improvement studies lacking per-arm statistics and were not included in the meta-analysis. The distribution of risk-of-bias judgements is shown in Figure 2.

3.4. *Effect of nurse-led interventions on door-to-balloon time*

Ten studies comprising 1,472 patients were combined in the primary random-effects meta-analysis. Nurse-led interventions were associated with a statistically significant reduction in door-to-balloon time, with a pooled mean difference of −40.26 minutes (95% confidence interval (CI): −54.36 to −26.46; $p < 0.001$). Because the guideline-recommended door-to-balloon target is 90 minutes, a reduction of this size is generally considered to represent a clinically important improvement. The individual study estimates and their relative weights are displayed in the forest plot (Figure 3). All ten studies individually favoured the nurse-led intervention (that is, every point estimate indicated a reduction in door-to-balloon time), and the variation in the magnitude of that reduction across studies is reflected in the high heterogeneity discussed in Section 3.5.

3.5. *Heterogeneity and prediction interval*

Between-study heterogeneity was substantial ($I^2 = 92\%$, $\tau^2 = 424.2$, Cochran's $Q = 139.4$, $p < 0.001$), indicating that the true effect varies considerably across settings. A 95% prediction interval was calculated to describe the range within which the true effect of a future study would be expected to fall. The prediction interval extended from −83.1 to 2.3 minutes. Although the magnitude of benefit is expected to vary, its direction (a reduction in door-to-balloon time) is expected to be preserved in almost all future settings. The heterogeneity statistics, with their confidence intervals, are summarized in Table 2.

3.6. *Subgroup analyses*

Two pre-specified subgroup analyses were performed as planned in our protocol: one by intervention category (triage/ECG vs team coordination) and one by risk of bias (low vs moderate). These analyses were conducted to identify potential sources of heterogeneity across studies. By intervention category, the effect was larger for nurse-driven triage and ECG interventions (4 studies; MD: −47.5 minutes, 95% CI −81.9 to −13.1) than for nurse-led team coordination and transfer interventions (6 studies; MD: −38.0 minutes, 95% CI −50.2 to −25.8), although the test for subgroup differences was not statistically significant ($p = 0.60$), and heterogeneity remained high within both subgroups (Table 3). By risk of bias, low-risk studies (3 studies; MD −34.5 minutes, 95% CI −68.1 to −0.9) and moderate-risk studies (7 studies; MD −43.0 minutes, 95% CI: −57.5 to −28.4) yielded consistent estimates in the same direction and of similar magnitude. The category-stratified forest plot is shown in Figure 4. Heterogeneity remained high within each subgroup.

3.7. *Meta-regression*

In an exploratory post-hoc meta-regression (not pre-specified in the protocol), we examined whether publication year explained the substantial between-study heterogeneity. Year was centred on the mean study year (2016) and modelled as a continuous covariate. The slope was negligible and non-significant (0.1 minutes per year, $p = 0.94$), and residual heterogeneity remained high ($I^2 = 92\%$), indicating that publication

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year did not account for the observed heterogeneity and that the effect did not change appreciably across the study period.

3.8. *Sensitivity analysis (leave-one-out)*

The robustness of the pooled estimate was examined by iteratively omitting one study at a time. The recalculated pooled mean difference remained negative and statistically significant throughout, ranging from −36.7 minutes (omitting Kuo 2013 (34)) to −44.7 minutes (omitting Lee CK 2019 (35)). No single study materially altered the conclusion, confirming that the finding is not dependent on any individual study. Omitting Lee CK 2019 (35) produced the largest shift and strengthened rather than weakened the pooled effect. This is expected because this study showed only a minimal reduction in door-to-balloon time (from a median of 66 to 65 minutes), thus acting as a near-null anchor in the primary analysis. Notably, although the study also reported the proportion of patients achieving D2B ≤90 minutes, the effect size included in our meta-analysis was derived from the continuous time data (median converted to mean ± standard deviation using the Wan et al. method), consistent with the primary outcome definition. The leave-one-out results are shown in Figure 5.

3.9. *Publication bias*

Small-study effects were assessed using a contour-enhanced funnel plot (Figure 6) and Egger's regression test. Egger's test was not statistically significant (p = 0.319). The trim-and-fill procedure imputed a single study, and the adjusted pooled estimate was −37.0 minutes, similar in direction and magnitude to the primary analysis.

3.10. *Secondary outcomes*

Secondary outcomes were reported inconsistently across studies and, where reported, event counts were small; they were therefore synthesized narratively rather than pooled. In-hospital mortality was reported in 10 studies and did not differ significantly between the pre- and post-intervention periods in any of them, consistent with the low absolute event rates in these cohorts. The proportion of patients achieving a door-to-balloon time ≤ 90 minutes was reported in 8 studies and improved consistently after the intervention (for example, 26% to 70% in Alyahya 2017 (36)). Door-to-ECG time, an early process measure on the causal pathway, was reported in 8 studies and decreased in parallel with the reduction in door-to-balloon time. Reinfarction or major adverse cardiac events (6 studies) and length of stay (3 studies) were reported too infrequently to support quantitative synthesis. The reporting frequency of each secondary outcome is summarized in Table 4.

