Archives of Academic Emergency Medicine. 2025; 13(1): e47

OPEN ACCESS

REVIEW ARTICLE

Prehospital ECG Interpretation Methods for ST-Elevation MI Detection and Catheterization Laboratory Activation: A Systematic Review and Meta-Analysis

Ahmad Alrawashdeh[1]*, Samar Ihtoub[1], Zaid I. Alkhatib[1], Mahmoud Alwidyan[1], Yousef S Khader[2], Sukaina Rawashdeh[3], Saeed Alqahtani[4], Dion Stub[5,6], Rahaf Alhamouri[7], Islam E Alkhazali[8], Ziad Nehme[9,10]

1. Department of Allied Medical Sciences, Faculty of Applied Medical Sciences, Jordan University of Science and Technology, Irbid, Jordan
2. Department of Public Health and Family Medicine, Faculty of Medicine, Jordan University of Science and Technology, Irbid, Jordan
3. Department of Internal Medicine, Faculty of Medicine, Jordan University of Science and Technology, Irbid, Jordan
4. Department of Emergency Medical Services, Prince Sultan Military College for Health Sciences, Dhahran, Saudi Arabia
5. School of Public Health and Preventive Medicine, Centre of Cardiovascular Research. and Education in Therapeutics (CCRET), Monash University, Melbourne, Australia
6. Department of Cardiovascular Medicine, Alfred Hospital, Melbourne, Australia
7. Department of Health Data Analytics, Kernel Research and Data Analytics, Irbid, Jordan
8. Department of Allied Medical Sciences, Faculty of Applied Medical Sciences, Al al-Bayt University, Mafraq, Jordan
9. Centre for Research and Evaluation, Ambulance Victoria, Melbourne, Australia
10. School of Public Health and Preventive Medicine, Department of Paramedicine, Monash University, Melbourne, Australia

Received: March 2025; Accepted: April 2025; Published online: 22 May 2025

Abstract: **Introduction:** The diagnostic accuracies of different electrocardiography (ECG) interpretation methods remain unclear. Therefore, this study aimed to systematically evaluate and compare the diagnostic accuracy of prehospital 12-lead ECG interpretation methods for identifying ST-elevation myocardial infarction (STEMI) and activating cardiac catheterization laboratories (CCLs). **Methods:** A comprehensive search was conducted in Medline, Scopus, and CINAHL databases up to August 2024. Two reviewers independently selected studies that assessed the diagnostic accuracy of prehospital 12-lead ECG in real-time STEMI identification and CCL activation. Pooled estimates of sensitivity, specificity, diagnostic odds ratio (DOR), and area under the curve (AUC) were calculated using bivariate generalized mixed-effects regression models or random-effects meta-analysis as appropriate. The quality of the included studies was assessed using the QUADAS-2 tool. **Results:** Thirty-six studies involving 67,168 patients were included. Overall, for STEMI identification, the pooled AUC of ECG was 0.96 (95%CI:0.94–0.98), sensitivity was 80% (95% CI, 69–88%), specificity was 97% (95%CI: 94–98%), and DOR was 114 (95%CI: 59–222). Ambulance clinicians achieved the highest DOR (264; 95%CI: 33–2125), followed by transmission method (136; 95%CI, 59–312) and computer-assisted analysis (78; 95%CI: 33–186). Transmission method demonstrated superior specificity (0.98; 95%CI: 0.94-0.99) and the lowest rates of inappropriate (13.2%; 95% CI: 8.6%–19.2%), and false-positive (11.0%; 95%CI: 6.9%–15.0%) CCL activations. **Conclusion:** All prehospital ECG interpretation methods yielded acceptable diagnostic accuracy for STEMI identification; however, transmission offered the greatest specificity and fewer unnecessary CCL activations. Adopting transmission-based strategies, where feasible, and enhancing training and decision support for ambulance clinicians may improve prehospital STEMI detection and resource utilization.

Keywords: Emergency medical services; ST-elevation myocardial infarction; Cardiac catheterization; 12-lead ECG; Diagnostic techniques and procedures

Cite this article as: Alrawashdeh A, Ihtoub S, I. Alkhatib Z, et al. Prehospital ECG Interpretation Methods for ST-Elevation MI Detection and Catheterization Laboratory Activation: A Systematic Review and Meta-Analysis. Arch Acad Emerg Med. 2025; 13(1): e47. https://doi.org/10.22037/aaemj.v13i1.2627.

1. Introduction

Rapid and accurate prehospital identification of ST-elevation myocardial infarction (STEMI) is essential for initiating timely reperfusion therapy and improving patient outcomes (1, 2). Advancements in emergency medical services (EMS) have made the use of prehospital 12-lead electrocardiogra-

* **Corresponding Author:** Ahmad Alrawashdeh; Department of Allied Medical Sciences, Faculty of Applied Medical Sciences, Jordan University of Science and Technology, Irbid, Jordan. Email: aaalrawashdeh@just.edu.joPhone: +962 79 9864033, ORCID: https://orcid.org/0000-0003-2458-8200.

phy (ECG) a cornerstone in early STEMI detection and management (3). However, the effectiveness of different ECG interpretation methods—such as ambulance clinician interpretation, computer-assisted analysis, and transmission to receiving centers for expert evaluation—varies, and their comparative diagnostic accuracies remain unclear (4).

Early recognition of STEMI by EMS has consistently demonstrated reductions in time to reperfusion therapy, whether through thrombolysis or percutaneous coronary intervention (PCI), leading to decreased morbidity and mortality (5-8). Accurate 12-lead ECG interpretation enables EMS providers to make informed triage decisions, initiate appropriate treatments, and properly activate cardiac catheterization laboratories (CCLs) before hospital arrival (9, 10). Inaccurate prehospital ECG interpretations can lead to inappropriate or false-positive CCL activations, straining healthcare resources and exposing patients to unnecessary risks associated with unwarranted invasive procedures (11).

Despite individual studies assessing the diagnostic accuracy of various prehospital 12-lead ECG interpretation methods, there is a lack of comprehensive comparisons among these methods to determine which offers the highest diagnostic accuracy in prehospital settings. Conversely, missed STEMI diagnoses can lead to delays in reperfusion therapy, resulting in poorer clinical outcomes (12). Understanding the diagnostic accuracy and impact of each interpretation method on inappropriate CCL activation rates is crucial for optimizing EMS protocols and enhancing patient care.

Therefore, this systematic review and meta-analysis aimed to compare the diagnostic accuracy of different prehospital 12-lead ECG interpretation methods in identifying STEMI in adult patients. The secondary objective was to assess rates of inappropriate and false-positive CCL activations associated with each interpretation method.

2. Methods

This systematic review and meta-analysis was conducted in accordance with the Preferred Reporting Items for Systematic Review and Meta-Analysis of Diagnostic Test Accuracy (PRISMA-DTA) guidelines (13). The protocol of this review was registered with the International Prospective Register of Systematic Reviews (PROSPERO; ID: CRD42022355925).

2.1. Search strategy

A comprehensive electronic search was performed in Medline, Scopus, and CINAHL databases to identify relevant studies published between January 1990 and August 2024. The start date was chosen because the feasibility of prehospital 12-lead ECG was first published in phase I of the FAST-MI study in 1990 (14). The search strategy combined Medical Subject Headings and text words related to four key concepts: 1) EMS, 2) STEMI or PCI, 3) 12-lead ECG, and 4) diagnostic accuracy (Supplementary Table S1). We also searched the reference lists of included studies and relevant reviews for additional articles.

2.2. Study selection criteria

Studies were eligible for inclusion if they were English-written peer-reviewed randomized controlled trials or observational studies (cohort, case-control, cross-sectional) that assessed the diagnostic accuracy of prehospital 12-lead ECG in identifying STEMI. The population of interest was adult patients (≥18 years) with suspected STEMI assessed in a prehospital setting by the ambulance service. Studies were excluded if they focused on acute coronary syndrome without specific data on STEMI, involved pediatric populations, were not published in English, or were abstracts, reviews, case reports, or not designed on population-based data. We excluded studies including artificial intelligence and machine learning interpretation and those that evaluated the diagnostic accuracy for adopted tools, scores, or other ECG paradigms such as occlusion myocardial infarction classification.

The intervention involved the use of prehospital 12-lead ECG for STEMI identification in real-time. This review focused on three methods of 12-lead ECG interpretation. First, the ambulance clinician interpretation, where ambulance clinicians with any skill level (i.e. physician, nurse, paramedic, or emergency medical technician) interpret the 12-lead ECGs autonomously without any assistance. Second, computer-assisted interpretation, which involves using onboard computer algorithms or software that automatically analyze the 12-lead ECGs. Third, transmission to a receiving center or an expert, where prehospital ECG data are transmitted to an emergency physician or a cardiologist, allowing specialists to remotely interpret the ECG and provide immediate feedback or instructions to ambulance clinicians.

The definition of STEMI in the included study met the international 12-lead ECG criteria at the time the study was conducted.

The comparator in our study was the reference standard used in each included study to confirm STEMI or the appropriateness of CCL activation, which could be the final hospital diagnosis, cardiologist or emergency physician interpretation, or angiography findings. Studies had to report sufficient data to estimate at least one diagnostic accuracy metric, including sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), or accuracy. We also included studies that assessed the accuracy of prehospital CCL activation for PCI using prehospital 12-lead ECG that reported sufficient data to estimate inappropriate CCL activation rate (proportion of canceled catheterizations due to ECG finding not consistent with STEMI), and false positive CCL activation rate (absence of a culprit coronary artery lesion for the patients who were candidates for angiography and did not receive PCI).

Two reviewers (AA and SI) independently screened the titles and abstracts of all retrieved articles for eligibility using Covidence Software. Full-text articles of potentially relevant studies were then assessed against the inclusion criteria. Discrepancies between reviewers were resolved through consensus.

2.3. Data extraction

Data were independently extracted by two reviewers using a standardized data extraction form developed for this study. The form was piloted on five randomly selected studies to ensure clarity and consistency. Extracted data included study characteristics (first author, year of publication, country, study design, setting, data sources, and study duration); participant characteristics (sample size, mean age, and gender distribution); intervention details (method of patient selection, the skill level of ambulance clinicians, and method of ECG interpretation); reference standards (final hospital diagnosis, cardiologist or emergency physician interpretation, or PCI findings); and outcomes (sensitivity, specificity, PPV, NPV, accuracy, numbers of true positives [TP], false positives [FP], true negatives [TN], and false negatives [FN], rates of inappropriate CCL activation, and false-positive CCL activation).

