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Utility of prehospital electrocardiogram interpretation in ST-segment elevation myocardial infarction utilizing computer interpretation and transmission for interventional cardiologist consultation

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Abstract

Objectives: We examined the appropriateness of prehospital cardiac catheter laboratory activation (CCL-A) in ST-segment elevation myocardial infarction (STEMI) utilizing the University of Glasgow algorithm (UGA) and remote interventional cardiologist consultation.

Background: The incremental benefit of prehospital electrocardiogram (PH-ECG) transmission on the diagnostic accuracy and appropriateness of CCL-A has been examined in a small number of studies with conflicting results.

Methods: We identified consecutive PH-ECG transmissions between June 2, 2010 and October 6, 2016. Blinded adjudication of ECGs, appropriateness of CCL-A, and index diagnoses were performed using the fourth universal definition of MI. The primary outcome was the appropriate CCL-A rate. Secondary outcomes included rates of false-positive CCL-A, inappropriate CCL-A, and inappropriate CCL nonactivation.

Results: Among 1088 PH-ECG transmissions, there were 565 (52%) CCL-As and 523 (48%) CCL nonactivations. The appropriate CCL-A rate was 97% (550 of 565 CCL-As), of which 4.9% ($n = 27$) were false-positive. The inappropriate CCL-A rate was 2.7% (15 of 565 CCL-As) and the inappropriate CCL nonactivation rate was 3.6% (19 of 523 CCL nonactivations). Reasons for appropriate CCL nonactivation ($n = 504$) included nondiagnostic ST-segment elevation ($n = 128$, 25%), bundle branch block ($n = 132$, 26%), repolarization abnormality ($n = 61$, 12%), artefact ($n = 72$, 14%), no ischemic symptoms ($n = 32$, 6.3%), severe comorbidities ($n = 26$, 5.2%), transient ST-segment elevation ($n = 20$, 4.0%), and others.

Conclusions: PH-ECG interpretation utilizing UGA with interventional cardiologist consultation accurately identified STEMI with low rates of inappropriate and false-positive CCL-As, whereas using UGA alone would have almost doubled CCL-As. The benefits of cardiologist consultation were identifying "masquerading" STEMI and avoiding unnecessary CCL-As.

KEYWORDS

acute coronary syndrome, cardiac catheterization laboratory, infarction, interventional cardiology, myocardial infarction, percutaneous coronary intervention, prehospital ECG interpretation, ST-segment elevation myocardial

1 | INTRODUCTION

Treatment delays of patients with ST-segment elevation myocardial infarction (STEMI) are associated with increased mortality.[1] Interpretation of prehospital electrocardiograms (PH-ECGs) and advanced notification of the percutaneous coronary intervention (PCI) center, with or without transmission, have been shown in a metanalysis to reduce total ischemic time and improve outcomes.[2] The PH-ECG can be interpreted by computer algorithms, paramedics, or transmission to clinicians for over-read. In healthcare settings where paramedics trained in ECG interpretation are not available, utilizing computer algorithms to detect STEMI in the field may be an attractive strategy to reduce total ischemic time.[3–6] However, in the absence of clinician over-read, this strategy has been associated with high rates of false-negative/positive STEMI diagnoses and inappropriate cardiac catheter laboratory (CCL) activations.[7–14] As a result, some guidelines recommend clinician oversight of computer-based CCL activation strategies.[15,16]

While the evidence supports a transmission-based CCL activation strategy in reducing total ischemic time, there is little evidence to suggest this strategy significantly increases diagnostic accuracy and appropriate CCL activations.[3,4] The small of number studies comparing the accuracy of PH-ECG computer interpretation (with or without paramedic over-read) with transmission for clinician interpretation have reported conflicting results.[13,17,18] In addition, these studies,[13,17,18] and others[19,20] reporting on the accuracy of PH-ECG transmission primarily involved transmission to emergency physicians for over-read. As examination of the appropriateness of CCL activation using PH-ECG transmission with interventional cardiologist over-read has not been assessed, we evaluated this strategy.

