CJC Open 2 (2020) 111–117

Original Article

Reducing Delay to Treatment of ST-Elevation Myocardial Infarction With Software Electrocardiographic Interpretation and Transmission (SCINET)

Justin M. Cloutier, MD, FRCPC, Christopher Hayes, MD, FRCPC, John Ducas, MD, FRCPC, and David W. Allen, MD, FRCPC

Section of Cardiology, Department of Internal Medicine, Max Rady College of Medicine, Rady Faculty of Health Sciences, University of Manitoba, Winnipeg, Manitoba, Canada

ABSTRACT

Background: Prehospital diagnosis of ST-elevation myocardial infarction (STEMI) has resulted in improved outcomes. However, many patients still walk in to the emergency department (ED) with STEMI, experiencing delays and worse outcomes. Software electrocardiogram (ECG) diagnosis of STEMI and electronic transmission to a cardiologist may result in improved door-to-device (D2D) times.

Methods: We retrospectively identified all patients presenting with STEMI from January 2015 to September 2016. Components of delay in D2D, ED variables, and the patients' ECGs were extracted from our regional database. All ECGs performed for suspected myocardial infarction in the region were extracted over the study period. We assessed the accuracy of the software 12SL in diagnosing STEMI, ED

RÉSUMÉ

Contexte : Le diagnostic préhospitalier de l'infarctus du myocarde avec élévation du segment ST (STEMI) contribue à améliorer les résultats pour les patients. Toutefois, de nombreux patients subissant un STEMI se présentent encore d'eux-mêmes au service des urgences, ce qui retarde leur traitement et entraîne des conséquences plus graves. Le diagnostic de STEMI au moyen d'un logiciel de prise d'électrocardiogramme (ECG) qui est ensuite transmis à un cardiologue par voie électronique pourrait réduire le délai entre l'arrivée à l'hôpital et la pose d'un dispositif (délai avant l'intervention).

Méthodologie : Nous avons rétrospectivement recensé tous les patients ayant subi un STEMI entre janvier 2015 et septembre 2016. Les facteurs entraînant l'augmentation du délai avant l'intervention, les

In ST-elevation myocardial infarction (STEMI), it is critical that reperfusion occurs as rapidly as possible. Since the first reports on the importance of time to reperfusion with angioplasty in the 1990s,[1] door-to-device (D2D) time is now recognized as a crucial quality indicator. If reperfusion occurs in more than 150 minutes versus less than 90 minutes, there is a 246% increased rate of in-hospital mortality.[2] A mere 14-minute increase in median reperfusion time is associated with increased in-hospital mortality.[3] This effect is not short-lived; for every 30-minute delay in revascularization, there is a 7.5% increase in 1-year mortality.[4] Given the urgency of rapid revascularization, treatment guidelines have established clear performance benchmarks: Percutaneous coronary intervention (PCI) should be performed within 120 minutes of initial presentation to hospital. This target of 120 minutes is the longest acceptable window and should be achieved with a frequency of at least 90%.[5] Local, regional, national, and institutional policies and protocols have proliferated, working to meet this target. Notably, direct transfer to a PCI-capable hospital from the field by emergency personnel trained in electrocardiogram (ECG) interpretation has drastically reduced D2D time and improved morbidity and mortality.[6-8] Unfortunately, D2D time remains elevated in patients who "walk-in" to the emergency department (ED) with chest pain who are subsequently diagnosed with STEMI.[9] If transfer to a PCI-capable center is required, this is associated with an almost doubling of reperfusion time.[10] There are multiple potential sources of delay; however, system delays have the strongest association with mortality.[6] In particular, the time from diagnostic ECG to physician decision that there is a STEMI and to pursue reperfusion has emerged as an important predictor of additional system delay and of mortality.[11] This explains the success of the prehospital ECG system: By immediately contacting an on-call cardiologist, the time from ECG to decision can be minimized.

One mechanism to reduce the delay in recognition and treatment of STEMI is the use of automated ECG

Received for publication December 3, 2019. Accepted February 11, 2020.

Ethics Statement: Ethics approval was obtained from the relevant local research ethics boards prior to study commencement.

Corresponding author: Dr Justin M. Cloutier, Y3039 Bergen Cardiac Centre, St Boniface Hospital, Winnipeg, Manitoba R2H 2A6, Canada. Tel.: +1-204-795-5016; fax: +1-204-487-0194.

E-mail: umclout3@myumanitoba.ca

See page 116 for disclosure information.

https://doi.org/10.1016/j.cjco.2020.02.003

contributors to delays in D2D, and the potential reduction in D2D if software diagnosis of STEMI resulted in activation of the cardiac catheterization laboratory.

