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Systematic Review/Meta-analysis

Effect of Prehospital Digital Electrocardiogram Transmission on Revascularization Delays and Mortality in ST-Elevation Myocardial Infarction Patients: Systematic Review and Meta-Analysis

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ABSTRACT

Background: Prehospital transmission of the 12-lead electrocardiogram (ECG) to the interventional cardiologist has become the standard of care in many ST-elevation myocardial infarction (STEMI) networks but has not been adopted universally. In this systematic review and meta-analysis, we assess the effect of prehospital digital ECG transmission in STEMI patients on door-to-device times, first medical contact-to-device times, and mortality.

Methods: We performed a systematic review of all English-language studies in MEDLINE, Embase, and CENTRAL (from inception to July 24, 2023), comparing the effect of prehospital digital ECG transmission to that of no ECG transmission in STEMI patients. We performed a random-effects meta-analysis.

Results: We included 17 observational studies totalling 4306 patients. Door-to-device times were reduced by 33.3 minutes in patients with

RÉSUMÉ

Contexte : La transmission préhospitalisation de l'électrocardiogramme (ECG) à 12 dérivations au cardiologue interventionniste est devenue la norme dans de nombreux centres de traitement de l'infarctus du myocarde avec élévation du segment ST (STEMI), mais cette pratique n'a pas encore été adoptée partout. Dans cette revue systématique et méta-analyse, nous évaluons l'effet de la transmission de l'ECG numérique préhospitalisation dans les cas de STEMI sur le délai entre le passage de la porte des urgences et l'intervention médicale, sur le délai entre la première consultation du patient et l'intervention médicale, ainsi que sur la mortalité.

Méthodologie : Nous avons réalisé une revue systématique de toutes les études anglaises dans les bases MEDLINE, EMBASE et CENTRAL (de leur création jusqu'au 24 juillet 2023), en comparant l'effet de la transmission des ECG numériques préhospitalisation à l'absence de

Meta-analyses have shown that primary percutaneous coronary intervention (PCI) reduces mortality, compared to fibrinolytic therapy alone.[1] However, recent studies have shown that pharmacoinvasive strategies with prehospital fibrinolysis may be associated with similar outcomes.[2,3] Time to treatment has been shown to be an important predictor for patients undergoing primary PCI.[4,5] Strategies to minimize time to primary PCI have become a major focus in the management of ST-elevation myocardial infarction (STEMI). Door-to-device times have become standard quality metrics for STEMI care, in Canada and internationally.[6] Prehospital 12-lead electrocardiogram (ECG) acquisition in the ambulance has become standard practice for earlier diagnosis of STEMI cases in the field. Although digital prehospital ECG transmission to the interventional cardiologist may improve case selection and patient outcomes, its utilization remains inconsistent in many regions.

This systematic review and meta-analysis aims to explore the potential impact of prehospital digital ECG transmission on door-to-device times, first-medical-contact (FMC)-to-device times, and mortality in STEMI patients.

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prehospital digital ECG transmission (95% confidence intervals [CIs] -50.5, -16.2 minutes; $P < 0.001$; I^2 99%). First-medical-contact-to-device time also was reduced with prehospital digital ECG transmission (mean difference, -24.7 minutes; 95% CI -37.1, -12.3 minutes; $P < 0.001$; I^2 96%). Prehospital digital ECG transmissions was associated with a 47% reduction in mortality compared to no prehospital digital ECG transmission (117 of 1322 (8.9%) vs 181 of 1322 (13.7%), odds ratio 0.53, 95% CI 0.40, 0.69; $P < 0.001$; $I^2 = 0\%$).

Conclusions: Prehospital ECG transmission in STEMI patients, coupled with a systems of care reduced door-to-device times, first-medical-contact-to-device times, and mortality. STEMI networks should consider these findings to advocate for prehospital ECG transmission within their systems of care.

Study Registration: CRD42024509271 (PROSPERO).

transmission de l'ECG dans les cas de STEMI. Nous avons effectué une méta-analyse à effets aléatoires.