2 | METHODS

2.1 | Study population

In 2010 New South Wales Ambulance, Australia, which serves a population of >8 million people, started on a local health district basis PH-ECG transmission for the diagnosis of STEMI utilizing the University of Glasgow algorithm (UGA)[21] to clinicians at the 24 h PCI center with the shortest anticipated travel time from the patient's location. In the South Western Sydney Local Health District (which serves ~1 million people), PH-ECGs were transmitted to interventional cardiologists at Liverpool Hospital and commenced in June 2010. We prospectively identified consecutive patients presenting with suspected STEMI between June 2, 2010 and October 6, 2016, who had PH-ECGs transmitted to Liverpool Hospital. Patients were included if they were ≥18 years of age and had a transmitted PH-ECG with a computer diagnosis of STEMI. Exclusion criteria were patients with missing data, serial, or duplicate transmissions (the first diagnostic PH-ECG was included for patients with dynamic ST-segment changes), patients who had no troponin tested, and those already treated with fibrinolytic therapy. Paramedics acquired ECGs on patients with chest pain or equivalent symptoms using Lifepak 15 monitors/defibrillators (Physio-Control) equipped with the UGA. However, paramedics were obliged to transmit ECGs with a computer diagnosis of STEMI even if performed for other reasons.

PH-ECGs were transmitted directly from paramedic-staffed ambulances to the mobile device of the on-call interventional cardiologist and simultaneously to the 24 h PCI center via Lifenet (a cloud-based network; Physio-Control). After business hours, the interventional cardiologist was offsite and received PH-ECG transmissions on their mobile device. The transmitted ECGs contained a callback number which the interventional cardiologist used to discuss with paramedics the options of prehospital CCL activation, or prehospital fibrinolysis, depending on clinical presentation and anticipated transport time. If the interventional cardiologist agreed with computer interpretation and primary PCI was planned, a single call to the hospital operator activated the CCL team and patients were transported directly to the CCL, bypassing the emergency department. If the interventional cardiologist disagreed with computer interpretation, or if the prehospital diagnosis of STEMI was unclear or patient candidacy for emergency angiography was questionable, paramedics were instructed to repeat the ECG and transport the patient to the 24 h PCI center for further assessment. If paramedics were unable to transmit the PH-ECG successfully, their protocol dictated transfer to the nearest hospital. During the study period, on-call interventional cardiologists responded to all PH-ECG transmissions. However, ECGs of patients presenting directly to the emergency department were initially read by emergency department staff and cardiology staff only reviewed on referral. The study

was approved by the South Western Sydney Local Health District (2019/ETH12962). The need for informed consent was waived.

2.2 | Definitions

PH-ECG transmissions that resulted in emergency coronary angiography were classified as CCL activation, and those that did not result in emergency angiography were classified as CCL nonactivation. Patients in whom emergency angiography did not occur due to death were included in the CCL activation group. PH-ECGs were adjudicated by two interventional cardiologists (authors A. F. and O. G.) blinded to CCL activation status, coronary angiography findings, and index diagnoses. Disagreements were resolved by consensus. STEMI ECG criteria were defined as persistent (≥20 min) ST-segment elevation of ≥1 mm (except ≥2 mm in men >40 years, ≥2.5 mm in men <40 years, or ≥1.5 mm in women in leads V2-3) in ≥2 contiguous leads.[22]