2.4. Risk of bias assessment

The quality and risk of bias of the included studies were independently assessed by two reviewers using the Quality Assessment of Diagnostic Accuracy Studies 2 (QUADAS-2) tool (13). The QUADAS-2 tool evaluates four domains: patient selection, index test, reference standard, and flow and timing. Each domain was rated as "low," "high," or "unclear" risk of bias.

2.5. Data synthesis

For the primary outcome, we calculated pooled estimates of diagnostic accuracy metrics, including sensitivity, specificity, positive likelihood ratio, negative likelihood ratio, diagnostic odds ratio (DOR), and area under the receiver operating characteristic curve (AUC). These were primarily calculated using bivariate generalized mixed-effects regression models, which account for the correlation between sensitivity and specificity and the variability within and between studies (15). The statistical heterogeneity among studies was assessed using the I^2 statistic, whereas the Deek's funnel plot asymmetry test was used to assess for publication bias.

To compare the 12-lead ECG interpretation methods, we conducted separate meta-analyses for each method of interpretation using the same above-mentioned approach. Sensitivity analyses were performed to assess the influence of individual studies on the pooled estimates by excluding outliers identified through scatter plots of standardized residuals and Cook's distance measures.

Random-effects meta-analysis models employing the DerSimonian and Laird method (16) were used to estimate the pooled mean age, proportion of male sex, and other diagnostic metrics, including PPV, NPV, accuracy, and rates of inappropriate and false-positive CCL activations. Stata software version 16 (Stata Corp LLC) was used to pool data. The statistical packages MIDAS and METAN were used for bivariate and random effects meta-analyses, respectively (17).

3. Results

The electronic literature search yielded 2,825 studies. After removing 931 duplicates, 1,793 irrelevant studies were excluded after the initial titles and abstracts screening. Then, 101 full-text articles were assessed against eligibility criteria and a total of 36 studies were included in the analysis (Figure 1).

3.1. Study characteristics

Table 1 summarizes the characteristics of the included studies, and detailed information for each study is provided in the supplementary table S2. Of the 36 included studies, 19 assessed the diagnostic accuracy of prehospital 12-lead ECG in identifying STEMI (18-36), and 18 studies evaluated the accuracy of CCL activation based on prehospital ECG interpretation (32, 37-53). One study assessed both STEMI identification and CCL activation (32).

Most studies were conducted in North America (n=27; 75%) and used retrospective observational designs (n=23; 66%). The median publication year was 2012 (IQR: 2006–2015). The total number of patients across all studies was 67,168, with 59,162 patients in the STEMI studies and 12,001 patients in the CCL activation studies. The pooled mean age was 61.6 years (95% CI: 57.0–65.8), and the pooled percentage of male patients was 63.2% (95% CI: 46.6%–79.7%). Participants were selected based on suspected STEMI (n=17 studies; 47%) or from available 12-lead ECG data (n=19 studies; 53%). In STEMI studies, the definitive treatment was PCI in eight studies, thrombolytic therapy in five studies, and not specified in six studies.

The methods of ECG interpretation assessed included ambulance clinician interpretation in seven STEMI studies and four CCL activation studies, computer-assisted interpretation in eight STEMI studies and nine CCL activation studies, and transmission to receiving centers in seven STEMI studies and nine CCL activation studies. The most frequent reference standard was the final hospital diagnosis (n=10; 53%) for STEMI studies and angiography findings (n=10; 56%) for CCL activation studies.

3.2. Diagnostic accuracy of ECG in identifying STEMI

The pooled performance estimates from the bivariate meta-analysis are presented in Table 2. The overall pooled AUC was 0.96 (n=17 studies; 95% CI: 0.94–0.98) (Figure 2A). Stratified by the method of ECG interpretation, ambulance clinicians achieved the highest AUC of 0.98 (n=5 studies; 95% CI: 0.97–0.99), followed by computer-assisted interpretation at 0.95 (n=8 studies; 95% CI: 0.93–0.97), and transmission to specialists at 0.94 (n=6 studies; 95% CI: 0.91–0.95) (Figure 2B). The overall pooled sensitivity was 80.0% (95% CI: 69%-88%; I2=96.6%) and pooled specificity was 97.0% (95% CI: 94.0%–98.0%; I2=100%). The pooled sensitivity was higher for ambulance clinicians (94%, 95% CI: 0.80-0.98), compared to the computer-assisted (73%; 95% CI: 58%-84%) and transmission (72%; 95% CI: 58%-83%) methods. While the specificity was lower for ambulance clinicians (94%; 95% CI: 74%-99%) with a wider confidence interval, compared to the computer-assisted (97%; 95% CI: 93%-98%) and transmission (98%; 95% CI: 94%-99%) methods.

The overall DOR was 114 (95% CI: 59-222), indicating high discriminatory performance. Ambulance clinicians had the highest DOR at 264 (95% CI: 33-2125), followed by transmission to emergency or cardiology specialists at 136 (95% CI: 59–312) and computer-assisted interpretation at 78 (95% CI: 33-186). Positive likelihood ratios were high across all methods, with an overall pooled positive likelihood ratio of 23.7 (95% CI: 12.9-43.3). Specifically, the positive likelihood ratio was lowest at 16.5 (95% CI: 3.2-85.3) for ambulance clinicians and highest at 38.3 (95% CI: 13.7-106.6) for transmission to specialists. These values suggest that a positive result substantially increases the likelihood of having STEMI, making the test highly confirmative across all methods.

Negative likelihood ratios varied among methods with a pooled estimate of 0.21 (95% CI: 0.13-0.32), showing moderate exclusive diagnostic informativeness. Ambulance clinicians had a stronger ability to rule out STEMI when negative (exclusive test) with a negative likelihood ratio of 0.06 (95% CI: 0.02–0.23), compared to the computer-assisted and transmission methods that had moderate ability with negative likelihood ratio values around 0.28. When the test was negative, the probability of STEMI diagnosis was 2% by ambulance clinicians but 7% in the computer-assisted and transmission methods (Supplementary Figure S1 Fegan Plot). These results are comparable to the pooled PPV, NPV, and accuracy as estimated using random-effect meta-analysis (Figure 3). The pooled accuracy was highest for transmission at 92.4% (95% CI: 89.0%–95.9%; I2= 97.0%), followed by ambulance clinicians at 88.3% (95% CI: 80.4%-96.2%; I2= 98.0%), and computer-assisted at 88% (95% CI: 82%–94%; I2= 99.1%).

The sensitivity analysis excluding one outlier and influential study (26) within the ambulance-clinicians method (Supplementary Figure S2) detected slight changes in the pooled estimates for overall and ambulance clinicians method (Supplementary Table S3). The Deek's funnel plot asymmetry test for all studies suggested no statistically significant evidence of publication bias (Slope coefficient -1.70; 95% CI: -36.27, 32.86; P=0.918) (Supplementary Figure S3).

3.3. Diagnostic accuracy of ECG in CCL activation

Figure 4 shows forest plots summarizing the pooled inappropriate and false-positive CCL activation rates. The overall pooled inappropriate CCL activation rate for all modes of interpretation was 17.1% (n=18 studies; 95% CI: 9.1%–25.1%), and the false-positive CCL activation rate was 13.5% (n=21 studies; 95% CI: 10.4%–16.6%).

The inappropriate CCL activation rate was lowest for the transmission method at 13.2% (n=8 studies; 95% CI: 8.6%–19.2%), compared to computer-assisted method at 22.3% (n=7 studies; 95% CI: 7.4%–37.3%) and ambulance clinician method at 19.4% (n=3 studies; 95% CI: 9.6%–29.2%). The false-positive CCL activation rate was lowest for the transmission method at 11.0% (n=9 studies; 95% CI: 6.9%–15.0%) and highest for ambulance clinicians at 25.9% (n=3 studies; 95% CI: 13.2%–38.6%). The false-positive CCL activation rate for computer-assisted method was 13.2% (n=9 studies; 95% CI: 8.3%–18.1%).

3.4. Quality assessment of included studies

The quality assessment results using QUADAS-2 are included in the supplementary file (Figure S4). Overall, most of the included studies had a low risk of bias for all domains, except for the “reference standard” domain. A total of 11 studies showed a high risk of bias in the reference standard domain (19, 22-28, 36, 38, 43). This was mainly because the results of the reference standard in these studies (physician, final hospital diagnosis, and PCI) were interpreted with the knowledge of the index test results (the prehospital initial diagnosis) and the risk of bias may not be avoidable in these studies. In the index test domain, a high risk of bias was found when the interpretation of the ambulance clinicians and transmission had been exposed to computer assistance diagnosis in 7 studies (20, 26, 35, 37, 39, 41, 45). Regarding the patient selection domain, one study had a high risk of bias because it had a case-control design with a nonconsecutive selection (53). Additionally, the “flow and timing” domain indicated that three studies had a high risk of bias because of the unknown period between the prehospital diagnosis and reference standard diagnosis and missing information about the final diagnosis for a few patients (38, 40, 47). No significant mismatch was found in the “applicability” domain to the review question except in three studies (20, 40, 43).

4. Discussion

This systematic review and meta-analysis evaluated the diagnostic accuracy of prehospital 12-lead ECG in identifying STEMI across different methods of interpretation. Across 36 studies (67,168 patients), all prehospital ECG interpretation methods showed high diagnostic accuracy for STEMI identification (AUC=0.96; sensitivity=80%; specificity=97%; DOR=114). Transmission method provided higher specificity (98%) and minimized inappropriate (13.2%) and false-positive (11%) CCL activations, with a favorable DOR (136) and the strongest positive likelihood ratio (38.3). Although computer-assisted method maintained high specificity (97%), its sensitivity was comparatively lower (73%). Ambulance clinicians achieved the highest sensitivity (94%) and greatest discriminatory power (DOR=264) but had lower specificity (94%) and higher rates of false-positive CCL activations (25.9%). However, ambulance clinicians presented the best rule-out capability for STEMI (2% residual risk if negative) compared with transmission and computer-assisted methods (7%).