3.11. *GRADE Certainty of Evidence*

The certainty of evidence for door-to-balloon time reduction was low. Starting from low certainty due to non-randomized study designs, evidence was downgraded by two levels for very serious risk of bias and one level for serious inconsistency (I^2 = 92%), but upgraded by one level for large magnitude of effect (pooled MD: −40.26 minutes, 95% CI: −54.36 to −26.46). Publication bias was not detected (Egger's test t = −1.06, p = 0.319). The GRADE evidence profile is presented in Table 5.

4. Discussion

Overall, the findings provide preliminary evidence that nursing may contribute meaningfully to the efficiency of time-critical STEMI care among patients undergoing primary PCI. Across 10 studies involving 1,472 patients, the pooled mean difference was −40.26 minutes (95% CI: −54.36 to −26.46), indicating a potentially clinically important improvement in the efficiency of reperfusion pathways. However, the substantial between-study heterogeneity (I^2 = 92%) and the wide 95% prediction interval (−83.1 to 2.3 minutes) indicate that the magnitude of this association may vary considerably across health care settings. The prediction interval is particularly relevant because, despite a favorable pooled estimate, the true effect in a future setting could be substantially smaller and may approach no effect. This variability is likely to reflect differences in baseline performance, workflow organization, staffing, communication systems, and implementation conditions rather than statistical heterogeneity alone. Accordingly, the pooled estimate should be interpreted as an average effect across heterogeneous settings rather than as an effect that can be expected uniformly across institutions. The overall certainty of evidence was low, primarily because the evidence base was dominated by non-randomized study designs and marked inconsistency. In addition, none of the 10 studies reporting mortality demonstrated a statistically significant reduction in mortality. However, reductions in D2B time have not consistently translated into improved survival. Karkabi et al. found that despite a significant reduction in median D2B time following a quality-improvement intervention, short- and long-term mortality did not differ between the pre- and post-intervention periods (37). Similarly, Menees et al. showed that despite a nationwide decline in median D2B time from 83 to 67 minutes, in-hospital mortality remained virtually unchanged (4.8% vs. 4.7%) (38). These findings suggest that treatment outcomes are influenced not only by D2B time but also by factors such as total ischemic time, patient risk profile, and the effectiveness of multidisciplinary care processes (39).

The absence of a demonstrated mortality benefit suggests that improvements in door-to-balloon time should not be interpreted as evidence of improved survival, particularly because mortality may also be influenced by total ischemic time, baseline patient risk, and factors occurring before hospital arrival. Therefore, the findings should be interpreted as preliminary evidence that nurse-led interventions may improve reperfusion efficiency, but not necessarily survival.

The present findings extend previous research on strategies to reduce reperfusion delays by focusing on the contribution of nursing within established STEMI pathways. Previous reviews have identified prehospital ECG acquisition and direct transfer to the catheterization laboratory as important components of efficient reperfusion systems (6, 40). Within these pathways, nursing may contribute to the timely execution and coordination of multiple processes rather than acting as an isolated determinant of reperfusion time. This interpretation is consistent with the findings of Hagiwara et al. (41), Nam et al. (42), and Peterson et al. (43), which emphasize the importance of rapid recognition, communication, and coordinated transfer throughout the STEMI pathway. Meta-analytic evidence from Loh et al. (44) also suggests that triage strategies incorporating nurse-led ECG protocols may shorten time to diagnosis and treatment, although the magnitude of benefit may depend on clinical and organizational context. Similarly, Moxham et al. (45) reported that prehospital digital ECG transmission, when incorporated into coordinated STEMI systems, may improve reperfusion efficiency and clinical outcomes. Taken together, these findings suggest that nursing may function as an important operational component within a broader system of timely STEMI recognition, activation, and transfer rather than

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as an independent intervention operating separately from other elements of care.

Several mechanisms may explain the observed reduction in D2B time. Nurse-led triage and early ECG acquisition may reduce diagnostic delays by allowing key processes to occur in parallel rather than sequentially (35, 46). Nurse coordination may also improve communication between emergency, cardiology, catheterization laboratory, and transport teams, particularly through standardized communication approaches such as Situation, Background, Assessment, and Recommendation (SBAR) (47). In addition, education, standardized protocols, and audit-and-feedback processes may support earlier recognition of STEMI, including atypical presentations and more consistent adherence to reperfusion pathways (48, 49). However, because these components are frequently implemented together as part of multifaceted quality-improvement programs, the independent contribution of each mechanism cannot be reliably separated (50).

The exploratory subgroup analysis did not provide evidence that one category of nurse-led intervention was superior to another. Interventions focused primarily on triage and rapid ECG acquisition produced a numerically greater reduction in D2B time than coordination-focused interventions (−47.5 vs. −38.0 minutes); however, the test for subgroup differences was not statistically significant ($p = 0.60$), and heterogeneity remained high in both subgroups. The numerical difference should therefore be interpreted cautiously and considered hypothesis-generating rather than confirmatory. No single nurse-led intervention type can currently be considered superior to another. These findings suggest that the potential value of a nurse-led intervention may depend on whether it targets the principal bottleneck within a particular institution.