Résultats : Nous avons retenu 17 études observationnelles totalisant 4 306 patients. Le délai entre le passage de la porte des urgences et l'intervention médicale a été réduit de 33,3 minutes chez les patients dont l'ECG numérique avait été transmis avant l'hospitalisation (intervalle de confiance [IC] à 95 % : -50,5; -16,2 minutes; $p < 0,001$; I^2 99 %). Le délai entre la première consultation et l'intervention médicale a également été réduit avec la transmission de l'ECG numérique préhospitalisation (différence moyenne -24,7 minutes; IC à 95 % : -37,1; -12,3 minutes; $p < 0,001$; i^2 96 %). La transmission des ECG numériques avant l'hospitalisation a été associée à une réduction de 47 % de la mortalité, comparativement à l'absence de transmission de l'ECG numérique (117/1322 [8,9 %] *vs* 181/1322 [13,7 %], risque relatif approché 0,53, IC à 95 % : 0,40; 0,69; $p < 0,001$; $I^2 = 0$ %).

Conclusions : La transmission de l'ECG avant l'hospitalisation des patients ayant subi un STEMI, couplée à un système de soins a réduit le délai entre le passage de la porte des urgences et l'intervention médicale, a réduit le délai entre la première consultation médicale et l'intervention médicale et a réduit la mortalité. Les centres de traitement des STEMI devraient tenir compte de ces conclusions pour promouvoir la transmission des ECG avant l'hospitalisation au sein de leur système de soins.

Enregistrement de l'étude : CRD42024509271 (PROSPERO).

By evaluating the available evidence, the focus of this systematic review is to determine the effects of prehospital digital ECG transmission on door-to-device times in STEMI patients. The secondary objective is to explore the effects of digital ECG transmission on FMC-to-device times and overall mortality in STEMI patients.

Material and Methods

This systematic review and meta-analysis is reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) and Meta-Analysis of Observational Studies in Epidemiology (MOOSE) guidelines.[7,8]

Data sources and search strategy

We performed a comprehensive and systematic literature search of MEDLINE, Embase, and Cochrane Central Register of Controlled Trials (CENTRAL) from inception to July 24, 2023. The following search terms were used: (ST elevation myocardial infarction) AND (ECG transmission). The search was limited to English-language studies, with no geographic restrictions. We reviewed references of included studies and prior systematic reviews to ensure inclusion of relevant studies.

Study selection

Two reviewers (R.M. and S.J.) independently screened all titles and abstracts to identify those studies that met the inclusion criteria. Full texts of studies that were potentially eligible were then reviewed by the same 2 reviewers for final selection. Disagreements were resolved by consensus. Inclusion criteria for eligible studies were randomized trials and observational studies that compared prehospital digital ECG transmission for STEMI to no digital ECG transmission, and reported one of the following outcomes: (i) door-to-device time; (ii) first medical contact-to-device time; or (iii) mortality within 30 days (if this was not available, in-hospital mortality was used).

Data extraction, study outcomes, and definitions

The primary outcome was door-to-device time in minutes. Data extraction was performed independently by 2 reviewers (R.M. and S.J.). For each of the selected studies, the following data were extracted, if available: study characteristics (author, journal of publication, year, sample size, intervention vs control group, prehospital cardiac catheterization laboratory activation), and clinical outcomes (door-to-device times, FMC-to-device times, and death).

We assessed for risk of publication bias by visual inspection of a funnel plot for the primary outcome. We did not use the Cochrane risk-of-bias tool, as it is designed for use with randomized trials.[9] Measurement of the quality and validity of observational trials is controversial.[8]

Statistical analysis

Data for continuous variables were collected as means ± standard deviations, and for categorical variables as proportions. For continuous variables, we used inverse variance to calculate the mean difference and a 95% confidence interval (CI). Medians and interquartile ranges were converted to means and standard deviations using published methods.[10] For binary outcomes, we utilized the Mantel-Haenszel method to compute odds ratios with 95% CIs. We used the DerSimonian—Laird random-effects model. We calculated the I^2 statistic, expressed as a percentage, to estimate the degree of heterogeneity among the trials. We classified heterogeneity as recommended in the Cochrane Handbook, as follows: 0% to 40% may not be important; 30% to 60% may represent moderate heterogeneity; 50% to 90% may represent