Results: A total of 379 patients presented to an ED in our region and received primary percutaneous coronary intervention over the study period. In the 143,574 ECGs performed over the study period for suspected STEMI, the overall sensitivity and specificity of 12SL were 90.5% and 99.98%, respectively. We estimated a potential 17-minute reduction in D2D in the 90.5% of patients correctly identified as having STEMI, with a false activation rate of 4%. Female patients and older patients experienced an even larger potential benefit, with 24- and 25-minute reductions in D2D, respectively.

Conclusions: Patients who walk in to an ED with STEMI experience significant system-related delays in recognition and treatment. Automated software diagnosis of STEMI is accurate and could result in significant improvements in D2D times.

variables relatives au service des urgences et les ECG des patients ont été extraits d'une base de données régionale. Tous les ECG réalisés dans les cas d'infarctus du myocarde suspectés dans la région pendant la période visée ont été extraits. Nous avons évalué l'exactitude des diagnostics de STEMI obtenus à l'aide du logiciel 12SL, les facteurs contribuant au délai avant l'intervention et la réduction potentielle de ce délai lorsque le diagnostic de STEMI obtenu par logiciel a permis au laboratoire de cathétérisme cardiaque de se préparer avant l'arrivée du patient.

Résultats : Au total, 379 patients se sont présentés au service des urgences d'un hôpital de la région et ont subi une intervention coronarienne percutanée primaire durant la période visée par l'étude. Sur les 143 574 ECG réalisés dans les cas de STEMI suspectés durant la période étudiée, la sensibilité et la spécificité globales du logiciel 12SL s'établissaient respectivement à 90,5 % et à 99,98 %. Nous avons estimé que le délai avant l'intervention avait été potentiellement réduit de 17 minutes chez les patients ayant reçu un diagnostic de STEMI correct (90,5 %), le taux d'activation inutile du laboratoire de cathétérisme s'établissant à 4 %. Les femmes et les patients plus âgés sont ceux qui semblent avoir bénéficié le plus de cette stratégie, la réduction potentielle du délai avant l'intervention s'établissant dans leurs cas à 24 et à 25 minutes, respectivement.

Conclusions : Les patients subissant un STEMI qui se présentent eux-mêmes au service des urgences doivent passer par toutes les étapes du processus d'admission avant que leur état soit reconnu et traité. Les outils de diagnostic automatisé du STEMI donnent des résultats justes, et leur utilisation pourrait réduire considérablement le délai entre l'arrivée à l'hôpital et l'intervention.

interpretation software to rapidly identify STEMI and activate the cardiac catheterization laboratory (CCL).

Accordingly, our objectives were to (1) assess the system delays in D2D time in patients who walk-in to the ED with STEMI in our region and identify ED variables associated with prolonged D2D times; (2) describe the accuracy of a contemporary computer program (MUSE 12SL; General Electric, Boston, MA) in diagnosing acute STEMI compared with physician interpretation; and (3) assess the potential reduction in D2D times if a system (SCINET) were implemented (Fig. 1) whereby software recognition of STEMI results in immediate transmission to a cardiologist and activation of the CCL.

Material and Methods

ECG identification

We retrospectively identified all ECGs performed in EDs in Winnipeg, Manitoba, Canada, from January 2015 to October 2016. There are 6 EDs in our city with a single high-volume PCI-capable centre. There were approximately 440 primary PCIs for STEMI per year during this time. We identified those ECGs interpreted as a STEMI by the ECG software "12SL" (Marquette 12SL, MUSE, GE Healthcare, Helsinki, Finland). To identify ECGs misinterpreted as "normal" by 12SL, we extracted all ECGs by patients who were sent to the CCL with a STEMI for