The substantial variation between studies, together with the multifaceted nature of most interventions, supports a context-sensitive interpretation of the findings. Hospitals differ in their baseline D2B performance, nursing scope of practice, staffing models, established STEMI pathways, catheterization laboratory availability, communication systems, and organizational culture; therefore, the effect of a given intervention may depend on the degree of opportunity for improvement at the targeted stage of care. For example, an ECG-focused intervention may offer limited additional benefit where diagnostic assessment is already rapid, whereas coordination-focused interventions may be more relevant when delays occur during activation or transfer. Conversely, hospitals with substantial diagnostic delays may have greater potential to benefit from early nursing triage and ECG acquisition. Because several programs incorporated combinations of triage, ECG acquisition, education, communication, protocol activation, transfer, and audit, the resulting improvement may reflect the interaction of several complementary changes rather than the isolated effect of a single component. Previous evidence suggesting that bundled quality-improvement strategies may be more effective than isolated measures is consistent with this interpretation (46), and a review by Naja et al. (50) indicate that multicomponent nursing interventions may provide broader benefits through continuity and coordination of care. Importantly, some interventions may also have been accompanied by other changes in the STEMI system, making attribution to nursing alone particularly challenging. Accordingly, the findings are best interpreted as evidence concerning nurse-led or nurse-involved pathway interventions embedded within complex health care systems rather than as evidence for a single transferable nursing procedure.

These findings have several implications for clinical practice and organizational policy. The available evidence provides preliminary support for integrating appropriately trained nurses into time-critical STEMI processes, including early ECG acquisition, recognition of suspected STEMI, activation of predefined pathways, communication with relevant teams, and facilitation of patient transfer. However, nurse-led intervention should not be interpreted as nurse-only management; rather, nursing responsibilities should be explicitly integrated within a multidisciplinary system involving emergency medicine, cardiology, catheterization laboratory personnel, and other relevant services. Implementation should begin with identification of the principal local source of reperfusion delay, followed by selection of a nursing intervention that directly addresses that bottleneck. At the organizational level, hospitals may consider clearly defined nursing roles, such as cardiac triage nurses or STEMI coordinators, particularly where communication, pathway activation, or transfer remain persistent sources of delay. Such roles may support protocol adherence, staff education, performance monitoring, and continuous quality improvement. Nevertheless, expanding nursing responsibilities without appropriate training, staffing, resources, and multidisciplinary support may not produce sustained improvement. The potential contribution of nursing is therefore likely to be greatest when nursing activities are integrated with, rather than substituted for, timely physician activation, catheterization laboratory readiness, effective communication, and efficient patient transfer.

In practice, health care organizations should identify local sources of reperfusion delay and consider nurse-led strategies that directly address these bottlenecks within a multidisciplinary STEMI pathway. Future research should use rigorous designs, such as cluster-randomized trials, and should evaluate sustainability, cost-effectiveness, and patient-centered outcomes to clarify when, where, and under what implementation conditions nurse-led interventions can provide meaningful benefit.

4.1. *Limitations*

Several limitations should be considered when interpreting these findings. First, most included studies employed nonrandomized designs, particularly before-and-after studies using historical controls. Consequently, the observed improvements may partly reflect secular changes in STEMI care, organizational developments, concurrent quality-improvement initiatives, or regression to the mean. This substantially limits causal inference, and the pooled association should not be interpreted as definitive evidence that the nursing intervention alone caused the reduction in D2B time.

Second, the interventions were heterogeneous and frequently multifaceted, and in several studies nurse-led activities were introduced as part of broader STEMI quality-improvement programs. As a result, it is difficult to isolate the effects of individual nursing components from those of concurrent changes in physician activation, patient transport, catheterization laboratory organization, or communication systems. This limits both the ability to attribute benefit specifically to nursing and the extent to which a single intervention model can be considered universally applicable.

Third, generalizability is constrained by the predominance of studies conducted in relatively well-resourced health care

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systems. Differences in nursing scope of practice, staffing, infrastructure, access to PCI, and prehospital systems may influence both implementation and effectiveness in other settings. The findings should therefore not be assumed to apply uniformly to rural, resource-limited, or low- and middle-income health care systems. Further research in these settings is needed to determine whether similar interventions are feasible and effective under different organizational and resource conditions.

Fourth, the review focused primarily on D2B time, an important process measure that does not directly establish improvements in mortality, morbidity, or quality of life. The absence of a statistically significant mortality benefit in the available studies further emphasizes this limitation. The available studies may also have had limited statistical power to detect differences in clinical outcomes. In addition, the estimation or conversion of summary statistics in some studies introduced additional uncertainty into the pooled estimates.