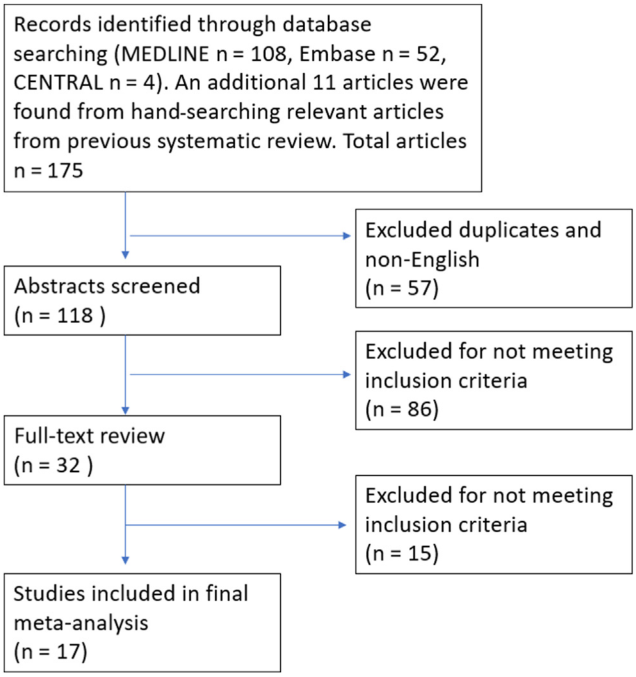

Figure 1. Flow diagram of study results. CENTRAL, Cochrane Central Register of Controlled Trials.

substantial heterogeneity; 75% to 100% indicates considerable heterogeneity.[9]

Statistical significance was defined as a *P*-value of ≤ 0.05. All statistical calculations were performed using Review Manager software (RevMan, Cochrane's web-based tool for managing systematic reviews, version 5.4.1).

Results

As depicted in Figure 1, a total of 164 citations were identified through database searching (MEDLINE n = 108; Embase n = 52; CENTRAL n = 4; Fig. 1). An additional 11 articles were found by hand-searching relevant articles from previous systematic reviews, for a total of 175 articles reviewed in abstract form. Duplicates and non-English abstracts were excluded, leaving 118 abstracts for review. We selected 32 for full-text review, based on inclusion criteria. The final meta-analysis included 17 studies after full-text review for inclusion criteria (Fig. 1).

Description of the studies

Details of the 17 selected studies [11-19,21-27] are presented in Table 1. The studies were published between 2000 and 2022. All studies, except for 4, combined digital prehospital ECG transmission with prehospital cardiac catheterization laboratory activation, bypassing the emergency room. Many of the studies looked at before-and-after implementation of prehospital digital ECG transmission, which was part of a system of care including prehospital cardiac catheterization laboratory activation.

Clinical outcomes

As shown in Figure 2, door-to-device time was reduced with prehospital digital ECG transmission; the mean difference is -33.3 minutes, with 95% CI -50.5, -16.2 minutes, $P < 0.001$; I^2 99%. FMC-to-device time also was reduced with prehospital digital ECG transmission, with mean difference -24.7, 95% CI -37.1, -12.3 minutes; $P < 0.001$; I^2 96% (Fig. 3). The mortality rate was lower in patients who had prehospital digital ECG transmission (117 of 1322 [8.9%]) vs those who did not (181 of 1322 [13.7%]; $P < 0.001$; I^2 0%; Fig. 4).

Publication bias was assessed with a funnel plot for the primary outcome as shown in Supplemental Figure S1 and suggested a low risk of publication bias.