The substantial heterogeneity observed in the included studies impacts the reliability and generalizability of the pooled estimates of this review. The heterogeneity may stem from differences in study designs, populations, settings, definitions of outcomes, and variations in the implementation of ECG interpretation methods. Additionally, the quality assessment revealed that most studies had a low risk of bias in the domains of patient selection and flow and timing. However, the index test may have been influenced by the knowledge of other tests since ambulance clinicians or a specialist who received transmitted 12-lead ECGs may have been influenced by the printed diagnosis suggested by the computer software (20, 26, 35, 37, 39, 41, 45), which may introduce automation bias (54). In addition, 12 studies (19, 20, 22-28, 36, 38, 43)(33%) carried a high risk of bias in the reference standard domain because the standard (e.g., physician diagnosis, final hospital findings, or angiography) might have been influenced by prior knowledge of prehospital ECG interpretations. This incorporation bias could inflate the pooled diagnostic performance metrics. While unavoidable in real-time clinical scenarios, it suggests the need for caution when interpreting these pooled estimates.

The findings suggest that transmission method, involving specialist interpretation, can enhance diagnostic accuracy and reduce unnecessary CCL activations. The involvement of a cardiologist, for example, can improve resource allocation and reduce door-to-device times and in-hospital mortality rates (39, 55). Although not yet universally mandated (56), prehospital ECG transmission is widely implemented in developed EMS systems, regardless of the method of interpretation (57). EMS systems must consider the feasibility and resource implications of implementing this technology. In settings where transmission is not feasible, efforts should focus on enhancing the training and decision support for ambulance clinicians to improve specificity without compromising sensitivity.

Still, ambulance clinician interpretation remains the most frequently adapted method of 12-lead ECG interpretation, followed by the computer-assisted method (57). While ambulance clinicians showed higher sensitivity and a stronger ability to rule out STEMI, our findings differ somewhat from an earlier meta-analysis reporting a similar level of sensitivity for computer-assisted method (58). This discrepancy could be due to our use of bivariate models that account for correlation between sensitivity and specificity and differences in study inclusion. As an essential decision support tool, computer algorithms can vary between manufacturers and over time due to technological advancements (59-61). These algorithms may be substituted with machine learning algorithms that have demonstrated superior accuracy in detecting acute coronary syndrome and STEMI compared with commercial software (62-64). However, careful validation and training are needed to prevent overreliance and automation bias (65).

Today, paramedic interpretation is usually preferable in many EMS systems as it is a faster and more cost-effective method (66). Also, emergency health services may also be more willing to tolerate some degree of false positive CCL activation to avoid missing true STEMI cases, prioritizing timely reperfusion. However, the extremely wide confidence interval for ambulance clinicians' DOR (33–2125) underscores notable variability in diagnostic performance across different EMS settings, reflecting one limitation of relying solely on this interpretive method.

Further, low accuracy in ECG interpretation by paramedics, especially in developing systems, remains concerning (67, 68). Regular training and competency standards for 12-lead ECG interpretation should be established to address this issue (69). The 2023 European Society of Cardiology (ECS) guidelines mandate regular and structured training of ambulance staff for a high-quality ambulance service (70). Integrating a multifaceted strategy, including standardized protocols, continuous quality assurance, artificial intelligence, and careful cost-effectiveness assessment, may enhance paramedic decision-making, improve diagnostic accuracy, and streamline resource use in prehospital STEMI care (60, 61, 71).

5. Limitations

The current review has several limitations. The substantial heterogeneity and risk of bias identified limit the certainty of the pooled estimates. Although subgroup and sensitivity analyses were explored, significant heterogeneity persisted. The retrospective nature of most included studies may introduce selection bias. Although the Deek's funnel plot did not indicate significant asymmetry, there is always a possibility of publication bias as the search was limited to English-language publications. We should acknowledge that the long timeframe over which these studies were conducted may have included evolving definitions of STEMI and advancements in paramedicine and technology.

6. Conclusions

All prehospital ECG interpretation methods for identifying STEMI demonstrate high diagnostic accuracy, yet important differences in performance were observed. The transmission-based method provided superior specificity and reduced unnecessary CCL activations, whereas ambulance clinicians, despite offering the strongest rule-out capability and highest sensitivity, faced challenges with lower specificity and more frequent false positive CCL activations. Computer-assisted method maintained strong specificity but lower sensitivity, suggesting a supportive, rather than a standalone, role for paramedics. Where transmission is not feasible, ongoing efforts to improve paramedic training, standardized protocols, quality assurance, and computer-assisted tools may help optimize accuracy and resource use.

7. Declarations

7.1. Acknowledgments

None.

7.2. Funding

Deanship of Research at Jordan University of Science and Technology (Research Grant No: 20240529); National Health and Medical Research Council to DS; National Heart Foundation fellowship to DS and ZN.

7.3. Data Availability Statement

Data available on request.

7.4. Author contributions

AA and SI conceived the idea, developed the study design, contributed to study selection, data extraction, data analysis, visualization, and quality assessment; AA and SI, and ZA wrote the first draft of the manuscript; and All authors critically reviewed and edited the manuscript and approved the final version.

7.5. Conflict of interest

The authors declare that there are no conflicts of interest related to this work.

7.6. Using artificial intelligence chatbots

The authors acknowledge that artificial intelligence (AI)–based chatbots (e.g., ChatGPT) were used solely to assist in drafting and refining text in certain portions of this manuscript. All content was verified and revised by the authors.

References

1. Baran, K.W., K.A. Kamrowski, J.J. Westwater, V.H. Tschida, C.F. Alexander, M.M. Beahrs, et al., Very rapid treatment of ST-segment–elevation myocardial infarction: utilizing prehospital electrocardiograms to bypass the emergency department. Circ. Cardiovasc. Qual. Outcomes, 2010. 3(4): p. 431-437.
2. Kerem, Y., J.S. Eastvold, D. Faragoi, D. Strasburger, S.E. Motzny, and E.B. Kulstad, The role of prehospital electrocardiograms in the recognition of ST-segment elevation myocardial infarctions and reperfusion times. J. Emerg. Med., 2014. 46(2): p. 202-207.
3. O'Connor, R.E., A.S. Al Ali, W.J. Brady, C.A. Ghaemmaghami, V. Menon, M. Welsford, et al., Part 9: acute coronary syndromes: 2015 American Heart Association guidelines update for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation, 2015. 132(18_suppl_2): p. S483-S500.
4. Ting, H.H., H.M. Krumholz, E.H. Bradley, D.C. Cone, J.P. Curtis, B.J. Drew, et al., Implementation and integration of prehospital ECGs into systems of care for acute coronary syndrome: a scientific statement from the American Heart Association Interdisciplinary Council on Quality of Care and Outcomes Research, Emergency Cardiovascular Care Committee, Council on Cardiovascular Nursing, and Council on Clinical Cardiology. Circulation, 2008. 118(10): p. 1066-1079.
5. Farshid, A., C. Allada, J. Chandrasekhar, P. Marley, D. McGill, S. O'Connor, et al., Shorter ischaemic time and improved survival with pre-hospital STEMI diagnosis and direct transfer for primary PCI. Heart Lung Circ., 2015. 24(3): p. 234-240.
6. Nam, J., K. Caners, J.M. Bowen, M. Welsford, and D. O'Reilly, Systematic review and meta-analysis of the benefits of out-of-hospital 12-lead ECG and advance notification in ST-segment elevation myocardial infarction patients. Ann. Emerg. Med., 2014. 64(2): p. 176-186. e9.
7. Garvey, J.L., B.A. MacLeod, G. Sopko, M.M. Hand, and N.H.A.A.P.C. Committee, Pre-hospital 12-lead electrocardiography programs: a call for implementation by emergency medical services systems providing advanced life support—National Heart Attack Alert Program (NHAAP) Coordinating Committee; National Heart, Lung, and Blood Institute (NHLBI); National Institutes of Health. J. Am. Coll. Cardiol., 2006. 47(3): p. 485-491.
8. Kahlon, T.S., K. Barn, M.M.A. Akram, J.C. Blankenship, C. Bower-Stout, D.J. Carey, et al., Impact of pre-hospital electrocardiograms on time to treatment and one year outcome in a rural regional ST-segment elevation myocardial infarction network. Catheter. Cardiovasc. Interv., 2017. 89(2): p. 245-251.
9. Camp-Rogers, T., S. Dante, M.C. Kontos, C.S. Roberts, L. Kreisa, and M.C. Kurz, The impact of prehospital activation of the cardiac catheterization team on time to treatment for patients presenting with ST-segment-elevation myocardial infarction. Am. J. Emerg. Med., 2011. 29(9): p. 1117-1124.
10. Kontos, M.C., M.R. Gunderson, J.K. Zegre-Hemsey, D.C. Lange, W.J. French, T.D. Henry, et al., Prehospital Activation of Hospital Resources (PreAct) ST-Segment–Elevation Myocardial Infarction (STEMI): A Standardized Approach to Prehospital Activation and Direct to the Catheterization Laboratory for STEMI Recommendations From the American Heart Association's Mission: Lifeline Program. J. Am. Heart Assoc, 2020. 9(2): p. e011963.
11. Henry, T.D., L. Younger, A. Derakhshan, S. Conte, E. Pappas-Block, R. Makkar, et al., Economic impact of false ST-segment elevation myocardial infarction (STEMI) cardiac catheterization laboratory (CCL) activations at a major Los Angeles county STEMI-receiving center (SRC). J. Am. Coll. Cardiol., 2016. 67(13S): p. 635.
12. McNair, P.W., K.C. Bilchick, and E.C. Keeley, Very late presentation in ST elevation myocardial infarction: predictors and long-term mortality. IJC Heart & Vasculature, 2019. 22: p. 156-159.
13. McInnes, M.D., D. Moher, B.D. Thombs, T.A. McGrath,