Fifth, although Egger's regression test did not demonstrate statistically significant evidence of small-study effects ($t = -1.06$, $df = 8$, $p = 0.319$), the relatively small number of included studies limits the ability of this test and the funnel plot to reliably exclude publication bias. Unpublished studies with null or negative findings may therefore have been missed, and the pooled estimate may consequently remain susceptible to publication bias.

Sixth, although the search strategy was designed to identify studies without an initial language restriction, the final review was limited to English-language publications for practical reasons. This restriction may have resulted in exclusion of potentially relevant studies published in other languages and may therefore have introduced language bias.

Seventh, nurse qualifications and training varied and were inconsistently reported. Interventions described as nurse-led ranged from care delivered by registered nurses to interventions involving specialist cardiac or additionally trained nurses. Consequently, the findings represent a broad category of nurse-led interventions rather than a standardized nursing role or training model, limiting conclusions regarding whether specific professional qualifications, levels of training, or scopes of practice are associated with greater effectiveness.

Eighth, one study (Chen 2026) (51) reported door-to-wire time rather than D2B time. However, a post hoc sensitivity analysis excluding this study yielded a pooled MD of −38.2 minutes (95% CI −52.1 to −24.3), consistent with the primary analysis (−40.26 minutes), confirming that its inclusion did not materially affect the overall estimate.

Taken together, these limitations and the low certainty of evidence indicate that the findings should be regarded as supportive rather than definitive. Although the pooled reduction in D2B time is clinically relevant, the magnitude of benefit remains uncertain and may be influenced by study design, baseline performance, intervention complexity, co-interventions, and local implementation conditions. Future studies should therefore distinguish the effects of nursing from concurrent system-level changes and should assess whether improvements in process measures are sustained and associated with meaningful patient-centered outcomes.

5. Conclusions

This systematic review suggests that nurse-led interventions may contribute to more efficient STEMI reperfusion pathways, particularly through early recognition, rapid ECG acquisition, timely activation, communication, coordination, and transfer. However, the high between-study heterogeneity, wide prediction interval, predominance of non-randomized designs, and low certainty of evidence indicate that the magnitude of benefit is uncertain and likely to vary across settings. The available evidence does not demonstrate a statistically significant mortality benefit, and the exploratory subgroup analysis does not support the conclusion that one category of nurse-led intervention is superior to another.

6. Declarations

6.1. *Acknowledgments*

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6.2. *Conflict of interests*

The authors declare that they have no competing interests.

6.3. *Funding and supports*

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6.4. *Authors' contributions*

A.Gh.R. and A.A.E. contributed to the conception and design of the study. A.Gh.R., M.T., and S.J. contributed to data collection and screening. S.J. performed the statistical analysis. A.Gh.R. drafted the manuscript. A.A.E. supervised the study and critically revised the manuscript. All authors read and approved the final manuscript. Acknowledgements
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6.5. *Ethical statement*

Not applicable. This study is a systematic review and meta-analysis of previously published studies; no primary data were collected. Ethical approval was therefore not required. The review protocol was registered in PROSPERO (CRD420261427758).

6.6. *Informed consent*

Not applicable.

6.7. *Availability of supporting data*

All data generated or analyzed during this study are included in this published article and its supplementary information files. The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

6.8. *Using artificial intelligence chatbots statement*

During the preparation of this work, the author(s) used DeepSeek (latest version as of August 2026) for language editing and improving the clarity and readability of the manuscript. After using this tool/service, the author(s) reviewed and edited the content as needed and take full responsibility for the content of the manuscript.

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6.9. *Other declarations*

Authors' information Not applicable.

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Table 1: Characteristics of the included studies

Study	Country	Intervention	Design	N	Pre-DTB (min)	Post-DTB (min)
Levis 2010 (30)	USA	Triage/ECG	Retrospective, chart review	72	—	57.3 ± 17.6
Borden 2012 (22)	USA	Triage/ECG	Before-and-after quality improvement	116 typical CP	137 ± 61	75 ± 37
Charles 2008 (33)	Singapore	Triage/ECG	Before-and-after audit	272	Median 130.5 *	Median 109.5
Coyne 2015 (52)	USA	Triage/ECG	Interventional before/after	100 (DTB subset)	134.3 ± 146.3	83.9 ± 39.8
Kuo 2013 (34)	Taiwan	Triage/ECG	FMEA-based before/after quality improvement	135	Median 154.0	Median 86.5
Lee CK 2019 (35)	Taiwan	Triage/ECG	Retrospective, before/after	202	Median 66	Median 65
Alyahya 2017 (36)	Saudi Arabia	Team coord	Retrospective, cohort	100	Median 107	Median 76.5
Chen X 2026 (51)	China	Team coord	Retrospective, before/after quality improvement	120	124.9 ± 29.8	60.8 ± 15.2
Khot 2007 (53)	USA	Team coord	Prospective, before/after	146	Median 113.5	Median 75.5
Koh 2018 (54)	Australia	Team coord	Prospective, before/after	83	67.1 ± 34.9	45.0 ± 22.7
Kunadian 2010 (55)	UK	Team coord	Prospective, before/after	841	Median 102	Median 66.5
Namdar 2021 (12)	Iran	Team coord	Non-randomized controlled trial	58	113.5 ± 43.6	79.3 ± 27.4
Medina 2007 (32)	USA	Team coord	quality improvement, performance improvement	Not reported	Mean 201	Mean <90
Berga Congost 2021 (31)	Spain	Education	Observational retrospective	327	Not reported	Not reported

CP: chest pain; DTB: door-to-balloon time; ECG: electrocardiogram; SD: standard deviation; Team coord: team coordination; FMEA: Failure Modes and Effect Analysis. Values are mean ± SD or median as reported in the source study.*For studies reporting median and interquartile range (IQR), the data were converted to mean and standard deviation using the method described by Wan et al. (29).