Subgroup analysis

A subgroup analysis was performed to help evaluate the heterogeneity by looking at studies that examined digital ECG transmission alone vs digital ECG transmission with prehospital cardiac catheterization lab activation. We found a trend toward a greater reduction in door-to-device times when prehospital digital ECG transmission was combined with prehospital catheterization lab activation (-35.1 minutes) vs prehospital digital ECG transmission alone (-11.2 minutes, $P = 0.08$; Supplemental Fig. S2). Similar findings were found with FMC-to-device times (-35 vs -11.3 minutes, $P = 0.09$), with a trend toward greater effect with prehospital activation with digital ECG transmission (Supplemental Fig. S3). Mortality benefits were consistent in both subgroups, with and without prehospital catheterization laboratory activation (Supplemental Fig. S4).

Discussion

This systematic review and meta-analysis of 17 observational studies including 4306 patients shows that prehospital digital ECG transmission, coupled with systems of care, in patients with STEMI, was associated with reductions in door-to-device times, FMC-to-device times, and mortality. These findings are important, given the low cost and simplicity of ECG transmission in the digital era.

The most important finding of this systematic review is the reduction in mortality incidence associated with prehospital ECG transmission. Furthermore, no significant heterogeneity was present in these findings. These results provide an important rationale for incorporating prehospital ECG transmission into clinical practice.

A prior systematic review and meta-analysis of 8 studies examining the effect of prehospital ECG and advance notification in patients with STEMI included both studies with a verbal description of the ECG and studies with digital ECG transmission. The analysis found a 39% relative risk reduction in mortality with no significant heterogeneity, as well as reductions in FMC-to-device times, with high degrees of heterogeneity,[28] which is consistent with our findings.

The substantial heterogeneity observed in door-to-device times with digital ECG transmission is challenging. A subgroup analysis of studies with and without the combination of prehospital cardiac catheterization laboratory activation with digital ECG transmission still had high rates of heterogeneity. As a result, prehospital cardiac catheterization laboratory

Table 1. Summary of studies

Study	Type of study/ setting	Intervention group	Control group	Prehospital cath lab activation (Y/N)	Other inclusions and exclusions	Outcomes
Adams et al.[11] **(2006),** n = 72	RO	Attempted and successful digital ECG transmission 2003–2005	Before digital ECG transmission 2001–2003	Y	Patients who had ECG transmission failure between 2003 and 2005 were excluded from intervention group.	D2D
Arinaga et al.[12] **(2022),** n = 48	RO	Mobile cloud-based ECG transmission	Convention ECG (physician checks ECG upon arrival to hospital)	N	Only patients with STEMI were included, located in Shin-Yukuhashi Hospital, Fukuoka, Japan. 8684 consecutive patients (84 STEMIs).	D2D, mortality
Brunetti et al.[14] **(2020),** n = 47	RO study	Patients brought in via EMS with digital ECG transmission	Patients present directly to ER	Y	Times adjusted for distance to cath lab used; no outcomes for mortality. Regions with prehospital digital ECG were from farther away than the control group, who were from closer regions, so time was adjusted	D2D (was actually door-to-wire)
Carstensen et al.[15] **(2007),** n = 301	PO registry	Prehospital ECG transmission and cath-lab activation	No prehospital ECG transmission	Y	Compared prehospital ECG transmission with cath-lab activation vs no prehospital ECG transmission and no cath-lab activation. Included symptom-onset-to-balloon time.	Mortality
Chao et al.[16] **(2018),** n = 84	RO, b/a	Smartphone application of ECG images to an IC	Verbal description of ECG to an IC	Unclear *Could activate cath-lab team in both arms	ECG described via phone for control group.	D2D, mortality
Dhruva et al.[17] **(2007),** n = 49	PO, b/a	June–December 2006 STAT MI program which includes ECG transmission from EMS to ED and offsite cardiologist	2005 (calendar year) data	Y	New Jersey University Hospital	D2D
Hutchison et al.[13] **(2009),** n = 229	PO	Prehospital ECG transmission with cath lab activation	No prehospital ECG, and no cath-lab activation	Y	Compared pre and post implementation of MonAMI project with prehospital ECG, fax transmission, and cath-lab activation	D2D time
Kawakami et al.[18] **(2016),** n = 162	PO study	Patients transferred using mobile telemedicine 12-lead ECG transmission	Direct transfer from field to hospital without ECG transmission	Unclear	Patients who had interhospital transfers were excluded from this analysis.	D2D, FMC-to-device, mortality
Kerem et al.[19] **(2014),** n = 50	RO	EMS ECG transmitted to ED physician, would activate cath lab if STEMI present	Patients transported by EMS without prehospital ECG	Y	July 1, 2007–July 31, 2008	D2D
Martinoni et al.[20] **(2011),** n = 1529	RO	Prehospital ECG with transmission to dedicated intensive care or EMSC local unit, confirmation of STEMI by a cardiologist alerted nearest cath lab	No prehospital ECG transmission	Unclear	Italian STEMI registry. Not clear if prehospital cath-lab activation.	FMC-to-device, mortality
Ong et al.[21] **(2013),** n = 283	Prospective (intervention) and retrospective (control)	12-lead ECG performed by EMS and transmitted to ER (in 3 hospitals, ER doctor activated cath lab upon receipt of ECG. 4th-hospital ER doctor received ECG and transmitted it to cardiologist. 5th hospital—faxed ECG was bypassed to PCI centre	Chest pain patients received 12-lead ECG in ER	Y	Skewed data, different protocols for different hospitals.	D2D