The following STEMI equivalents were recorded: left bundle branch block (BBB) (new/presumed new or preexisting with Sgarbossa concordance[23]), posterior MI, and left main coronary ischemia. Posterior MI was defined as ST-segment depression ≥0.5 mm in leads V1–V3 with a prominent R wave or R/S ratio >1.[24] Left main coronary ischemia was defined as ST-segment elevation in aVR accompanied by ≥1 mm ST-segment depression in ≥6 leads.[22] In addition, the following STEMI mimics were recorded: the early repolarization pattern,[25] pericarditis,[26] left ventricular hypertrophy,[27,28] old MI,[22] Brugada pattern,[29] preexisting left BBB,[30] and paced rhythm. Nondiagnostic ST-segment elevation was defined as ≥0.5 and <1 mm in ≥1 lead. Pathologic Q waves and BBB were defined according to the fourth universal definition MI (4th UDMI) and American College of Cardiology Foundation/American Heart Association/Heart Rhythm Society recommendations, respectively.[22,30]

To determine the rate of MI, the authors (A. F. and O. G.) adjudicated all cases according to the 4th UDMI after reviewing clinical presentations, PH-ECGs, coronary angiograms, and troponin T kinetics.[22] Patients were classified as (1) STEMI, (2) non-STEMI, and (3) no MI. The infarct-related artery was defined as significant angiographic coronary stenoses (≥70%, except for left main coronary artery ≥50%) or altered thrombolysis in myocardial infarction flow grade (<3) in a coronary artery corresponding to the myocardial territory on the index PH-ECG.[31] In the setting of left BBB, STEMI was adjudicated in patients with cardiac ischemic symptoms and appropriate troponin T kinetics in the presence of Sgarbossa concordance or an infarct-related artery on coronary angiography.[23]

The fourth-generation troponin T assay (Roche Diagnostics) was used until June 15, 2011 (99th percentile upper reference limit ≥0.01 ng/ml), and the fifth-generation (high-sensitivity) troponin T assay (Roche Diagnostics) was used thereafter (99th percentile upper reference limit ≥14 ng/L). Peak troponin T levels were divided by the upper reference limits to facilitate comparison between fourth- and fifth-generation assays. First medical contact was defined as time of contact with paramedics, and device time was defined as time of the first device used to achieve reperfusion in the infarct-related artery.

2.3 | Endpoints

Definitions of the study endpoints are shown in Table 1. The primary endpoint was the appropriate CCL activation rate. Secondary

TABLE 1 Definitions of the study endpoints

Endpoint	Definition
Primary endpoint	
Appropriate CCL activation rate	The number of appropriate CCL activations divided by the total number of CCL activations. Appropriate CCL activation is defined as CCL activation in a patient with all of the following: (1) cardiac ischemic symptoms (<12 h), (2) STEMI ECG criteria/equivalents, and (3) absence of contraindications to emergency coronary angiography[a]
Secondary endpoints	
False-positive CCL activation rate	The number of appropriate CCL activations in patients without an adjudicated index diagnosis of STEMI divided by the total number of appropriate CCL activations
Inappropriate CCL activation rate	The number of inappropriate CCL activations divided by the total number of CCL activations. Inappropriate CCL activation is defined as CCL activation in a patient with any of the following: (1) absence of cardiac ischemic symptoms, (2) absence of STEMI ECG criteria/equivalents, or (3) presence of contraindications to emergency coronary angiography
Inappropriate CCL nonactivation rate	The number of inappropriate CCL nonactivations divided by the total number of CCL nonactivations. Inappropriate CCL nonactivation is defined as CCL nonactivation in a patient with all of the following: (1) cardiac ischemic symptoms (<12 h), (2) STEMI ECG criteria/equivalents, and (3) absence of contraindications to emergency coronary angiography

Abbreviations: CCL, cardiac catheter laboratory; ECG, electrocardiogram; STEMI, ST-segment elevation myocardial infarction.

[a]STEMI ECG criteria were defined as ST-segment elevation of ≥1 mm (except ≥2 mm in men >40 years, ≥2.5 mm in men <40 years, or ≥1.5 mm in women in leads V2-3) in ≥2 contiguous leads. STEMI equivalents were defined as: (1) left bundle branch block (new/presumed new or preexisting with Sgarbossa concordance), (2) posterior myocardial ischemia, (3) left main coronary artery ischemia, and (4) return of spontaneous circulation following witnessed out of hospital cardiac arrest from a shockable rhythm.

endpoints included rates of false-positive CCL activation, inappropriate CCL activation, and inappropriate CCL nonactivation. The appropriateness of CCL activation was independently classified by the authors (A. F. and O. G.) according to clinical context and PH-ECG findings blinded to the outcome of coronary angiography.