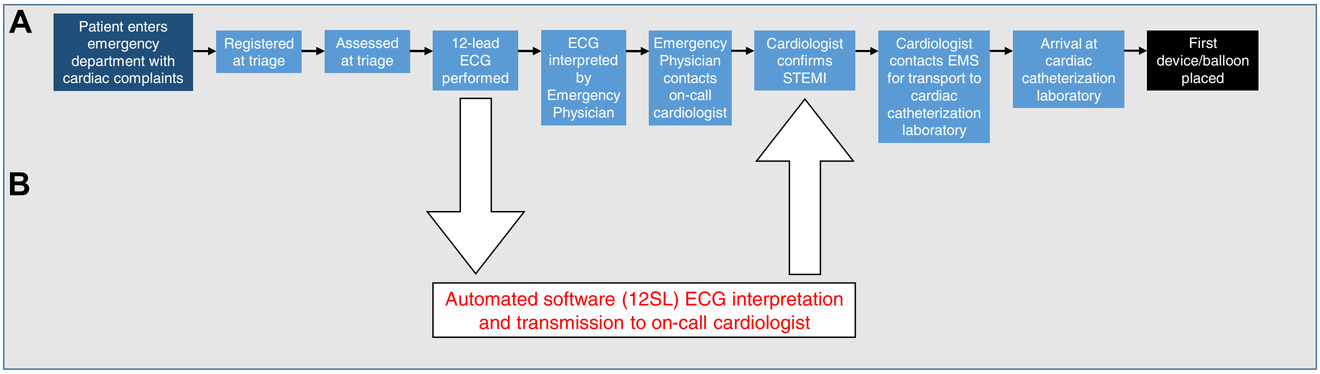


Figure 1. (**A**) Current emergency department (ED) workflow for patients presenting with chest pain and suspected ST-elevation myocardial infarction (STEMI). (**B**) Proposed system (SCINET) to transmit and activate the cardiac catheterization laboratory (CCL) based on 12SL diagnosis of STEMI. ECG, electrocardiogram; EMS, emergency medical services.

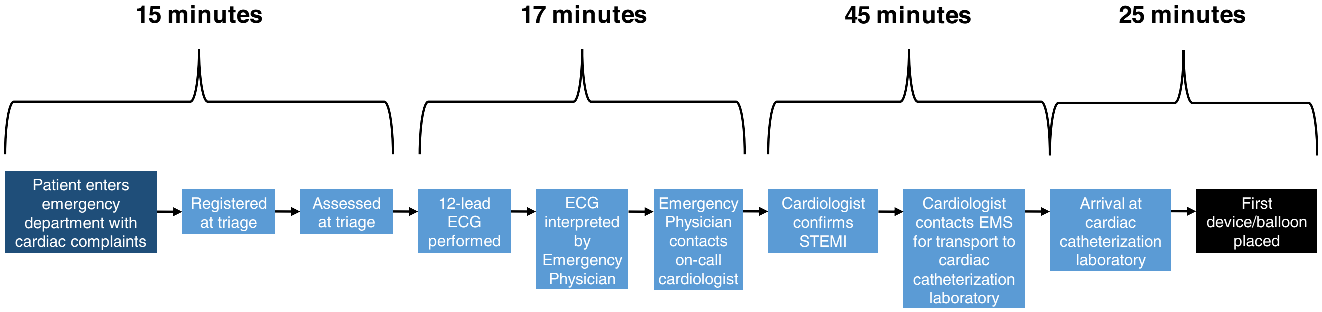
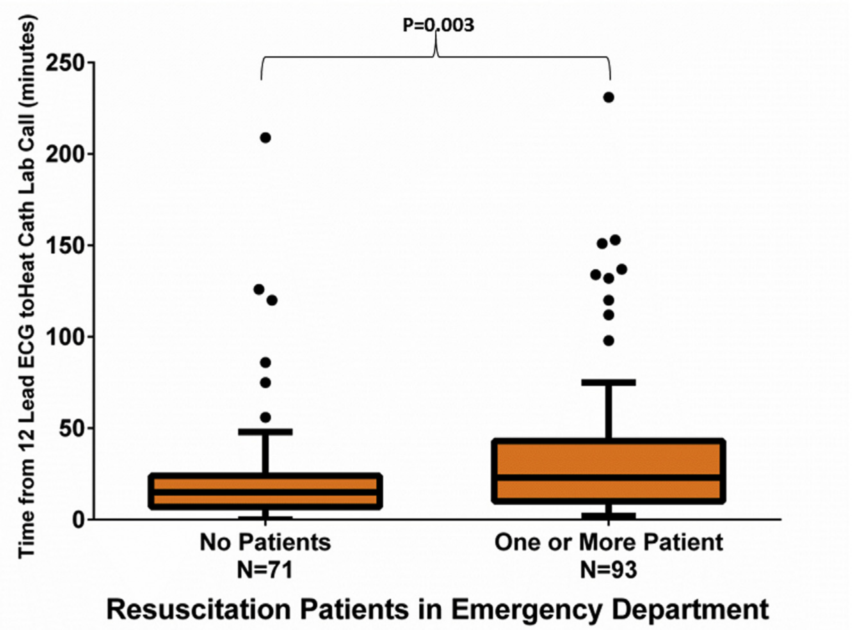


Figure 2. Components of delay in door-to-device (D2D) in the emergency department (ED) workflow for patients presenting to the ED with ST-elevation myocardial infarction (STEMI) over the study period.

primary PCI as well. Two cardiologists blinded to patient data and cardiac catheterization results interpreted the ECGs and served as the gold standard. Diagnosis of STEMI was based on the criteria proposed in the Third Universal Definition of Myocardial Infarction.[12] Sensitivity, specificity, and 95% confidence intervals (CIs) were estimated using the Clopper-Pearson method.