Park et al.[22] **(2020)**, n = 115	PO study	12-lead ECG transmitted digitally to an on-call cardiologist; cardiologist spoke to ED to activate cath lab team	Prior 3 months before program implemented with no digital ECG transmission, composed of both interhospital and EMS patients	Y	August 2015—July 2016	D2D, FMC-to-device
Roswell et al.[23] **(2014)**, n = 245	RO	Prehospital transmission with cardiologist review to bypass ER and go directly to cath lab	Evaluation of patient begins in ER	Y		D2D, FMC-to-device, mortality
Sakai et al.[24] **(2018)**, n = 39	RO	Ambulance with ECG transmission	Ambulance transfer without ECG transmission; ECG done in ER	Y		D2D, FMC-to-device, mortality
Sanchez-Ross et al.[25] **(2011)**, n = 142	PO	ECGs transmitted to cardiologists on a smartphone; cardiologist activated cath lab	STEMIs treated as non-stat MI pathway—walk-in or EMS with no ECG transmission	Y		D2D, mortality
Sejersten et al.[26] **(2008)**, n = 235	RO	Prehospital ECG to cardiologist via mobile phone and cardiologist would activate team	Retrospective from DANAMI-2 trial, (randomized trial PCI vs thrombolytics—PCI group only included), no prehospital ECG	Y		D2D, FMC-to-device
Sorensen et al.[27] **(2011)**, n = 676	PO study	Prehospital diagnosis transmitted ECG wirelessly to primary PCI centre; on-call cardiologists would speak to EMS and activate cath lab—direct referral	No prehospital diagnosis	Y	Ambulances gradually equipped with ability to digitally transmit ECGs, so at times, both control and intervention were added, based on which ambulance the patient got	D2D, FMC-to-device, mortality

b/a, before and after; cath, catheterization; DANAMI-2 trial, **Dan**ish Trial in **A**cute **M**yocardial **I**nfarction-**2;** D2D, door-to-device; ECG, electrocardiogram; ED, emergency department; EMS, emergency medical services; ER, emergency room; FMC, first medical contact; EMSC, xx; IC, intensive care; MI, myocardial infarction; MonAMI project, N, no; PCI, percutaneous coronary intervention; PO, prospective observational; RO, retrospective observational; STAT-MI program, T-Segment Analysis Using Wireless Technology in Acute Myocardial Infarction; STEMI, ST-elevation myocardial infarction; Y, yes.

activation as a combined intervention does not explain the heterogeneity entirely.