2.4 | Statistical analysis

All analyses were performed using R (v4.1.2) and the *gtsummary* package.[32] Categorical variables are presented as numbers (%) and continuous variables as medians with interquartile range [IQR].

3 | RESULTS

Between June 2, 2010 and October 6, 2016, 1583 PH-ECG transmissions were assessed for eligibility, and of these, 1088 (69%) met the inclusion criteria (Figure 1). Reasons for exclusion (n = 498, 31%) included serial/duplicate ECGs (n = 264, 17%), missing data (n = 133, 8.4%), troponin not tested (n = 70, 4.4%), and fibrinolytic-treated patients (n = 28, 1.8%). PH-ECG transmission resulted in 565 (52%) CCL activations and 523 (48%) CCL nonactivations. Baseline characteristics of the study population are shown in Table 2. The median patient age was 65 years [IQR, 55–78] and 28% (n = 301) were female.

Among 565 CCL activations, the appropriate CCL activation rate was 97% (n = 550), 90% (n = 507) underwent primary PCI, 1.2% (n = 7) underwent coronary artery bypass grafting, and 7.3% (n = 41) had no culprit artery on invasive coronary angiography. In patients who underwent primary PCI, the median first medical contact-to-device time was 99 min [IQR, 78–118]. Of the 550 appropriate CCL activations, 4.9% (n = 27) did not have an adjudicated index diagnosis of STEMI (the false-positive CCL activation rate). Discharge diagnoses in patients with false-positive CCL activation are shown in Table 3. Inappropriate CCL activation was adjudicated in 15 of 565 CCL activations (2.7% of CCL activations; 1.4% of PH-ECG transmissions), of which 11 patients did not have an adjudicated index diagnosis of MI and 3 patients had non-STEMI. Reasons for inappropriate CCL activation are shown in Table 4.

Among 523 CCL nonactivations, 504 were appropriate (96% of CCL nonactivations; 46% of PH-ECG transmissions), and 19 were inappropriate (3.6% of CCL nonactivations; 1.7% of PH-ECG transmissions) (Figure 1). Of 504 appropriate CCL nonactivations, reasons for nonactivation included nondiagnostic ST-segment elevation (n = 128, 25%), artefact (n = 72, 14%), BBB (n = 132, 26%, of which 70 were right BBB without STEMI ECG criteria and 62 were preexisting left BBB), repolarization abnormality (n = 61, 12%), and others (Figure 2). In the 19 patients who had inappropriate CCL nonactivation, the adjudicated index diagnoses were STEMI (n = 18, 95%) and Takotsubo cardiomyopathy (n = 1, 5.0%). All 19 inappropriate CCL nonactivations were found to have STEMI ECG criteria on blinded adjudication, and all underwent invasive coronary angiography during index hospitalization.

4 | DISCUSSION

We examined the appropriateness of CCL activation in patients with STEMI utilizing PH-ECG computer interpretation and transmission to interventional cardiologists for over-read. We found low rates of the