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Table 2: Between-study heterogeneity and prediction interval for the primary outcome

Statistic	Value (95% CI)
I^2 (inconsistency)	92% (82% to 98%)
τ^2 (between-study variance)	424.2 (162.0 to 1530.1)
Cochran's Q (p-value)	139.4 (p < 0.001)
95% prediction interval	−83.1 to 2.3 minutes

CI: confidence interval.

Table 3: Subgroup analyses by intervention category and by risk of bias

Subgroup	k	MD (min)	95% CI	I^2
By intervention category				
Triage and ECG	4	−47.5	−81.9 to −13.1	95%
Team coordination	6	−38.0	−50.2 to −25.8	88%
By risk of bias				
Low	3	−34.5	−68.1 to −0.9	98%
Moderate	7	−43.0	−57.5 to −28.4	74%

CI: confidence interval; MD: mean difference; ECG: electrocardiography.

Table 4: Reporting frequency of secondary outcomes across the included studies

Secondary outcome	Studies reporting
Proportion achieving DTB ≤ 90 min	8 / 14
Door-to-ECG time	8 / 14
In-hospital mortality	10 / 14
30-day / other mortality	4 / 14
Reinfarction / MACE	6 / 14
Length of stay	3 / 14

DTB: door-to-balloon time; ECG: electrocardiogram; MACE: major adverse cardiac events.

Table 5: GRADE Evidence Profile: Nurse-Led Interventions vs. Standard Care for Door-to-Balloon Time Reduction in STEMI Patients

Outcome	DTB Time
Number of studies	10
Risk of Bias	Very Serious
Inconsistency	Serious
Indirectness	Not Serious
Imprecision	Not Serious
Publication Bias	Not Serious
Large Effect	Yes
MD (95% CI)	-40.26 (−54.36 to −26.46)
Certainty	Low

DTB: door-to-balloon time; GRADE: Grading of Recommendations, Assessment, Development, and Evaluation; CI: confidence interval; MD: mean difference; STEMI: ST-segment elevation myocardial infarction.

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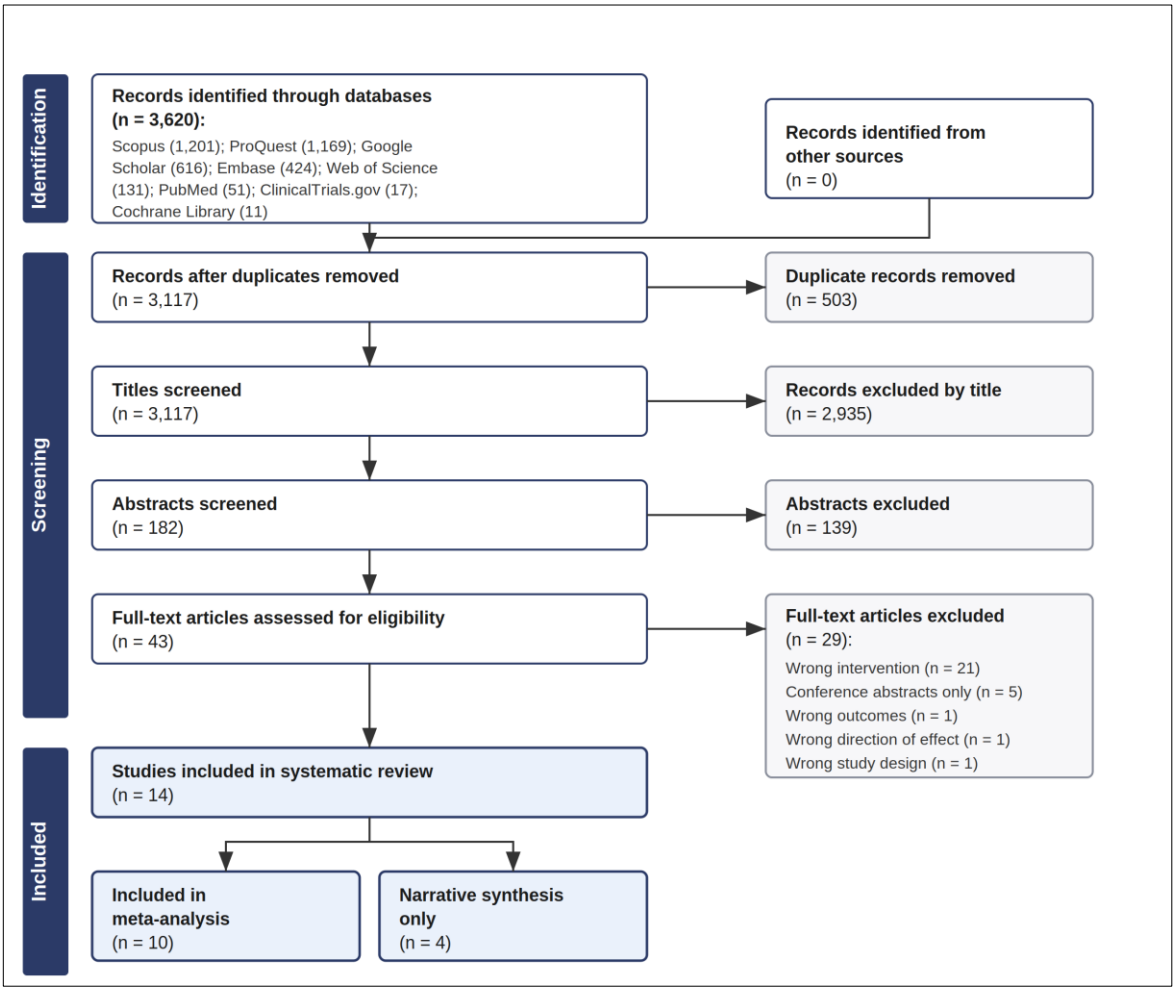