P.M. Bossuyt, T. Clifford, et al., Preferred reporting items for a systematic review and meta-analysis of diagnostic test accuracy studies: the PRISMA-DTA statement. JAMA, 2018. 319(4): p. 388-396.
14. Karagounis, L., S.K. Ipsen, M.R. Jessop, K.M. Gilmore, D.A. Valenti, J.J. Clawson, et al., Impact of field-transmitted electrocardiography on time to in-hospital thrombolytic therapy in acute myocardial infarction. Am. J. Cardiol., 1990. 66(10): p. 786-791.
15. Vogelgesang, F., P. Schlattmann, and M. Dewey, The evaluation of bivariate mixed models in meta-analyses of diagnostic accuracy studies with SAS, Stata and R. Methods Inf. Med., 2018. 57(03): p. 111-119.
16. IntHout, J., J.P. Ioannidis, and G.F. Borm, The Hartung-Knapp-Sidik-Jonkman method for random effects meta-analysis is straightforward and considerably outperforms the standard DerSimonian-Laird method. BMC Med. Res. Methodol., 2014. 14(25).
17. Dwamena, B.A., METAANALYTIC INTEGRATION OF DIAGNOSTIC ACCURACY STUDIES IN STATA. 2007.
18. Aufderheide, T.P., G.E. Hendley, R. Thakur, J.R. Mateer, H.A. Stueven, D.W. Olson, et al., The diagnostic impact of prehospital 12-lead electrocardiography. Ann. Emerg. Med., 1990. 19(11): p. 1280-1287.
19. Foster, D.B., J.H. Dufendach, C.M. Barkdoll, and B.K. Mitchell, Prehospital recognition of AMI using independent nurse/paramedic 12-lead ECG evaluation: impact on in-hospital times to thrombolysis in a rural community hospital. Am. J. Emerg. Med., 1994. 12(1): p. 25-31.
20. Anroedh, S., I. Kardys, K. Akkerhuis, M. Biekart, B. van der Hulst, G. Deddens, et al., e-Transmission of ECGs for expert consultation results in improved triage and treatment of patients with acute ischaemic chest pain by ambulance paramedics. Neth. Heart J., 2018. 26: p. 562-571.
21. Aufderheide, T.P., M.H. Keelan, G.E. Hendley, N.A. Robinson, T.E. Hastings, R.F. Lewin, et al., Milwaukee Prehospital Chest Pain Project—phase I: feasibility and accuracy of prehospital thrombolytic candidate selection. Am. J. Cardiol., 1992. 69(12): p. 991-996.
22. Bhalla, M.C., F. Mencl, M.A. Gist, S. Wilber, and J. Zalewski, Prehospital electrocardiographic computer identification of ST-segment elevation myocardial infarction. Prehosp. Emerg. Care, 2013. 17(2): p. 211-216.
23. Bosson, N., S. Sanko, R.E. Stickney, J. Niemann, W.J. French, J.G. Jollis, et al., Causes of prehospital misinterpretations of ST elevation myocardial infarction. Prehosp. Emerg. Care, 2017. 21(3): p. 283-290.
24. Clark, E.N., M. Sejersten, P. Clemmensen, and P.W. Macfarlane, Automated electrocardiogram interpretation programs versus cardiologists' triage decision making based on teletransmitted data in patients with suspected acute coronary syndrome. Am. J. Cardiol., 2010. 106(12): p. 1696-1702.
25. de Champlain, F., L.J. Boothroyd, A. Vadeboncoeur, T. Huynh, V. Nguyen, M.J. Eisenberg, et al., Computerized interpretation of the prehospital electrocardiogram: predictive value for ST segment elevation myocardial infarction and impact on on-scene time. Can J Emerg Med, 2014. 16(2): p. 94-105.
26. Ducas, R.A., A.W. Wassef, D.S. Jassal, E. Weldon, C. Schmidt, R. Grierson, et al., To transmit or not to transmit: how good are emergency medical personnel in detecting STEMI in patients with chest pain? Can. J. Cardiol., 2012. 28(4): p. 432-437.
27. Feldman, J.A., K. Brinsfield, S. Bernard, D. White, and T. Maciejko, Real-time paramedic compared with blinded physician identification of ST-segment elevation myocardial infarction: results of an observational study. Am. J. Emerg. Med., 2005. 23(4): p. 443-448.
28. Kudenchuk, P.J., M.T. Ho, W.D. Weaver, P.E. Litwin, J.S. Martin, M.S. Eisenberg, et al., Accuracy of computer-interpreted electrocardiography in selecting patients for thrombolytic therapy. J. Am. Coll. Cardiol., 1991. 17(7): p. 1486-1491.
29. Lai, J.H., C. Lui, T.W. Chan, B.C. Wong, M.S. Tsui, B.K. Wan, et al., Diagnostic accuracy of a prehospital electrocardiogram rule-based algorithm for ST-elevation myocardial infarction: results from a population-wide project. Hong Kong Med. J., 2024. 30(4): p. 271-280.
30. Le May, M.R., R. Dionne, J. Maloney, J. Trickett, I. Watpool, M. Ruest, et al., Diagnostic performance and potential clinical impact of advanced care paramedic interpretation of ST-segment elevation myocardial infarction in the field. Can J Emerg Med, 2006. 8(6): p. 401-407.
31. Melville, M.R., D. Gray, and M. Hinchley, The potential impact of prehospital electrocardiography and telemetry on time to thrombolysis in a United Kingdom center. Ann. Noninvasive Electrocardiol., 1998. 3(4): p. 327-332.
32. Muhrbeck, J., J. Persson, and C. Hofman-Bang, Catheterization laboratory activations and time intervals for patients with pre-hospital ECGs. Scand. Cardiovasc. J., 2018. 52(2): p. 74-79.
33. Sejersten, M., D. Young, P. Clemmensen, J. Lipton, D. VerSteeg, T. Wall, et al., Comparison of the ability of paramedics with that of cardiologists in diagnosing ST-segment elevation acute myocardial infarction in patients with acute chest pain. Am. J. Cardiol., 2002. 90(9): p. 995-998.
34. Terkelsen, C., B. Nørgaard, J.F. Lassen, J. Gerdes, J. Ankersen, F. Rømer, et al., Telemedicine used for remote prehospital diagnosing in patients suspected of acute myocardial infarction. J. Intern. Med., 2002. 252(5): p. 412-420.
35. van't Hof, A.W., S. Rasoul, H. van de Wetering, N. Ernst, H. Suryapranata, J.C. Hoorntje, et al., Feasibility and benefit of prehospital diagnosis, triage, and therapy by paramedics only in patients who are candidates for primary angioplasty for acute myocardial infarction. Am. Heart J., 2006. 151(6): p. 1255. e1-1255. e5.
36. Wilson, R.E., H.S. Kado, R.F. Percy, R.C. Butterfield, J.

Sabato Jr, J.A. Strom, et al., An algorithm for identification of ST-elevation myocardial infarction patients by emergency medicine services. Am. J. Emerg. Med., 2013. 31(7): p. 1098-1102.

37. Boivin-Proulx, L.-A., A. Matteau, C. Pacheco, A. Bastiany, S. Mansour, A. Kokis, et al., Effect of real-time physician oversight of prehospital STEMI diagnosis on ECG-inappropriate and false positive catheterization laboratory activation. CJC open, 2021. 3(4): p. 419-426.
38. Bosson, N., A.H. Kaji, J.T. Niemann, B. Squire, M. Eckstein, W.J. French, et al., The utility of prehospital ECG transmission in a large EMS system. Prehosp. Emerg. Care, 2015. 19(4): p. 496-503.
39. Davis, D.P., C. Graydon, R. Stein, S. Wilson, B. Buesch, S. Berthiaume, et al., The positive predictive value of paramedic versus emergency physician interpretation of the prehospital 12-lead electrocardiogram. Prehosp. Emerg. Care, 2007. 11(4): p. 399-402.
40. Eckstein, M., W. Koenig, A. Kaji, and R. Tadeo, Implementation of specialty centers for patients with ST-segment elevation myocardial infarction. Prehosp. Emerg. Care, 2009. 13(2): p. 215-222.
41. Faour, A., C. Cherrett, O. Gibbs, K. Lintern, C.J. Mussap, R. Rajaratnam, et al., Utility of prehospital electrocardiogram interpretation in ST-segment elevation myocardial infarction utilizing computer interpretation and transmission for interventional cardiologist consultation. Catheter. Cardiovasc. Interv., 2022. 100(3): p. 295-303.
42. Garvey, J.L., L. Monk, C.B. Granger, J.R. Studnek, M.L. Roettig, C.C. Corbett, et al., Rates of cardiac catheterization cancelation for ST-segment elevation myocardial infarction after activation by emergency medical services or emergency physicians: results from the North Carolina Catheterization Laboratory Activation Registry. Circulation, 2012. 125(2): p. 308-313.
43. Garvey, J.L., J. Zegre-Hemsey, R. Gregg, and J.R. Studnek, Electrocardiographic diagnosis of ST segment elevation myocardial infarction: an evaluation of three automated interpretation algorithms. J. Electrocardiol., 2016. 49(5): p. 728-732.
44. Lu, J., A. Bagai, C. Buller, A. Cheema, J. Graham, M. Kutryk, et al., Incidence and characteristics of inappropriate and false-positive cardiac catheterization laboratory activations in a regional primary percutaneous coronary intervention program. Am. Heart J., 2016. 173: p. 126-133.
45. Mixon, T.A., E. Suhr, G. Caldwell, R.D. Greenberg, F. Colato, J. Blackwell, et al., Retrospective description and analysis of consecutive catheterization laboratory ST-segment elevation myocardial infarction activations with proposal, rationale, and use of a new classification scheme. Circ. Cardiovasc. Qual. Outcomes, 2012. 5(1): p. 62-69.
46. Potter, B.J., A. Matteau, S. Mansour, R. Essiambre, M. Montigny, S. Savoie, et al., Performance of a new "physician-less" automated system of prehospital ST-segment elevation myocardial infarction diagnosis and catheterization laboratory activation. Am. J. Cardiol., 2013. 112(2): p. 156-161.
47. Rasmussen, M.B., L. Frost, C. Stengaard, J.U. Brorholt-Petersen, K.K. Dodt, H.M. Søndergaard, et al., Diagnostic performance and system delay using telemedicine for prehospital diagnosis in triaging and treatment of STEMI. Heart, 2014. 100(9): p. 711-715.
48. Sanchez-Ross, M., G. Oghlakian, J. Maher, B. Patel, V. Mazza, D. Hom, et al., The STAT-MI (ST-segment analysis using wireless technology in acute myocardial infarction) trial improves outcomes. JACC Cardiovasc. Interv., 2011. 4(2): p. 222-227.
49. Squire, B.T., J.H. Tamayo-Sarver, P. Rashi, W. Koenig, and J.T. Niemann, Effect of prehospital cardiac catheterization lab activation on door-to-balloon time, mortality, and false-positive activation. Prehosp. Emerg. Care, 2014. 18(1): p. 1-8.
50. Tanguay, A., E. Brassard, J. Lebon, F. Bégin, D. Hébert, and J.-M. Paradis, Effectiveness of a prehospital wireless 12-lead electrocardiogram and cardiac catheterization laboratory activation for ST-elevation myocardial infarction. Am. J. Cardiol., 2017. 119(4): p. 553-559.
51. Young, D.R., M. Murinson, C. Wilson, B. Hammond, M. Welch, V. Block, et al., Paramedics as decision makers on the activation of the catheterization laboratory in the presence of acute ST-elevation myocardial infarction. J. Electrocardiol., 2011. 44(1): p. 18-22.
52. Youngquist, S.T., A.P. Shah, J.T. Niemann, A.H. Kaji, and W.J. French, A comparison of door-to-balloon times and false-positive activations between emergency department and out-of-hospital activation of the coronary catheterization team. Acad. Emerg. Med., 2008. 15(8): p. 784-787.
53. Swan, P.Y., B. Nighswonger, G.L. Boswell, and S.J. Stratton, Factors associated with false-positive emergency medical services triage for percutaneous coronary intervention. West. J. Emerg. Med., 2009. 10(4): p. 208-12.
54. Goddard, K., A. Roudsari, and J.C. Wyatt, Automation bias: a systematic review of frequency, effect mediators, and mitigators. J. Am. Med. Inform. Assoc., 2012. 19(1): p. 121-127.
55. Mori, H., A. Maeda, Y. Akashi, J. Ako, Y. Ikari, T. Ebina, et al., The impact of pre-hospital 12-lead electrocardiogram and first contact by cardiologist in patients with ST-elevation myocardial infarction in Kanagawa, Japan. J. Cardiol., 2021. 78(3): p. 183-192.
56. Byrne, R.A., X. Rossello, J.J. Coughlan, E. Barbato, C. Berry, A. Chieffo, et al., 2023 ESC Guidelines for the management of acute coronary syndromes: Developed by the task force on the management of acute coronary syndromes of the European Society of Cardiology (ESC). Eur. Heart J. Acute Cardiovasc, 2023. 13(1): p. 55-161.