Primary PCI analysis

To estimate the potential impact of a system whereby activation of the CCL occurs automatically upon recognition of STEMI by 12SL, we analyzed data from our regional STEMI database, which prospectively collects clinical data on all patients presenting with STEMI. This database includes detailed information regarding time from first medical contact to performance of 12-lead ECG, time from 12-lead ECG being performed to CCL activation, and other components of the D2D time. We then assessed for correlation between various ED factors and D2D time, such as patient acuity, number of patients being resuscitated, number of patients in the waiting room, and number of patients with chest pain as the primary symptom via Spearman correlation. We estimated the potential impact of our proposed system (SCINET) in reducing D2D times by eliminating the time between the ECG being performed to CCL activation in those patients in whom 12SL accurately identified the presence of a STEMI. We also assessed the "false-positive" rate or those ECGs that were incorrectly identified as a STEMI by 12SL and would have resulted in inappropriate activation of the CCL.



Cohort	Median	25th Percentile	75th Percentile
No Patients in Resus	15 Minutes	7 Minutes	24 Minutes
One or More Patients in Resus	23 Minutes	10 Minutes	44 Minutes

Figure 3. Time from 12-lead electrocardiogram (ECG) to cardiac catheterization laboratory activation in minutes with no patients in resuscitation bay versus 1 or more at our regional percutaneous coronary intervention (PCI) centre.

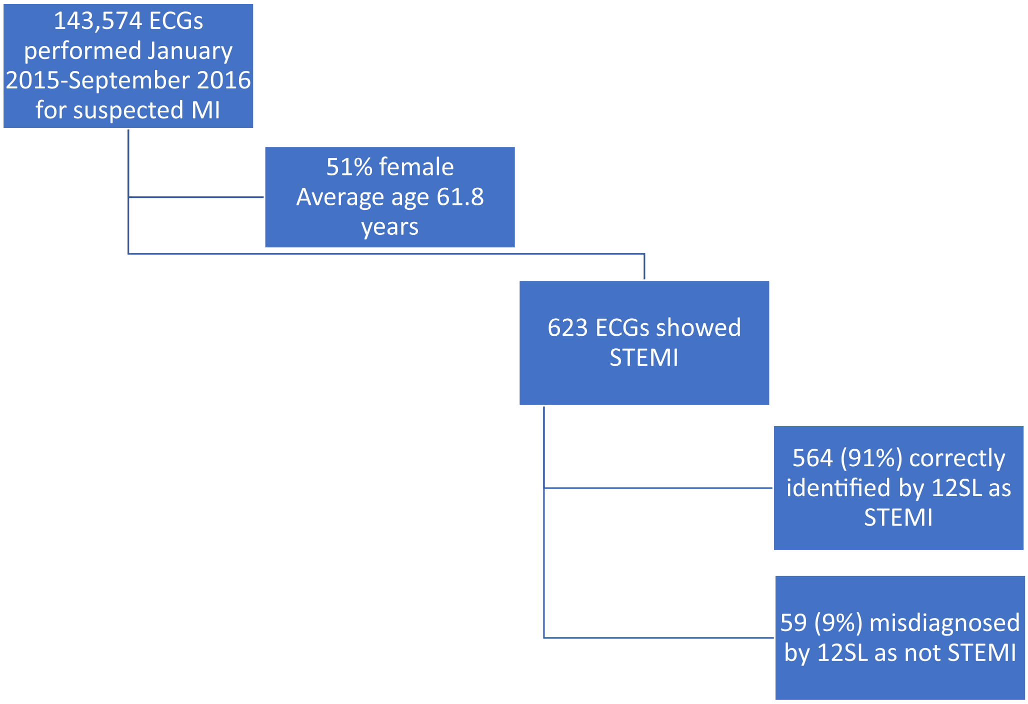


Figure 4. Electrocardiograms (ECGs) over the study period and 12SL diagnosis. MI, myocardial infarction; STEMI, ST-elevation myocardial infarction.