Figure 1: Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) 2020 flow diagram of study identification, screening, and inclusion.

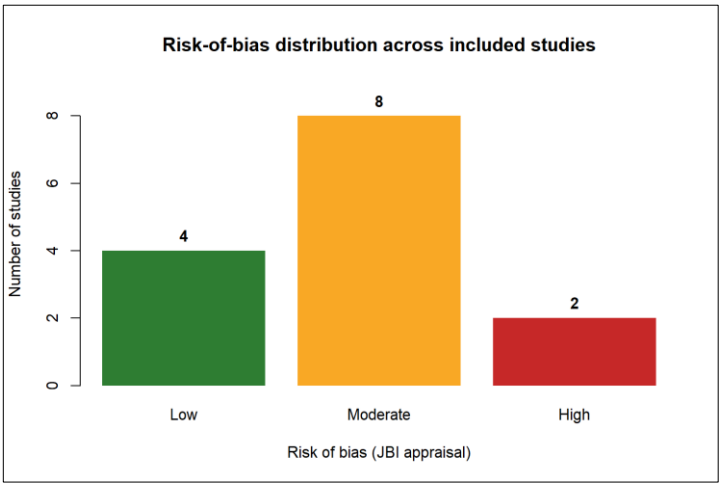


Figure 2: Distribution of risk-of-bias judgements across the included studies (JBI critical-appraisal checklists). JBI: Joanna Briggs Institute.

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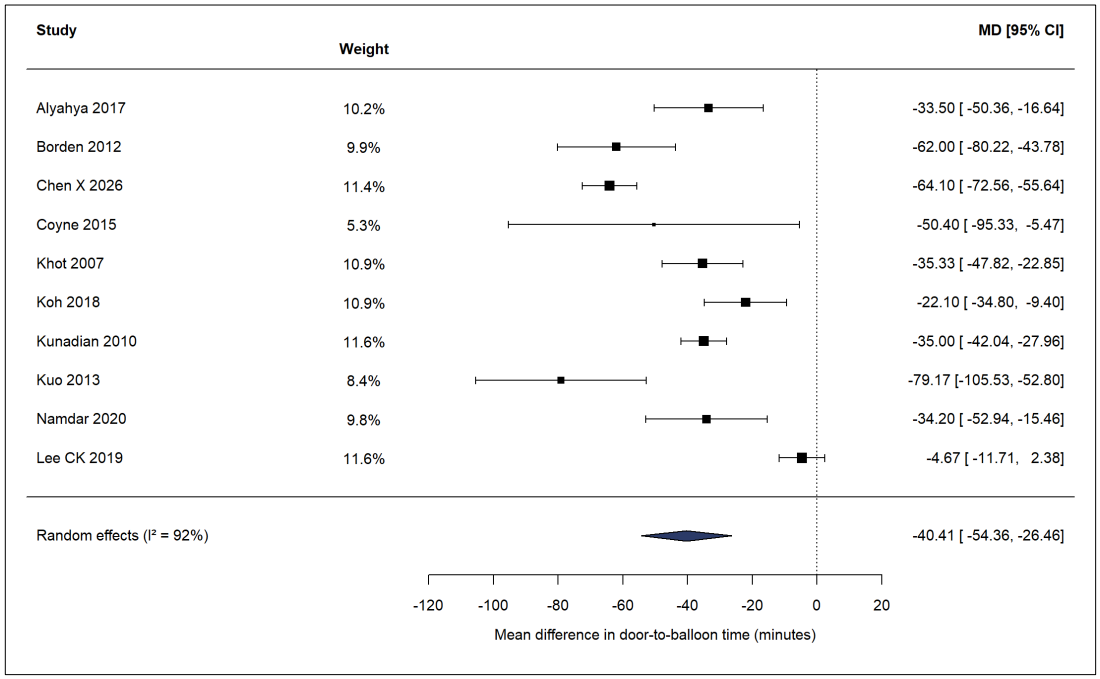


Figure 3: Forest plot of the effect of nurse-led interventions on door-to-balloon time (random-effects model). Squares are study mean differences sized by weight; horizontal lines are 95% confidence intervals; the diamond is the pooled estimate. CI: confidence interval; MD: mean difference.