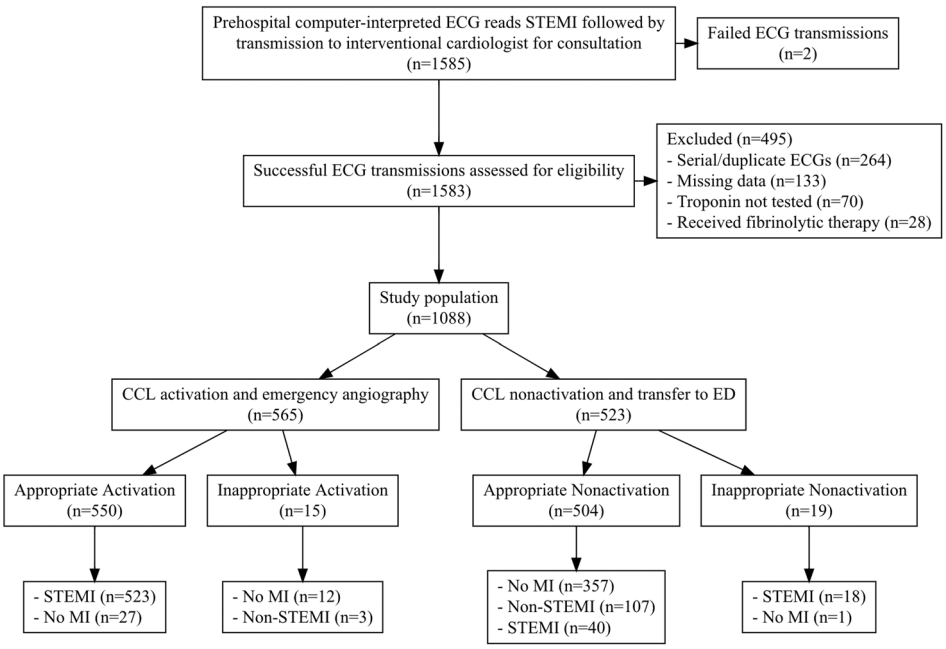

FIGURE 1 Study flow diagram with identification of the study population by classification according to the appropriateness of cardiac catheter laboratory activation (CCL) and the fourth universal definition of myocardial infarction. Three patients with CCL activation expired before emergency coronary angiography. ECG, electrocardiogram; ED, emergency department; STEMI, ST-segment elevation myocardial infarction.

TABLE 2 Baseline characteristics of the study population

Variable	Study population (*n* = 1088)
Baseline characteristics	
Age [IQR], years	65 [55–78]
Female, *n* (%)	301 (28)
Past medical history	
Diabetes mellitus, *n* (%)	329 (30)
Hypertension, *n* (%)	694 (64)
Dyslipidaemia, *n* (%)	639 (59)
Previous myocardial infarction, *n* (%)	292 (27)
Previous stroke, *n* (%)	104 (9.6)
Family history of coronary artery disease, *n* (%)	104 (9.6)
Smoking history, *n* (%)	550 (51)
Index ECG[a]	
STEMI criteria, *n* (%)	661 (61)
Nondiagnostic ST-segment elevation, *n* (%)[b]	150 (14)
Left bundle branch block, *n* (%)	78 (7.2)
Right bundle branch block, *n* (%)	119 (11)
Left main coronary ischemia, *n* (%)[c]	5 (0.5)
Presentation characteristics	
Cardiac arrest, *n* (%)	17 (1.6)
Peak troponin T/upper reference limit [IQR][d]	47 [2–282]
Invasive coronary angiography, *n* (%)	669 (61)
Infarct-related artery, *n* (%)	602 (55)
Right coronary	262 (44)
Left anterior descending	242 (40)
Circumflex	84 (14)
Graft	10 (1.7)
Left main	4 (0.7)
PCI, *n* (%)	560 (51)
CABG, *n* (%)	12 (1.1)
Treatment intervals[e]	
FMC-to-ECG [IQR], min	6 [4–9]
FMC-to-door [IQR], min	38 [29–48]
FMC-to-device [IQR], min	99 [78–118]
Door-to-device [IQR], min	57 [39–77]
Diagnostic classification[f]	
Myocardial infarction, *n* (%)	691 (64)
STEMI, *n* (%)	581 (53)
Non-STEMI, *n* (%)	110 (10)
No myocardial infarction, *n* (%)	397 (36)

Note: Values are *n* (%) or median [IQR].