Results

System delays and ED predictors of D2D delays

Over the study period, 379 patients presented to a regional ED or urgent care centre with a STEMI and received primary PCI. We analyzed the components of D2D time for patients self-presenting to the ED with STEMI and subsequently transferred to our primary PCI centre over the study period. Figure 2 shows the breakdown of D2D time over the entire process chain—from the moment the patient enters the ED to the time that the culprit artery is opened. The median D2D time across all regional EDs was 113 minutes (interquartile range [IQR], 92-151 minutes) compared with 75 minutes (IQR, 64-88 minutes) for patients who called 911 and had prehospital ECG performance and direct transfer to the CCL from the field. There was a median 17-minute (IQR, 10-31 minutes) delay from the ECG being performed to activation of the CCL. Other major delays are summarized in Figure 3 and include time from activation to arrival of the CCL team and patient at our regional PCI centre. When assessing ED variables correlated with D2D times, we found a weak positive between the number of patients with chest pain and lower D2D times (Supplemental Table S1) and an association between the number of critically ill patients undergoing resuscitation in the ED and increased D2D times. Specifically, at our regional PCI centre, there was a median 8-minute delay in ECG performance to CCL activation when 1 or more patients was in the resuscitation bay compared with no patients in the resuscitation bay (Fig. 3). Other variables such as number of patients in the waiting room and count of patients waiting to be seen were not correlated with D2D times (Supplemental Table S1).

ECG interpretation

From January 2015 to September 2016, 143,574 ECGs were performed at an ED or urgent care centre in our region (Fig. 4), and 12SL interpreted 564 of these ECGs as a STEMI. Fifty-one percent of the ECGs were performed on female patients, and the median age was 63 years (IQR, 54-70 years of age). Table 1 illustrates a 4×4 breakdown of the

Table 1. 4×4 breakdown of the diagnostic accuracy of 12SL in diagnosing STEMI compared with independent, blinded physician interpretation

	True STEMI	Not STEMI	Total
12SL + STEMI	564	27	591
12SL - STEMI	59	142,924	142,983
Total	623	142,951	143,574
Sensitivity (95% CI)			90.5% (88.0%-92.7%)
Specificity (95% CI)			99.98% (99.97%-99.99%)
PPV (95% CI)			95.5% (93.4%-97.0%)
NPV (95% CI)			99.96% (99.94%-99.97%)

CI, confidence interval; NPV, negative predictive value; PPV, positive predictive value; STEMI, ST-elevation myocardial infarction.

Table 2. Sensitivity, specificity, positive and negative predictive values of 12SL in ECG diagnosis of STEMI among patients within cohort who received primary PCI and potential reduction in D2D time

Study cohort	Sample size	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	Potential time saved
Overall	379	83% (79%-87%)	91% (76%-98%)	99% (97%-100%)	34% (25%-45%)	17 min
Age < 75 y	311	82% (77-86%)	90% (73%-98%	99% (96%-100%)	34% (23%-45%)	17 min
Age ≥ 75 y	68	87% (77%-94%)	100% (48%-100%)	100% (94%-100%)	38% (14%-68%)	24 min
Male	269	82% (77%-87%)	89% (72%-98%)	99% (96%-100%)	37% (25%-49%)	15 min
Female	110	85% (76%-91%)	100% (54%-100%)	100% (96%-100%)	27% (11%-50%)	25 min
QRS < 120 ms	327	86% (81%-90%)	90% (73%-98%)	99% (97%-100%)	38% (27%-51%)	18 min
QRS ≥ 120 ms	52	64% (49%-77%)	100% (48%-100%)	100% (88%-100%)	23% (8%-45%)	15 min
Heart rate < 100 beats/min	304	83% (78%-88%)	100% (87%-100%)	100% (98%-100%)	37% (26%-49%)	17 min
Heart rate ≥ 100 beats/min	75	81% (70%-89%)	57% (18%-90%)	100% (86%-99%)	24% (7%-50%)	23 min

CI, confidence interval; NPV, negative predictive value; PPV, positive predictive value.

diagnostic accuracy of 12SL in diagnosing STEMI. Overall, 12SL had excellent sensitivity (90.5%, 95% CI, 88-92.7) and specificity (99.98%, 95% CI, 99.97-99.9) for diagnosing STEMI (Tables 1 and 2). The sensitivity and specificity were reduced in patients with tachycardia (heart rate of ≥ 100 beats/min) or with a QRS duration of 120 ms or more (Table 2). When looking at territory of infarction, 12SL had reduced sensitivity for detection of isolated septal and posterior myocardial infarctions, but otherwise excellent sensitivity and specificity for other territories (Table 3). Overall, the positive predictive value of the software in diagnosing STEMI was 95.5% (95% CI, 93.4-97.0) and the negative predictive value was 99.96% (99.94-99.97).