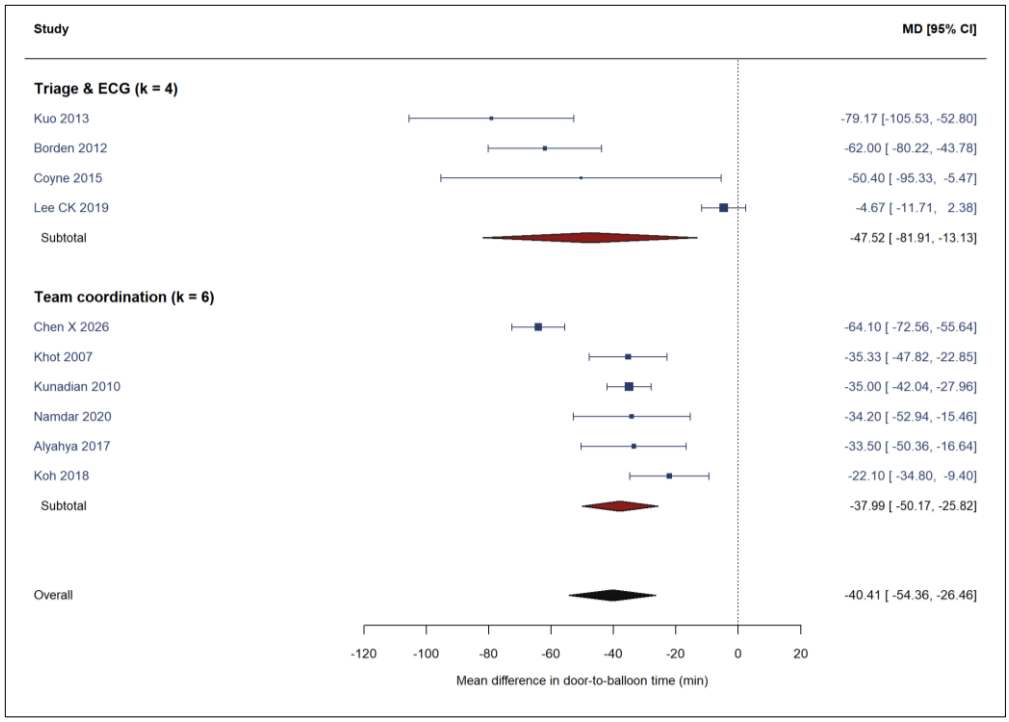


Figure 4: Forest plot stratified by intervention category, showing a pooled subtotal for each subgroup and the overall pooled estimate. CI: confidence interval; ECG: electrocardiogram; MD: mean difference.

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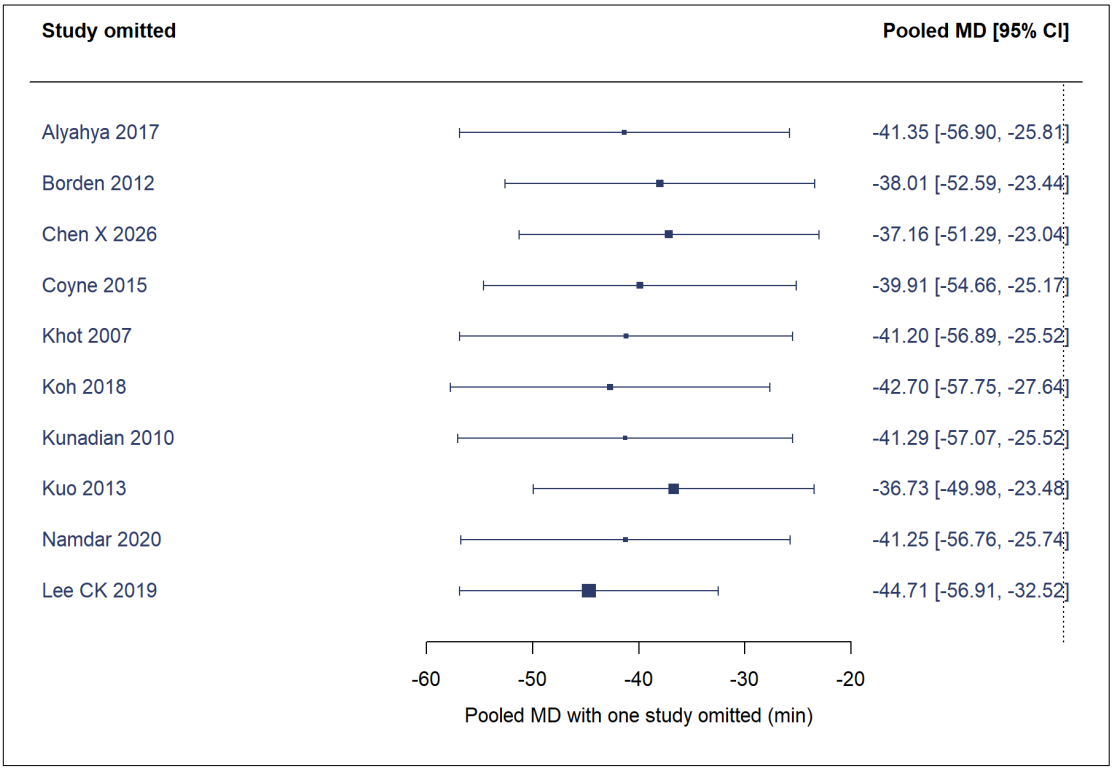