Another potential source of heterogeneity is the differences in systems of care at different centres. For example, a study from one centre in Denmark had very low rates of door-to-device times, measured as 30 minutes in both groups—with and without digital ECG transmission.[27] A door-to-device time of 30 minutes at baseline is so good that any intervention may have difficulty significantly modifying that, and it represents an outstanding system of care in both groups. In contrast, when the entire country of Denmark was examined in a study by Sejersten et al. (2008), as a part of the DANish trial in Acute Myocardial Infarction 2 (DANAMI-2),[26] the use of digital ECG transmission had a door-to-device time of 49 minutes vs 112 minutes in the control group, which is much more consistent with the median door-to-device times in large contemporary registries.[6]

The degree of evidence needed for widespread implementation may be lower for technologies such as digital ECG transmission, which carries minimal risks and costs, compared to other interventions with greater potential risks and financial barriers. This decreased need argues for implementation of digital ECG transmission despite the evidence coming from observational studies.

Al-Zaiti, et al.[29] examined innovative solutions and digital advancements for wireless ECG transmission. This study reviewed the technological and logistical challenges faced in adopting these advancements, and it highlighted concerns, such as equipment malfunction and transmission failure, lack of reliability of mobile phone networks, lack of compliance, integration with medical records, and the need for robust education when implementing these digital technologies.[29] Digital technology has advanced significantly since this review was published (2013), and many of these issues have since been resolved.

Secure e-mail transmission of the ECG is a commonly used method for digital ECG transmission, and it is low-cost and simple. Other examples are the emergence of privacy-compliant smartphone applications, such as SMART-AMI (https://hhscebi.ca/smartami/) and Stenoa (https://www.stenoa.com), which leverage smartphones to transmit ECG data while preserving patient privacy and data integrity. Smartphone applications can have the ability to preactivate catheterization labs and have treatment algorithms built in, potentially including pharmacoinvasive strategies.

Limitations

The first limitation is that no randomized trials have compared digital ECG transmission to no digital ECG transmission. Given this, we are unable to determine causality. However, a reassuring finding is that the point estimate for almost all studies favours the intervention (digital ECG transmission) for the key primary and secondary outcomes. The pooled estimate and 95% CIs are also in favour of digital ECG transmission in all 3 meta-analyses. A second significant limitation is the high level of heterogeneity in door-to-device times and FMC-to-device times, meaning that any summary estimates of effects should be interpreted with caution. The

Study or Subgroup	ECG Transmission Mean	SD	Total	No ECG Transmission Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Adams et al,[11] (2006)	48.6	28.4	24	104.5	39.7	48	6.5%	-55.90 [-71.88, -39.92]
Arinaga et al,[12] (2022)	56.4	12.6	23	55.8	8.4	25	6.8%	0.60 [-5.51, 6.71]
Brunetti et al,[14] (2020)	53	43	23	86	55	24	5.8%	-33.00 [-61.16, -4.84]
Carstensen et al,[15] (2007)	43.5	11	108	120	21	193	6.9%	-76.50 [-80.12, -72.88]
Chao et al,[16] (2018)	90.4	9.8	44	119.3	16.3	40	6.8%	-28.90 [-34.72, -23.08]
Dhruva et al,[17] (2007)	80.1	35.4	20	145.6	76.9	29	5.6%	-65.50 [-97.50, -33.50]
Hutchinson et al,[13] (2009)	55	10	107	99	16	122	6.9%	-44.00 [-47.41, -40.59]
Kawakami et al,[18] (2016)	67.6	23.9	37	74	21.8	125	6.8%	-6.40 [-15.00, 2.20]
Kerem et al,[7] (2014)	66	36.2	30	79	26.3	20	6.4%	-13.00 [-30.34, 4.34]
Ong et al,[20] (2013)	66.8	83.1	156	86.2	82.5	127	6.3%	-19.40 [-38.79, -0.01]
Park et al,[21] (2020)	49.9	28.3	20	59.1	12.8	95	6.6%	-9.20 [-21.87, 3.47]
Roswell et al,[22] (2014)	45	16.7	59	64.4	23.9	186	6.8%	-19.40 [-24.87, -13.93]
Sakai et al,[23] (2018)	99.1	109.5	24	145.4	202	15	1.8%	-46.30 [-157.52, 64.92]
Sanchez-Ross et al,[24] (2011)	64.1	33.9	92	131.7	62.6	50	6.4%	-67.60 [-86.28, -48.92]
Sejersten et al,[25] (2008)	48.6	24	146	115.9	38.4	89	6.8%	-67.30 [-76.18, -58.42]
Sorensen et al,[26] (2011)	35.4	16.4	460	32.8	14.9	216	6.9%	2.60 [0.11, 5.09]
Total (95% CI)			**1373**			**1404**	**100.0%**	**-33.31 [-50.47, -16.16]**