Abbreviations: CABG, coronary artery by-pass graft surgery; ECG, electrocardiogram; FMC, first medical contact; IQR, interquartile range; PCI, percutaneous coronary intervention; STEMI, ST-segment elevation myocardial infarction.

[a]Index ECG characteristics are not categories of a single variable and are not mutually exclusive, therefore they do not add up to 100%.

[b]Nondiagnostic ST-segment elevation was defined as ≥0.5 and <1 mm in ≥1 lead.

[c]Left main coronary ischemia was defined as ST-segment elevation in lead aVR accompanied by ≥1 mm ST-segment depression in ≥6 leads.

[d]Troponin level divided by the upper reference limit to facilitate comparison between fourth-generation and high-sensitivity assays.

[e]Treatment intervals for patients undergoing primary PCI (*n* = 501).

[f]Adjudicated according to the fourth universal definition of MI.

TABLE 3 Discharge diagnoses in patients with false-positive cardiac catheter laboratory activation

Variable	Frequency (*n* = 27)
Pericarditis, *n* (%)	8 (30)
Takotsubo cardiomyopathy, *n* (%)	7 (26)
Chest pain—unspecified, *n* (%)	6 (22)
Syncope, *n* (%)	2 (7.4)
Arrhythmia, *n* (%)	1 (3.7)
Pancreatitis, *n* (%)	1 (3.7)
Respiratory tract infection, *n* (%)	1 (3.7)
Vomiting—unspecified, *n* (%)	1 (3.7)

Note: Values are *n* (%). False-positive cardiac catheter laboratory activations were defined as appropriate activations in patients without an adjudicated index diagnosis of ST-segment elevation myocardial infarction.

following: inappropriate CCL activation (2.7% of CCL activations; 1.4% of PH-ECG transmissions), inappropriate CCL nonactivation (3.6% of CCL nonactivations; 1.7% of PH-ECG transmissions), and false-positive CCL activation (4.9% of appropriate CCL activations; 2.5% of PH-ECG transmissions). Importantly, ~1/2 of all PH-ECG transmissions did not result in CCL activation after remote interventional cardiologist consultation. Also, >75% of CCL non-activations were due to STEMI mimics such as nondiagnostic ST-segment elevation, BBB, repolarization abnormality, and artefact.

Identifying STEMI by PH-ECG acquisition aims to reduce total ischemic time, though this may lead to high rates of emergency coronary angiography in patients who may subsequently not have a STEMI diagnosis confirmed. Several studies examining the appropriateness of prehospital CCL activation utilizing computer interpretation alone demonstrated high inappropriate CCL activation rates,

ranging between 23% and 65%.[11,13,14,33] Our study is the largest to examine the appropriateness of CCL activation utilizing PH-ECG transmission to interventional cardiologists. In previous studies, the PH-ECG was transmitted to emergency physicians,[17–20] and in two studies, cardiologists were part of the ECG reading team[34] or consulted in unclear cases.[13]

Initial studies on PH-ECG transmission conducted more than a decade ago primarily examined the effect of PH-ECG transmission on reperfusion times, and compared transmission to cardiologists with historical controls, self-presenting patients, or failed transmissions.[35–39] These studies involved small numbers of patients and were limited by wireless technology resulting in a high rate of failed transmissions (11%–44%).[35–39] Additionally, systematic examination of the appropriateness of CCL activation using mutually exclusive criteria was not performed. In all of these studies, transmission compared with controls was associated with significant reductions in reperfusion times.[35–39]