Estimated impact of SCINET in reducing D2D times

Table 2 summarizes the estimated reduction in D2D times in this cohort with implementation of SCINET. Overall, immediate transmission of an ECG interpreted as a STEMI by 12SL could have resulted in a 17-minute reduction in D2D time in the overall cohort. On subgroup analysis, older patients and women would have experienced even greater reductions in D2D times, with 24 minutes saved in patients aged 75 years and older and 25 minutes in female patients. The percentage of patients achieving a benchmark D2D time of less than 120 minutes was estimated at 80.4% with SCINET vs 59.8% with the current system. Over the study period, SCINET would have resulted in 27 false activations of the CCL, which represents approximately 4% of all ECGs interpreted as a STEMI by 12SL, or approximately 1.2 false activations per month. Most of these were due to Brugada pattern, pericarditis, or benign early repolarization.

Discussion

In patients with STEMI, there was a significant delay (median 17 minutes) from the time an ECG was performed to activation of the CCL. Busier EDs with more patients needing resuscitation appeared to increase the delay, suggesting that the ED physician and other ED staff are delayed by competing interests to the detriment of patients presenting with STEMI. Our proposed system (SCINET) of immediate transmission based on the software diagnosis of STEMI could eliminate "ECG to decision time" and result in significantly reduced D2D times. The software algorithm 12SL accurately identified STEMI in a population of patients presenting to the ED, with a sensitivity of approximately 91% and specificity of more than 99%. In effect, 17 minutes potentially could be saved in the 90.5% of patients correctly identified as STEMI with a false activation rate of 4%. Additionally, we found that women and older patients experienced greater potential reductions in D2D times, groups who have historically experienced greater delays and worse outcomes.[6] This estimated reduction in D2D time is clinically significant given recent registry data from the **F**eedback **I**ntervention and **T**reatment **T**imes in **ST**-**E**levation **M**yocardial **I**nfarction (FITT-STEMI) trial have confirmed that for every additional 10-minute delay in PCI for patients with STEMI at the highest risk, there is an additional 3.31 additional deaths per 100 PCI-treated patients.[13] Furthermore, we found that such a system would result in minimal false activations, with approximately 1.2 false activations per month.

Previous studies have assessed the diagnostic performance of ECG interpretation software as far back as the early 1990s.[14] Each computer interpretation system has a unique algorithm that has been tested in different populations and held to different standards: interpretation by cardiologists, emergency physicians, and discharge diagnosis of STEMI. Thus, there are wide ranges in sensitivity (58%-78%) and specificity (68%-100%) of ECG interpretation algorithms. Because of the unacceptably high false-negative rate, guidelines recommend that computer-assisted ECG interpretation not be used as the sole means to diagnose

Table 3. Sensitivity, specificity, positive and negative predictive values of 12SL in ECG diagnosis of STEMI based on territory of myocardial infarction

Study cohort	Sample size	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)
Anterior	143	80% (73%-87%)	99% (97%-100%)	98% (94%-100%)	89% (85%-93%)
Septal	88	50% (39%-61%)	99% (97%-100%)	94% (82%-99%)	87% (83%-90%)
Lateral	131	84% (77%-90%)	98% (95%-99%)	96% (90%-99%)	92% (88%-95%)
Inferior	190	86% (80%-90%)	96% (92%-98%)	95% (91%-98%)	87% (82%-91%)
Posterior	34	24% (11%-41%)	99% (97%-100%)	73% (39%-94%)	93% (90%-95%)

CI, confidence interval; NPV, negative predictive value; PPV, positive predictive value.

STEMI.[15] A more recent publication by Garvey et al.[16] assessed the diagnostic accuracy of 3 "proprietary software algorithms" in the detection of STEMI in the prehospital setting. The population studied included patients with verified prehospital STEMI and those with suspected acute coronary syndrome. They found that the overall sensitivity of the algorithms ranged from 67% to 79%, and the specificity ranged from 95% to 98%. We found overall higher sensitivity and specificity in the 12SL algorithm, which might be due to a larger sample size (their study analyzed 500 records), differences in the population studied, selection of diagnostic criteria for CCL activation, or superior performance of the algorithm.

Some have assessed the utility of a nonphysician interpretation in reducing D2D in patients with STEMI who are assessed by emergency medical personnel, and one group assessed the utility of a software interpretation of STEMI resulting in direct transfer to the CCL without transmission or reinterpretation in the prehospital setting.[17,18] The efficacy of such a system has not been evaluated in patients who do not call an ambulance but rather walk in to the ED. Automated ECG interpretation software has been present in some form since the initial computerization of ECGs in the 1970s.[19] A study by Willems et al. in 1991[14] assessed the diagnostic performance of computer programs in the interpretation of ECGs compared with a cardiologist. The median sensitivity of computer programs for diagnosing acute myocardial infarction was 72% compared with 80% for cardiologists. In more than 20 years, despite evolution in software interpretation, no rigorous study has reevaluated the accuracy of computer programs in diagnosing STEMI. It is widely accepted that a human with ECG interpretation training be at the frontline in diagnosing STEMI and activating the CCL. However, if the automated ECG interpretation can be demonstrated as accurate and reliable, there is potential in eliminating the time it takes for human interpretation and having automated activation of the CCL. Of note, our study did highlight the danger in relying on software interpretation of "normal ECG" to decant patients and ECGs for less-urgent assessment: We found that 12SL missed 59 patients with STEMI. This is in contrast to the conclusions of Hughes et al.,[20] who assessed the negative predictive value of 12SL in 855 triage ECGs. They estimated a negative predictive value of 99%. However, their sample size was considerably smaller and there was a low number of ECGs interpreted as STEMI, which limits the generalizability of their findings.