57. Zègre-Hemsey, J.K., M.D. Patel, A.R. Fernandez, M.M. Pelter, J. Brice, and W. Rosamond, A Statewide Assessment of Prehospital Electrocardiography Approaches of Acquisition and Interpretation for ST-Elevation Myocardial Infarction Based on Emergency Medical Services Characteristics. Prehosp. Emerg. Care, 2020. 24(4): p. 550-556.
58. Tanaka, A., K. Matsuo, M. Kikuchi, S. Kojima, H. Hanada, T. Mano, et al., Systematic review and meta-analysis of diagnostic accuracy to identify ST-segment elevation myocardial infarction on interpretations of prehospital electrocardiograms. Circ Rep, 2022. 4(7): p. 289-297.
59. Pilbery, R., M.D. Teare, S. Goodacre, and F. Morris, The Recognition of STEMI by Paramedics and the Effect of Computer inTerpretation (RESPECT): a randomised crossover feasibility study. Emerg. Med. J., 2016. 33(7): p. 471-476.
60. Chen, K.-W., Y.-C. Wang, M.-H. Liu, B.-Y. Tsai, M.-Y. Wu, P.-H. Hsieh, et al., Artificial intelligence-assisted remote detection of ST-elevation myocardial infarction using a mini-12-lead electrocardiogram device in prehospital ambulance care. Front. cardiovasc. med, 2022. 9: p. 1001982.
61. Takeda, M., T. Oami, Y. Hayashi, T. Shimada, N. Hattori, K. Tateishi, et al., Prehospital diagnostic algorithm for acute coronary syndrome using machine learning: a prospective observational study. Sci. Rep., 2022. 12(1): p. 14593.
62. Al-Zaiti, S.S., C. Martin-Gill, J.K. Zègre-Hemsey, Z. Bouzid, Z. Faramand, M.O. Alrawashdeh, et al., Machine learning for ECG diagnosis and risk stratification of occlusion myocardial infarction. Nat. Med., 2023. 29(7): p. 1804-1813.
63. Alrawashdeh, A., S. Alqahtani, Z.I. Alkhatib, K. Kheirallah, N.Y. Melhem, M. Alwidyan, et al., Applications and Performance of Machine Learning Algorithms in Emergency Medical Services: A Scoping Review. Prehosp. Disaster Med., 2024. 39(5): p. 368-378.
64. Zworth, M., H. Kareemi, S. Boroumand, L. Sikora, I. Stiell, and K. Yadav, Machine learning for the diagnosis of acute coronary syndrome using a 12-lead ECG: a systematic review. Can J Emerg Med, 2023. 25(10): p. 818-827.
65. Bond, R.R., T. Novotny, I. Andrsova, L. Koc, M. Sisakova, D. Finlay, et al., Automation bias in medicine: The influence of automated diagnoses on interpreter accuracy and uncertainty when reading electrocardiograms. J. Electrocardiol., 2018. 51(6, Supplement): p. S6-S11.
66. Antman, E.M., M. Hand, P.W. Armstrong, E.R. Bates, L.A. Green, L.K. Halasyamani, et al., 2007 focused update of the ACC/AHA 2004 guidelines for the management of patients with ST-elevation myocardial infarction: a report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines: developed in collaboration with the Canadian Cardiovascular Society endorsed by the American Academy of Family Physicians: 2007 writing group to review new evidence and update the ACC/AHA 2004 guidelines for the management of patients with ST-elevation myocardial infarction, writing on behalf of the 2004 writing committee. Circulation, 2008. 117(2): p. 296-329.
67. Funder, J.L., L. Ross, and S. Ryan, How effective are paramedics at interpreting ecgs in order to recognize STEMI? A systematic review. Australasian Journal of Paramedicine, 2020. 17: p. 1-9.
68. Alalwan, M.A., T. Alshammari, H. Alawjan, H. Alkhayat, A. Alsaleh, I. Alamri, et al., Electrocardiographic interpretation by emergency medical services professionals in Saudi Arabia: A cross sectional study. PLoS One, 2023. 18(10): p. e0292868.
69. Kashou, A., A. May, C. DeSimone, and P. Noseworthy, The essential skill of ECG interpretation: How do we define and improve competency? Postgrad. Med. J., 2020. 96(1133): p. 125-127.
70. Byrne, R.A., X. Rossello, J.J. Coughlan, E. Barbato, C. Berry, A. Chieffo, et al., 2023 ESC Guidelines for the management of acute coronary syndromes: Developed by the task force on the management of acute coronary syndromes of the European Society of Cardiology (ESC). European Heart Journal, 2023. 44(38): p. 3720-3826.
71. Daudelin, D.H. and H.P. Selker, Medical error prevention in ED triage for ACS: use of cardiac care decision support and quality improvement feedback. Cardiol. Clin., 2005. 23(4): p. 601-614.

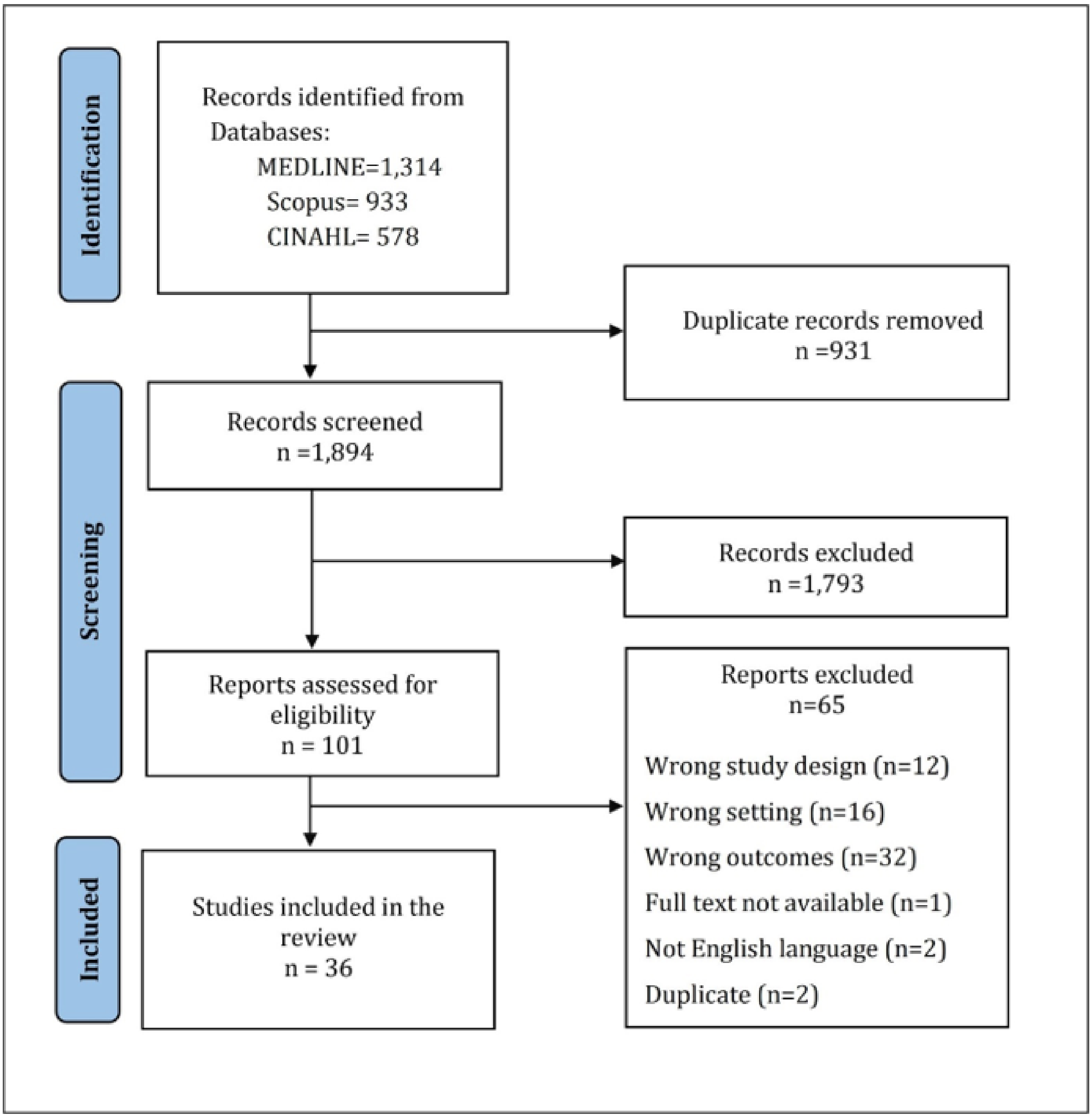


Figure 1: Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) flow diagram.