The incremental benefit of PH-ECG transmission on the diagnostic accuracy and appropriateness of CCL activation has been examined in a small number of studies with conflicting results.[13,17,18] Davis et al.[17] compared paramedic-based CCL activation versus transmission to emergency physicians for interpretation and demonstrated improved positive predictive value for identifying STEMI during the transmission phase of their trial (96% vs. 78%, $p < 0.01$). Diagnostic accuracy was determined according to cardiologist interpretation and the effect of PH-ECG transmission on total ischemic time was not reported. In contrast, Bosson et al.[13] compared PH-ECG computer-based CCL activation versus transmission to emergency physicians. They found that PH-ECG transmission resulted in a small reduction in the false-positive CCL activation rate from 61% to 55% (difference, 6%, 95% CI, −9%, −3%). False-positive activations were defined as those not resulting in emergent PCI or referral for coronary artery bypass grafting during hospitalization. However, 28% of PH-ECGs were transmitted successfully and transmission had no effect on total ischemic time. More recently, Boivin-Proulx et al.[18] examined the appropriateness of 428 PH-ECG-based CCL activations and reported a trend toward a reduction in the number of inappropriate CCL activations with transmission to emergency physicians for over-read compared with PH-ECG computer interpretation (7% vs. 3%, $p = 0.062$). However, PH-ECG transmission was associated with longer reperfusion times (median FMC-to-device time, 86 vs. 76 min, $p < 0.001$). Their definition of inappropriate CCL activation was based solely on the PH-ECG and did not consider symptoms, so this probably underestimated the inappropriate CCL activation rate.

In our cohort, PH-ECG transmission to interventional cardiologists for over-read resulted in a low inappropriate CCL activation rate (2.7% of CCL activations; 1.4% of PH-ECG transmissions). The interventional cardiologist's decision to activate the CCL for emergency coronary angiography occurred remotely and not on site after the patient had arrived. This is operationally pertinent in healthcare systems where the CCL team is offsite after business hours, though this may not be as relevant when the CCL team is onsite 24 h. Nevertheless, mobilizing the CCL team for a case unnecessarily when a decision could be made remotely is inefficient.

TABLE 4 Reasons for inappropriate cardiac catheter laboratory activation

Variable	Frequency ($n = 15$)
Nondiagnostic ST-segment elevation, *n* (%)[a]	7 (47)
Left ventricular hypertrophy, *n* (%)	5 (33)
Absence of cardiac ischemic symptoms, *n* (%)	1 (6.7)
Early repolarization pattern, *n* (%)	1 (6.7)
Right bundle branch block, *n* (%)	1 (6.7)

Note: Values are *n* (%). Inappropriate cardiac catheter laboratory activations were defined as activations in patients with any of the following: (1) absence of cardiac ischemic symptoms, (2) absence of STEMI ECG criteria/equivalents, or (3) presence of contraindications to emergency coronary angiography.

[a]Nondiagnostic ST-segment elevation was defined as ≥0.5 and <1 mm in ≥1 lead.

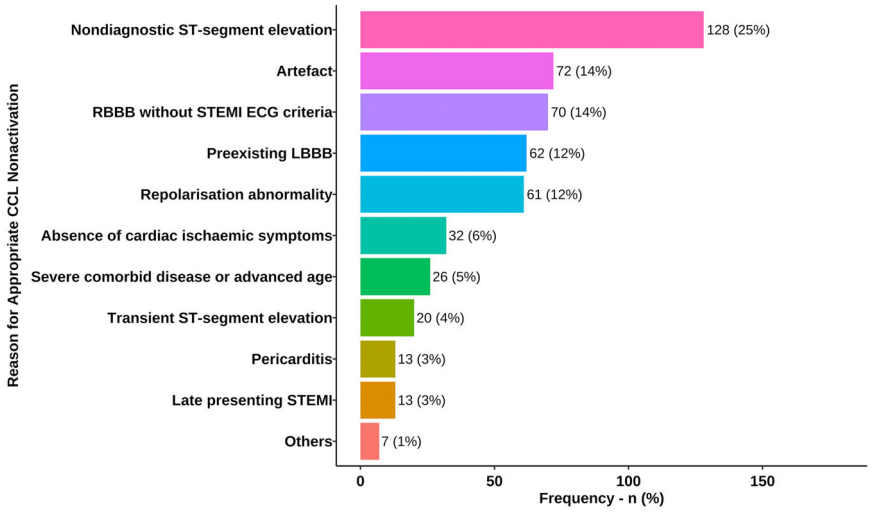

FIGURE 2 Reasons for appropriate cardiac catheter laboratory nonactivation. Others included old MI ($n = 6$) and patient refusal ($n = 1$). CCL, cardiac catheter laboratory; LBBB, left bundle branch block; RBBB, right bundle branch block; STEMI, ST-segment elevation myocardial infarction. [Color figure can be viewed at wileyonlinelibrary.com]

In a busy tertiary PCI center, this could detract from the care given to other critically ill patients.