Prehospital ECG and diagnosis of STEMI, with direct transfer to a PCI-capable centre, have revolutionized the care of patients with STEMI and resulted in more patients achieving target D2D times.[21] Presently, software algorithm ECG diagnosis of STEMI is generally used as an adjunct to physician or trained emergency medical personnel ECG interpretation in triaging patients with suspected acute coronary syndromes.[22,23] Some healthcare systems have assessed the performance of "physician-less" systems of prehospital STEMI diagnosis and CCL activation using software algorithms.[24,25] One such system described by Potter et al.[25] involved the use of Zoll software (Zoll E series monitor-defibrillator; Zoll Medical Corporation, Chelmsford, MA). The emergency medical personnel performed ECGs in any patient with symptoms suggestive of an acute coronary syndrome. If the software interpretation was consistent with an acute STEMI, the patient was transported immediately to CCL without further transmission or interpretation. They were able to achieve a target D2D time of < 90 minutes in 99% of patients. They found that their false activation rate was approximately 4% to 5%, similar to our findings and similar to published reports of physician-based CCL activation.[25] In any system, it is paramount that the false activation rate be as low as possible to minimize patient harm or frustration, CCL staff fatigue and burnout, and costs to the medical system.[26]

Although there are some data regarding the efficacy of prehospital computer diagnosis of STEMI and activation of the CCL, to our knowledge, there have been no reports on such a system operating within the ED. Unfortunately, many patients still present to the ED with a STEMI rather than calling an ambulance, and in fact we found that most patients in our region do not call an ambulance and as a result experience significant delays in diagnosis and treatment. The ED is a busy environment, with ED physicians, nurses, and other staff dealing with a variety of competing interests. Our analysis of ED predictors of D2D times suggest that during busier times, with patients needing active resuscitation, there is increased delay in time from performance of ECG to activation of the CCL. Although the present study did not address potential impacts on D2D times for centres outside of the target transfer time to a primary PCI centre, conceivably SCINET could work in such an environment as well.

Systems of care should be redundant and resistant to human error as much as possible. We believe that a system whereby software diagnosis of STEMI results in activation of the CCL would be accurate with an acceptable "false activation" and result in improved D2D times and ultimately improved clinical outcomes for patients presenting with STEMI.

Conclusions

Software algorithm diagnosis of STEMI in patients presenting to the ED with suspected acute coronary syndrome is accurate, and direct transmission and activation of the CCL based on computer diagnosis of STEMI would result in minimal false activations and reduce D2D times. Women and patients aged more than 75 years appear to benefit most, groups that historically have experienced longer D2D times. Further assessment of this system on a pilot basis will be undertaken to better understand its real-world efficacy and cost-effectiveness.

Acknowledgements

The authors thank Brett Hiebert for statistical support and database management, and Linda McLean for assistance in retrieving the ECGs.

Funding Sources

The authors have no funding sources to declare.

Disclosures

The authors have no conflicts of interest to disclose.

References

1. Brodie BR, Stuckey TD, Wall TC, et al. Importance of time to reperfusion for 30-day and late survival and recovery of left ventricular function after primary angioplasty for acute myocardial infarction. J Am Coll Cardiol 1998;32:1312-9.

2. McNamara RL, Wang Y, Herrin J, et al. Effect of door-to-balloon time on mortality in patients with ST-segment elevation myocardial infarction. J Am Coll Cardiol 2006;47:2180-6.

3. Rathore SS, Curtis JP, Chen J, et al. Association of door-to-balloon time and mortality in patients admitted to hospital with ST elevation myocardial infarction: national cohort study. BMJ 2009;338:1312-5.

4. De Luca G, Suryapranata H, Ottervanger JP, Antman EM. Time delay to treatment and mortality in primary angioplasty for acute myocardial infarction: every minute of delay counts. Circulation 2004;109:1223-5.