Table S 1: Search strategy for Medline, CINAHL, and Scopus (Keywords only)

Type	EMS	STEMI/PCI	Diagnosis accuracy	12-lead ECG
MeSH term	exp Emergency Medical Services/ exp Ambulances/ exp Emergency Medical Technicians/	exp Myocardial Infarction/ exp ST Elevation Myocardial Infarction/	"Sensitivity and specificity"[MeSH) OR predict*[tw) OR diagnos*[tw) OR accura*[tw)	(MH" Electrocardiography+")
keywords	(prehospital or pre-hospital or out-of-hospital or paramedic? or paramedic$ or ambulance? or emergency medical service? or EMS or emergency service? or emergency technician? or emergency medical technician?).ti,ab.	(Acute myocardial infarction or AMI or STEMI or ST-Elevation Myocardial Infarction or st elevation acute coronary syndrome or heart attack or st elevation).ti,ab. Cardiac catheter* Lab*	Sensitivity OR detect* OR diagnos* OR “diagnostic accuracy” OR specificity* OR OR positive OR negative false negative; FP, false positive; TN, true negative; TP, true positive.	electrocardio*" OR "ECG" OR "EKG" OR "12-lead"

Table 1: Characteristics and outcomes of all included studies in the analysis

Variables	Overall	STEMI diagnosis	CCL activation
Total studies			
Number	36	19	18
Number of cases			
Sum	67,168	59,162	12,001
Age (year)			
Pooled mean (95% CI)	61.6 (57.0-65.8)	65.6 (65.3-65.9)	61.3 (56.2-66.4)
Male	63.2 (46.6-79.7)	62.9 (56.9-68.9)	69.0 (67.2-70.9)
Pooled percentage (95% CI)			
Year of publication			
Median (IQR)	2012 (2006-2015)	2006 (1998-2014)	2014 (2011-2016)
Study duration in years			
Median (IQR)	1.21 (1-2)	1 (0.7-1.3)	2 (1-3)
Study design, n (%)			
Prospective	13 (34.0)	6 (28.0)	7 (39.0)
Retrospective	23 (66.0)	13 (72.0)	11 (61.0)
Region, n (%)			
North America	27 (75.0)	12 (63.0)	15 (83.0)
Europe	7 (19.0)	6 (31.0)	2 (11.0)
Asia-Pacific	2 (6.0)	1 (6.0)	1 (6.0)
Sample selection method, n (%)			
Suspected STEMI	17 (49.0)	8 (44.0)	10(56.0)
Available 12-lead ECG	19 (51.0)	11 (56.0)	8 (44.0)
Definitive treatment, n (%)			
PCI	25 (69.0)	8 (42.0)	18 (100.0)
Thrombolytic	5 (14.0)	5 (26.0)	0 (0.0)
Not Specified	6 (17.0)	6 (32.0)	0 (0.0)
Skill level of attending ambulance, n (%)			
BLS (emergency medical technicians)	4 (11.0)	1 (5.0)	4 (22.0)
ALS (paramedics and nurses)	32 (89.0)	18 (95.0)	14 (88.0)
Mode of ECG interpretation (index test) n (%)			
Ambulance clinicians	11 (31.0)	7 (37.0)	4 (22.2)
Computer	17 (47.0)	8 (41.0)	9 (50.0)
Transmission	15 (42.0)	7 (37.0)	9 (50.0)
Reference standards n (%)			
Cardiologists/ ER physicians	10 (28.0)	8 (42.0)	2 (11.0)
Final hospital diagnosis	15 (42.0)	10 (53.0)	6 (33.0)
PCI	11 (30.0)	1 (5.0)	10 (56.0)

STEMI: ST-elevation myocardial infarction; CCL: cardiac catheterization laboratory; ECG: electrocardiograph; PCI: percutaneous coronary intervention; BLS: basic life support; ALS: advanced life support; ER: emergency room; IQR: interquartile range; CI: confidence interval.

Table 2: The pooled screening performance characteristics estimates from the bivariate meta-analysis for all STEMI studies and by the methods of interpretation

Metrics	Overall (n=19)	Ambulance clinician (n=5)	Computer (n=8)	Transmission (n=6)
AUC	0.96 (0.94-0.98)	0.98 (0.97-0.99)	0.95 (0.93-0.97)	0.94 (0.91-0.95)
Sensitivity	0.80 (0.69-0.88)	0.94 (0.80-0.98)	0.73 (0.58-0.84)	0.72 (0.58-0.83)
Specificity	0.97 (0.94-0.98)	0.94 (0.74-0.99)	0.97 (0.93-0.98)	0.98 (0.94-0.99)
Diagnostic Odds Ratio	114 (59-220)	264 (33-2125)	78 (33-186)	136 (59-312)
Positive Likelihood Ratio	23.7 (12.9-43.3)	16.5 (3.2-85.3)	21.6 (10.7-43.9)	38.3 (13.7-106.6)
Negative Likelihood Ratio	0.21 (0.13,0.32)	0.06 (0.02-0.23)	0.28 (0.17-0.45)	0.28 (0.18-0.44)
I-square	100 (100,100)	96 (94-99)	98 (98-99)	99 (99,100)

All measures are presented with 9% confidence interval. AUC: area under the receiver operating characteristic curve; STEMI: ST-elevation myocardial infarction.

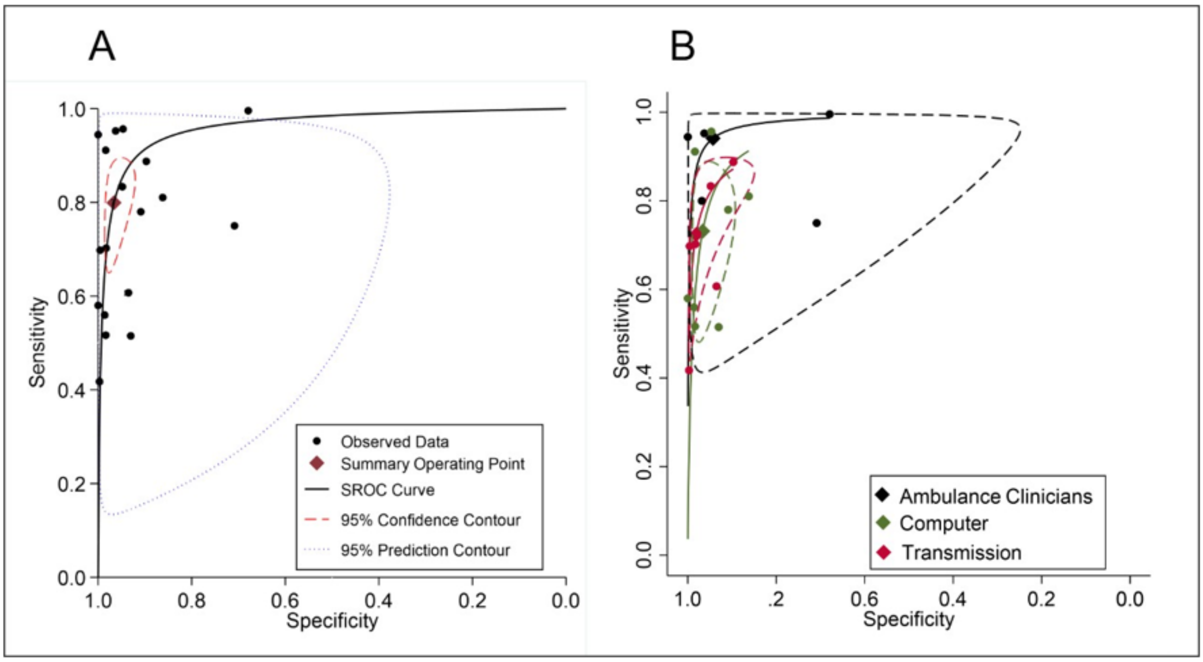


Figure 2: Area under the summary receiver operating characteristic (SROC) curve analysis for all ST-elevation myocardial infarction studies (A) and across the methods of interpretation (B).