In our analysis, the inappropriate CCL nonactivation rate (missed STEMI) was low (3.6% of CCL nonactivations; 1.7% of PH-ECG transmissions). Data on this metric are lacking in the literature, as most studies examining the appropriateness of prehospital CCL activation report the inappropriate or false-positive CCL activation rate.[4] Lange et al.[14] reported 1332 CCL activations and found an inappropriate CCL cancellation rate of 1%. However, the decision to proceed with emergency coronary angiography occurred after the CCL team physically reviewed patients on arrival. Ducas et al.[34] reported 380 CCL activations, utilizing a system of PH-ECG computer interpretation with transmission for physician over-read, and reported an inappropriate CCL nonactivation rate of 5.7%. Arguably, this is the most important metric of all, as missing a STEMI is usually more harmful than unnecessary emergency coronary angiography.

Our results show that the involvement of a clinician is needed in the triage of prehospital STEMI patients, as ~1/2 of PH-ECG transmissions did not result in CCL activation after remote interventional cardiologist consultation. Also, >75% of CCL nonactivations were due to STEMI mimics. The benefits of interventional cardiologist over-read and remote consultation were identifying "masquerading" STEMI and avoiding unnecessary CCL activations. This is important in STEMI systems of care where paramedics are obliged to transmit PH-ECGs with a computer diagnosis of STEMI even if the ECG was performed for other reasons, as in our case. Studies utilizing machine learning algorithms have reported high sensitivity (>96%) and specificity (>97%) for detecting STEMI; however, these algorithms have not been tested in the prehospital setting and are not in widespread clinical use.[40,41] Studies are needed to determine whether using machine learning ECG algorithms in the prehospital setting will reduce false-activation rates.

4.1 | Limitations

This was a single center study that utilized PH-ECG interpretation using the UGA with transmission to interventional cardiologists, limiting its generalizability to other STEMI systems of care. Adjudication of the appropriateness of CCL activation depended on a combination of objective and subjective components. While classification was performed by two cardiologists independently, blinded to the findings of emergency coronary angiography, misclassification may still have occurred. PH-ECGs that did not meet the UGA ECG criteria for STEMI were not transmitted and therefore were not available for analysis. As a result, sensitivity, specificity, positive, and negative predictive values could not be determined. It is important to note that the inappropriate CCL nonactivation rate (missed STEMI) only included patients who were flagged as meeting STEMI ECG criteria by the UGA on the PH-ECG.

5 | CONCLUSIONS

Prehospital identification of STEMI utilizing the UGA and remote interventional cardiologist consultation resulted in low rates of inappropriate CCL activation and nonactivation. The benefits of remote cardiologist consultation were identifying STEMI mimics and avoiding unnecessary CCL activations. We believe the involvement of clinicians trained in ECG interpretation, regardless of speciality, would improve the efficiency of computer-based PH-ECG interpretation primarily by detecting "masquerading" STEMI, provided that the process does not negatively impact reperfusion times. As prehospital activation of the CCL aims to reduce reperfusion times, healthcare systems will need to judge whether PH-ECG interpretation only or transmission should be utilized for CCL activation.

ACKNOWLEDGMENTS

The authors wish to thank the many New South Wales Ambulance paramedics, Liverpool Hospital cardiologists, and nursing staff whose help was critical to completing this study.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request. The analysis source code has been made publicly available on Github (https://github.com/akfaour/CCL-A.git).

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