5. O'Gara PT, Kushner FG, Ascheim DD, et al. 2013 ACCF/AHA Guideline for the Management of ST-Elevation Myocardial Infarction: A Report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol 2013;61:e78-140.

6. Terkelsen CJ, Sørensen JT, Maeng M, et al. System delay and mortality among patients with STEMI treated with primary percutaneous coronary intervention. JAMA 2010;304:763.

7. Ducas RA, Labos C, Allen D, et al. Association of pre-hospital ECG administration with clinical outcomes in ST-segment myocardial infarction: a systematic review and meta-analysis. Can J Cardiol 2016;32:1531-41.

8. Kawecki D, Gierlotka M, Morawiec B, et al. Direct admission versus interhospital transfer for primary percutaneous coronary intervention in ST-segment elevation myocardial infarction. JACC Cardiovasc Interv 2017;10:438-47.

9. Curtis JP, Portnay EL, Wang Y, et al. The pre-hospital electrocardiogram and time to reperfusion in patients with acute myocardial infarction, 2000-2002. Findings from the National Registry of Myocardial Infarction-4. J Am Coll Cardiol 2006;47:1544-52.

10. Wang TY, Peterson ED, Ou FS, et al. Door-to-balloon times for patients with ST-segment elevation myocardial infarction requiring interhospital transfer for primary percutaneous coronary intervention: a report from the National Cardiovascular Data Registry. Am Heart J 2011;161:76-83.e1.

11. Mullvain R, Saman DM, Rostvedt A, Landgren P. ECG-to-decision time impact on 30-day mortality and reperfusion times for STEMI care. Crit Pathw Cardiol 2018;17:19-24.

12. Thygesen K, Alpert JS, Jaffe AS, et al. Third universal definition of myocardial infarction. Circulation 2012;126:2020-35.

13. Scholz KH, Maier SKG, Maier LS, et al. Impact of treatment delay on mortality in ST-segment elevation myocardial infarction (STEMI) patients presenting with and without haemodynamic instability: results from the German prospective, multicentre FITT-STEMI trial. Eur Heart J 2018;39:1065-74.

14. Willems JL, Abreu-Lima C, Arnaud P, et al. The diagnostic performance of computer programs for the interpretation of electrocardiograms. N Engl J Med 1991;325:1767-73.

15. O'Connor RE, Al Ali AS, Brady WJ, et al. Part 9: Acute coronary syndromes: 2015 American Heart Association guidelines update for cardiopulmonary resuscitation and emergency cardiovascular care. Circulation 2015;132:S483-500.

16. Garvey JL, Zegre-Hemsey J, Gregg R, Studnek JR. Electrocardiographic diagnosis of ST segment elevation myocardial infarction: an evaluation of three automated interpretation algorithms. J Electrocardiol 2016;49:728-32.

17. de Champlain F, Boothroyd LJ, Vadeboncoeur A, 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;16:94-105.

18. Potter BJ, Matteau A, Mansour S, et al. Sustained performance of a "physicianless" system of automated prehospital STEMI diagnosis and catheterization laboratory activation. Can J Cardiol 2017;33:148-54.

19. Rautaharju PM. Eyewitness to history: landmarks in the development of computerized electrocardiography. J Electrocardiol 2016;49:1-6.

20. Hughes KE, Lewis SM, Katz L, Jones J. Safety of computer interpretation of normal triage electrocardiograms. Acad Emerg Med 2014;21:355-65.

21. Ducas RA, Philipp RK, Jassal DS, et al. Cardiac Outcomes Through Digital Evaluation (CODE) STEMI Project: prehospital digitally-assisted reperfusion strategies. Can J Cardiol 2012;28:423-31.

22. Garvey JL, MacLeod BA, Sopko G, Hand MM. 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 Instit. J Am Coll Cardiol 2006;47:485-91.

23. Coffey C, Serra J, Goebel M, et al. Prehospital acute ST-elevation myocardial infarction identification in San Diego: a retrospective analysis of the effect of a new software algorithm. J Emerg Med 2018;55:71-7.

24. Potter BJ, Matteau A, Mansour S, 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;112:156-61.

25. Potter BJ, Matteau A, Mansour S, et al. Sustained performance of a "physician-less" system of automated pre-hospital STEMI diagnosis and catheterization laboratory activation. Can J Cardiol 2016;33:148-54.

26. Lange DC, Rokos IC, Garvey JL, et al. False activations for ST-segment elevation myocardial infarction. Interv Cardiol Clin 2016;5:451-69.

Supplementary Material

To access the supplementary material accompanying this article, visit *CJC Open* at https://www.cjcopen.ca/ and at https://doi.org/10.1016/j.cjco.2020.02.003.