Heterogeneity: Tau² = 1113.25; Chi² = 1592.62, df = 15 ($P < 0.00001$); I² = 99%
Test for overall effect: Z = 3.81 ($P = 0.0001$)

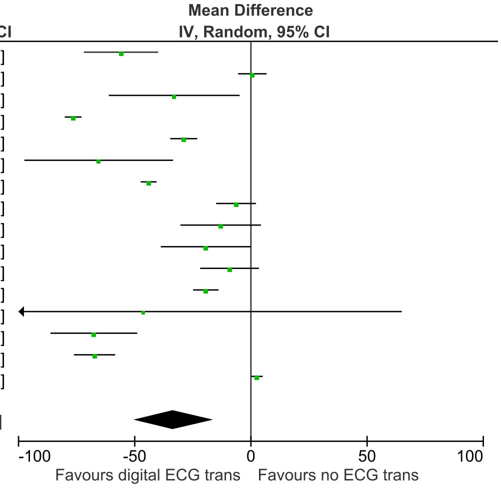

Figure 2. Door-to-device forest plot of comparison—digital electrocardiogram (ECG) transmission vs no digital ECG transmission. CI, confidence interval; df, degrees of freedom; ECG, electrocardiogram; SD, standard deviation; trans, transmission.

lack of heterogeneity with mortality is important and reassuring, especially because mortality is the most important outcome in this meta-analysis. A third limitation is that most studies were performed more than 10 years ago and so may be less applicable to the current era. Mechanisms for digital ECG transmission have evolved during this time. A fourth limitation is that many studies were before-and-after studies and so compared patients from different time periods, which may introduce bias. A fifth limitation is that many studies combined digital ECG transmission with additional changes in systems of care, such as prehospital activation, and therefore, determining the independent effects of digital ECG transmission is difficult. A sixth limitation is that false activation was not collected in the available studies, and future studies need to determine whether the amount of false activation can be reduced.

Despite challenges, randomized trials of digital interventions such as prehospital digital ECG transmission are valuable, as they would help these technologies become incorporated into guidelines and clinical practice. In the absence of randomized controlled trials, lower-quality evidence, such as that from observational studies, still could provide valuable insights for guidelines and clinical practice. However, such evidence should be approached with caution, and considerations of limitations must be taken into account.

Conclusion

We found that prehospital digital ECG transmission, coupled with systems of care in patients with STEMI in this systematic review and meta-analysis of observational studies, significantly reduced door-to-device times, FMC-to-device times, and mortality. These findings have important implications and suggest that regional STEMI networks should advocate for digital prehospital ECG transmission in their healthcare protocols, to improve patient care.

Ethics Statement

The research presented in this article has complied with all applicable ethical guidelines.

Study or Subgroup	ECG Transmission Mean	SD	Total	No ECG Transmission Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Arinaga 2022	78	13.4	23	78.8	8.4	25	14.5%	-0.80 [-7.19, 5.59]
Kawakami 2016	97	23.1	37	103.5	23.3	125	14.1%	-6.50 [-14.99, 1.99]
Martinoni 2011	52	14	475	78	18	1057	15.0%	-26.00 [-27.66, -24.34]
Park 2020	79.2	29.1	20	92.5	27.9	95	12.6%	-13.30 [-27.23, 0.63]
Roswell 2014	79.3	22.8	59	97.8	29.1	186	14.3%	-18.50 [-25.66, -11.34]
Sakai 2018	125.3	100.1	24	167.6	197.9	15	1.2%	-42.30 [-150.16, 65.56]
Sejersten 2008	77.5	22.5	146	127	36.2	89	14.1%	-49.50 [-57.86, -41.14]
Sorensen 2010	91.4	22.3	460	147.5	55.2	216	14.2%	-56.10 [-63.74, -48.46]
Total (95% CI)			**1244**			**1808**	**100.0%**	**-24.73 [-37.14, -12.31]**