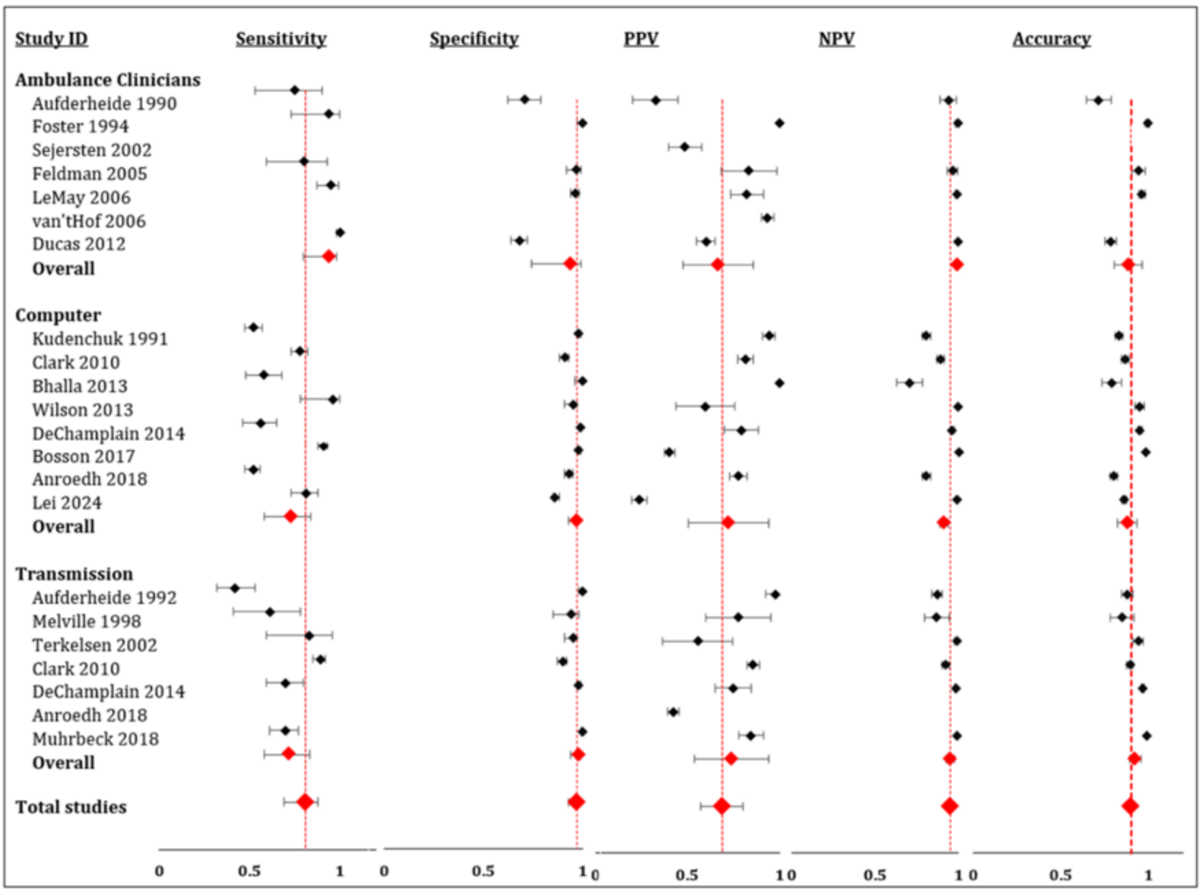


Figure 3: The forest plot for all methods of interpretation for all diagnostic performance metrics. PPV: positive predictive value; NPV: negative predictive value.

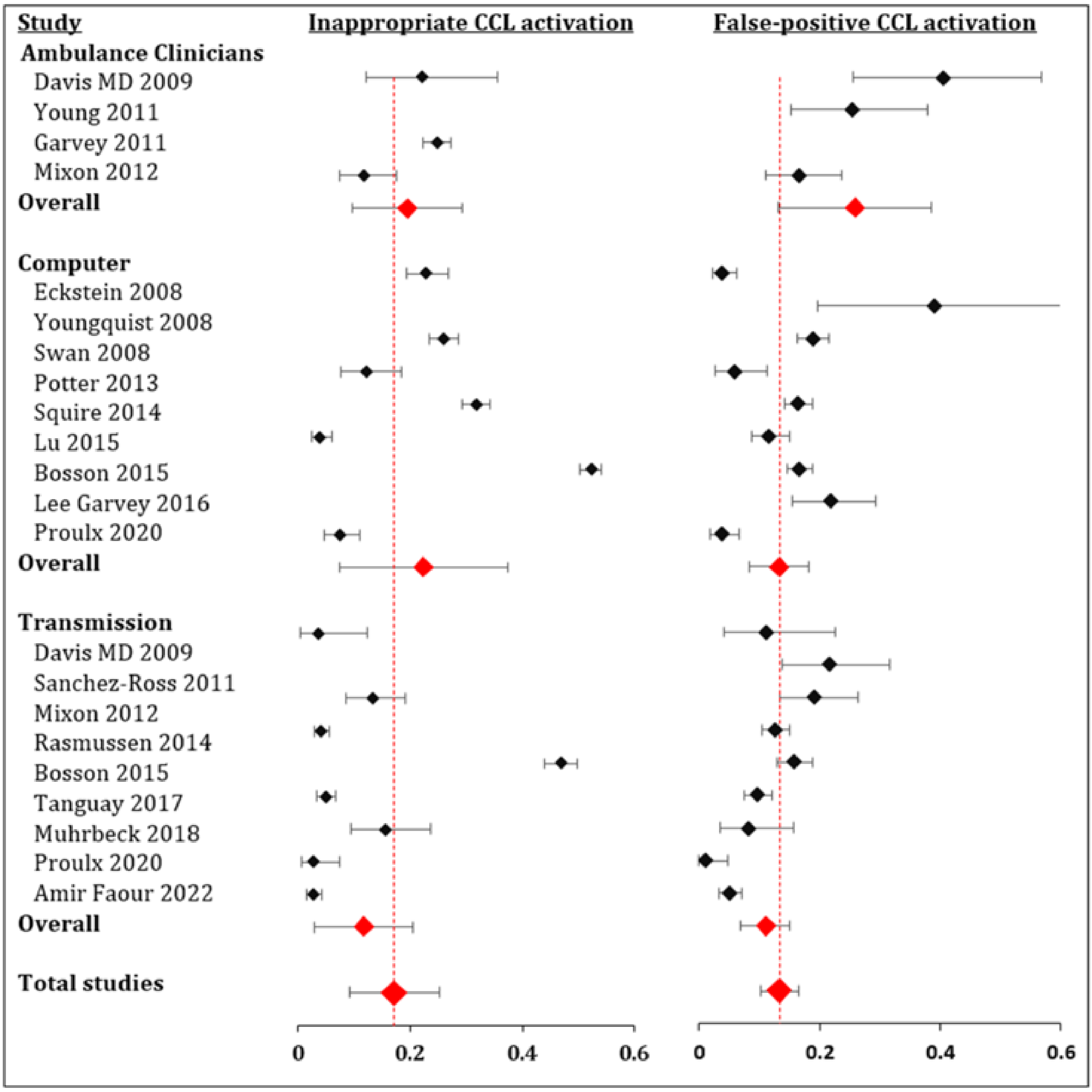


Figure 4: The forest plot for all methods of interpretation for inappropriate and false-positive cardiac catheterization laboratory (CCL) activation.

Table S 2: The characteristics of the included studies

Study	Subject	Study design	Sample size	Country	EMT level	Index test(s)	Reference standard
van Tt Hof, 2006	STEMI	Retrospective	209	Netherlands	Paramedics	Ambulance Clinicians	Final hospital diagnosis
Foster, 1994	STEMI	Retrospective	155	USA	ALS providers	Ambulance Clinicians	Final hospital diagnosis
Clark, 2010	STEMI	Retrospective	912	Denmark	Paramedics	Computer/ Transmission	Final hospital diagnosis
De Champlain, 2014	STEMI	Retrospective	1247	Canada	Paramedics/ BLS	Computer/ Transmission	Cardiologist
Feldman, 2005	STEMI	Prospective	151	USA	Paramedics	Ambulance Clinicians	Cardiologist
Sejersten, 2002	STEMI	Retrospective	121	USA	Paramedics	Ambulance Clinicians	PCI
Melville,1998	STEMI	Prospective	100	UK	Paramedics	Transmission	Final hospital diagnosis
Bhalla, 2013	STEMI	Retrospective	200	USA	EMT	Computer	Physicians
Le May, 2006	STEMI	Prospective	411	Canada	ACPs	Ambulance Clinicians	Cardiologist
Bosson, 2017	STEMI	Retrospective	44611	USA	Paramedics	Computer	Final hospital diagnosis
Kudenchuk, 1991	STEMI	Retrospective	1189	USA	Paramedics	Computer	Physicians
Ducas, 2012	STEMI	Prospective	380	Canada	Paramedics	Ambulance Clinicians	Cardiologist
Wilson, 2013	STEMI	Retrospective	309	USA	Paramedics	Computer	Physicians
Anroedh, 2018	STEMI	Retrospective	1421	Netherlands	Paramedics	Computer/ Transmission	Final hospital diagnosis
CJ, 2002	STEMI	Retrospective	250	Denmark	Paramedics	Transmission	Physicians
Aufderheide, 1990	STEMI	Retrospective	151	USA	Paramedics	Ambulance Clinicians	Final hospital diagnosis
Aufderheide, 1992	STEMI	Prospective	439	USA	Paramedics	Transmission	Final hospital diagnosis
Lai, 2024	STEMI	Prospective	2284	Asia	EMS Personnel	Computer	Final hospital diagnosis
Muhrbeck, 2018	Both	Retrospective	4298	Sweden	Paramedic and nurse	Transmission	Final hospital diagnosis
Tanguay, 2017	Cath	Retrospective	673	Canada	BLS-EMTs	Transmission	PCI
Faour, 2022	Cath	Prospective	565	Australia	Paramedics	Transmission	Final hospital diagnosis
Squire, 2014	Cath	Retrospective	1448	USA	Paramedics	Computer	PCI
Potter, 2013	Cath	Prospective	155	Canada	First responder	Computer	PCI
Davis MD, 2009	Cath	Prospective	166	USA	Paramedics	Ambulance Clinicians/ Transmission	Cardiologist
Young, 2011	Cath	Retrospective	47	USA	Paramedics	Ambulance Clinicians	PCI
Garvey, 2011	Cath	Retrospective	1150	USA	Paramedics	Ambulance Clinicians	PCI
Garvey, 2016	Cath	Retrospective	151	USA	Paramedics	Computer	PCI
Lu, 2015	Cath	Retrospective	442	Canada	Paramedics	Computer	Final hospital diagnosis
Proulx, 2020	Cath	Retrospective	428	Canada	Ambulance technician	Computer/ Transmission	Final hospital diagnosis
Eckstein, 2008	Cath	Prospective	1220	USA	Paramedics	Computer	PCI
Rasmussen, 2014	Cath	Prospective	919	Denmark	Paramedics	Transmission	Final hospital diagnosis
Sanchez-Ross, 2011	Cath	Prospective	92	USA	EMS Personnel	Transmission	PCI
Bosson, 2015	Cath	Retrospective		USA	Paramedics	Computer/ Transmission	PCI
Swan, 2009	Cath	Retrospective	529	USA	BLS and ALS	Computer	PCI
Youngquist, 2008	Cath	Prospective		USA	Paramedics	Computer	Cardiologist
Mixon, 2012	Cath	Retrospective	345	USA	EMS personnel	Transmission/ Ambulance Clinicians	Final hospital diagnosis

BLS: basic life support; EMT: emergency medical technician; PCI: precautious coronary intervention; ALS: advance life support; ACP: advance care Practitioner; EMS: emergency medical support; Cath: Catheterization laboratory activation; STEMI: ST-elevation myocardial infarction.