Figure 5: Leave-one-out sensitivity analysis; each row shows the pooled mean difference recalculated with the named study omitted. CI: confidence interval; MD: mean difference.

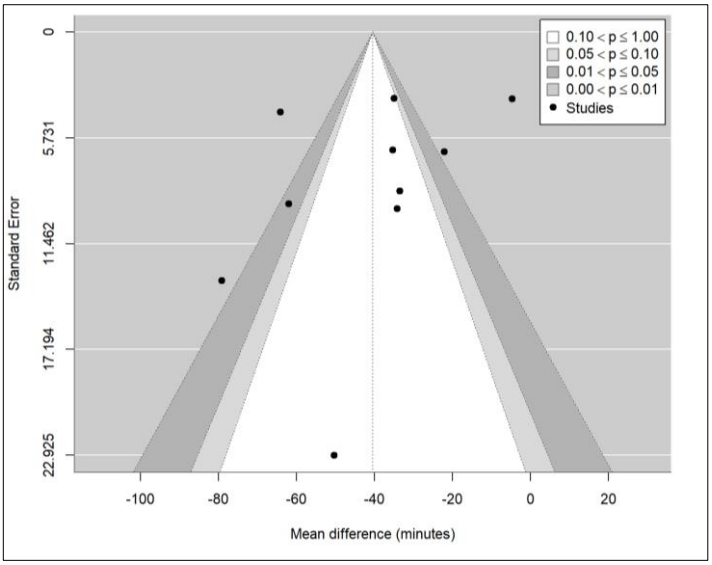


Figure 6: Contour-enhanced funnel plot for the primary outcome; shaded bands denote conventional statistical-significance regions.

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Supplementary Table 1: Search strategy in different databases

Databases	Search Strategy	Date	Records Number
Scopus	(("door-to-balloon" OR "door to balloon" OR DTB OR "reperfusion time" OR "door-to-needle") AND (STEMI OR "ST elevation" OR "myocardial infarction" OR "acute coronary syndrome") AND (nurse OR nursing OR "nurse-led" OR "triage nurse" OR "emergency nursing"))	19 June 2026	1201
Embase	('door-to-balloon' OR 'door to balloon' OR dtb) AND (stemi OR 'myocardial infarction') AND (nurse OR nursing OR 'nurse-led')	19 June 2026	424
Cochrane Library	Cochrane Library was searched using the following strategy in the Search Manager: Line 1: "door-to-balloon" OR "door to balloon" OR DTB OR "reperfusion time" Line 2: STEMI OR "ST elevation" OR "myocardial infarction" Line 3: nurse OR nursing OR "nurse-led" OR "triage nurse" OR "emergency nursing" Line 4: #1 AND #2 AND #3	19 June 2026	11
Web of Science	("door-to-balloon" OR "door to balloon" OR DTB OR "reperfusion time") AND (STEMI OR "myocardial infarction") AND (nurse OR nursing OR "nurse-led")	19 June 2026	131
PubMed	("Door-To-Balloon" OR "Door to Balloon" OR DTB) AND STEMI AND (Nurse OR Nursing OR "Nurse-Led")	19 June 2026	51
Google Scholar	("Emergency Nursing" OR "Emergency Nurse" OR "Nurse-Led" OR "Nurse Initiated" OR "Triage Nurse") AND ("Door-To-Balloon" OR "Door to Balloon" OR DTB OR "Reperfusion Time") AND ("STEMI" OR "ST-Elevation Myocardial Infarction") AND ("Intervention" OR "Protocol" OR "Pathway" OR "RCT" OR "Randomized Controlled Trial")	19 June 2026	616
Clinical-Trials.gov	STEMI AND (nurse OR nursing OR "nurse-led") AND (time OR delay OR reperfusion)	19 June 2026	17
ProQuest	(STEMI OR "myocardial infarction") AND (nursing OR "nurse-led") AND ("door-to-balloon" OR "reperfusion time")	19 June 2026	1169
			3620

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