Heterogeneity: Tau² = 266.96; Chi² = 177.00, df = 7 ($P < 0.00001$); I² = 96%
Test for overall effect: Z = 3.90 ($P < 0.0001$)

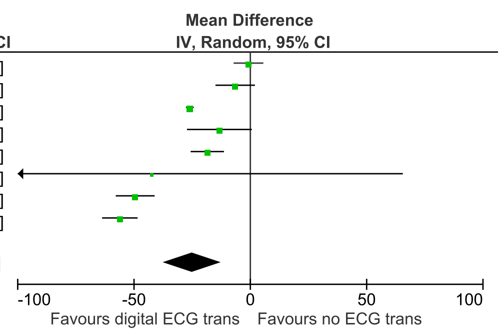

Figure 3. First medical contact-to-device forest plot of comparison—digital electrocardiogram (ECG) transmission vs no digital ECG transmission. CI, confidence interval; df, degrees of freedom; SD, standard deviation; trans, transmission.

Study or Subgroup	ECG Transmission Events	ECG Transmission Total	No ECG Transmission Events	No ECG Transmission Total	Weight	Odds Ratio M-H, Random, 95% CI
Arinaga et al,[12] (2022)	1	23	0	25	0.7%	3.40 [0.13, 87.72]
Carstensen et al,[15] (2007)	2	108	14	193	3.3%	0.24 [0.05, 1.08]
Chao et al,[16] (2018)	1	44	5	40	1.6%	0.16 [0.02, 1.46]
Kawakami et al,[18] (2016)	0	37	3	125	0.8%	0.47 [0.02, 9.24]
Martinoni et al,[19] (2011)	25	475	83	1054	35.3%	0.65 [0.41, 1.03]
Roswell et al,[22] (2014)	0	59	4	186	0.9%	0.34 [0.02, 6.42]
Sakai et al,[23] (2018)	4	24	2	15	2.2%	1.30 [0.21, 8.15]
Sanchez-Ross et al,[24] (2011)	1	92	3	50	1.4%	0.17 [0.02, 1.70]
Sorensen et al,[26] (2011)	83	460	67	216	53.7%	0.49 [0.34, 0.71]
Total (95% CI)		**1322**		**1904**	**100.0%**	**0.53 [0.40, 0.69]**
Total events	117		181			

Heterogeneity: Tau² = 0.00; Chi² = 6.29, df = 8 (*P* = 0.61); I² = 0%
Test for overall effect: Z = 4.57 (*P* < 0.00001)

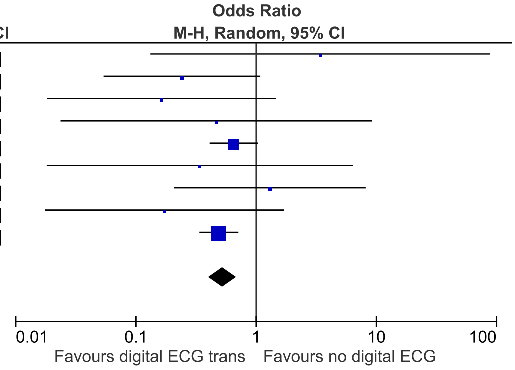

Figure 4. Forest plot of mortality—digital electrocardiogram (ECG) transmission vs no digital ECG transmission. CI, confidence interval; df, degrees of freedom; M-H, Mantel–Haenszel; SD, standard deviation; trans, transmission.

Patient Consent

Patient consent was not needed for this systematic review and meta-analysis, because it involves the analysis of previously published data, without the use of any individual patient data or direct patient involvement.

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Supplementary Material

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