Table S 3: Sensitivity analysis after excluding outliers and influential studies

Metrics	Overall	Ambulance clinician (n=4)	Computer (n=8)	Transmission (n=6)
AUC	0.95 (0.93, 0.96)	0.96 (0.94 - 0.98)	0.95 (0.93 - 0.97)	0.94 (0.91, 0.95)
Sensitivity	0.76 (0.67, 0.83)	0.90 (0.76, 0.96)	0.73 (0.58, 0.84)	0.72 (0.58, 0.83)
Specificity	0.97 (0.95, 0.98)	0.96 (0.81, 0.99)	0.97 (0.93, 0.98)	0.98 (0.94, 0.99)
Diagnostic Odds Ratio	106 (54, 208)	232 (17, 3108)	78 (33, 186)	136 (59, 312)
Positive Likelihood Ratio	26.0 (14.2, 47.6)	24.9 (3.9, 159.5)	21.6 (10.7, 43.9)	38.3 (13.7, 106.6)
Negative Likelihood Ratio	0.25 (0.18, 0.34)	0.11 (0.04, 0.27)	0.28 (0.17, 0.45)	0.28 (0.18, 0.44)
I-square	100 (99, 100)	57 (3-100)	99 (98, 99)	99(99,100)

AUC: area under the curve.

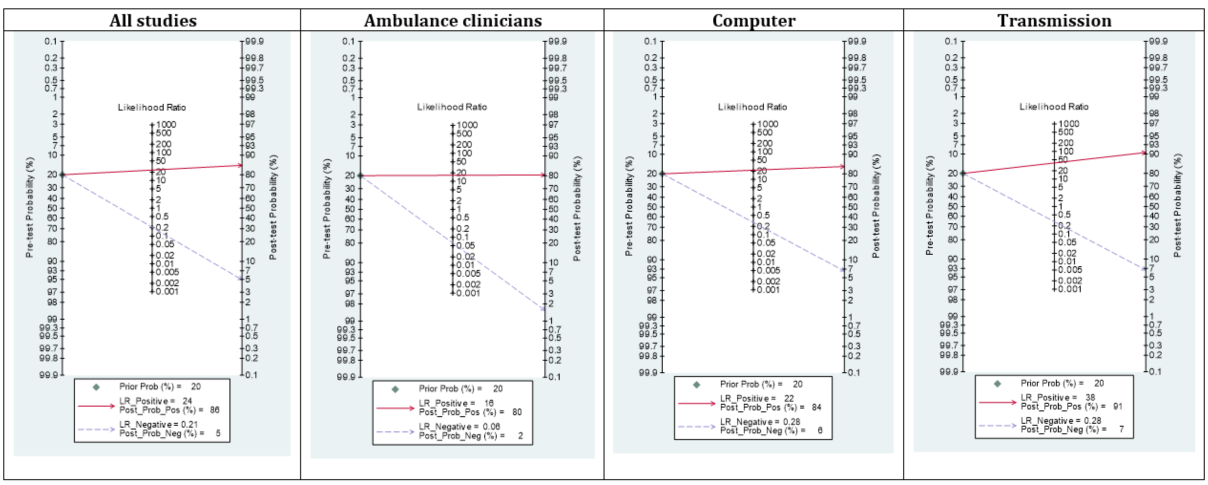


Figure S 1: Fegan Plots of different electrocardiogram interpretation methods for ST-elevation myocardial infarction identification in prehospital setting. Prob: probability; LR: likelihood ratio; Pos: positive; Neg: negative.

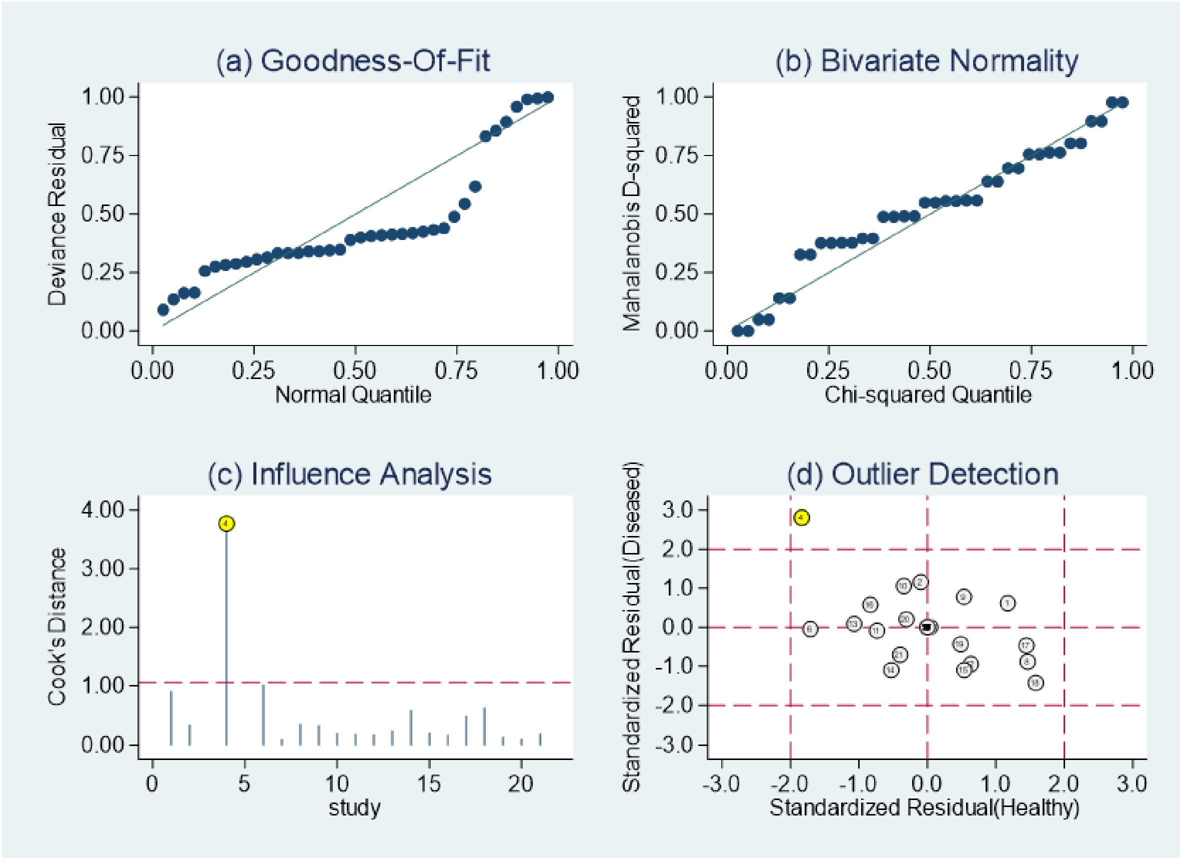
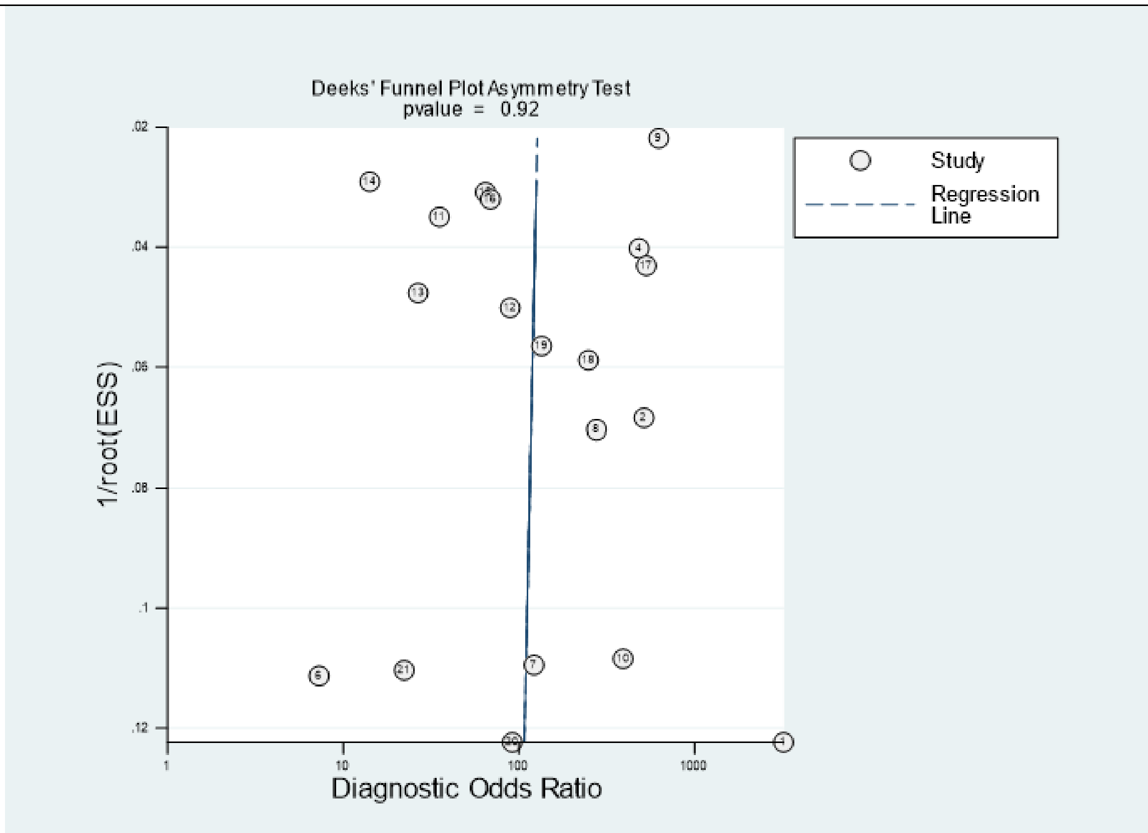


Figure S 2: Outliers and influential studies.



yb	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Bias	-.2891239	16.46305	-0.02	0.986	-35.18923	34.61098
Intercept	4.902572	.7302988	6.71	0.000	3.354408	6.450736

Figure S 3: Deeks' funnel plot asymmetry test. ESS: effective sample size; Coef.: coefficient; Std. Err.: standard error; Conf. confidence.