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Original Article

Effect of Real-Time Physician Oversight of Prehospital STEMI Diagnosis on ECG-Inappropriate and False Positive Catheterization Laboratory Activation

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ABSTRACT

Background: ST-elevation myocardial infarction diagnosis at first medical contact (FMC) and prehospital cardiac catheterization laboratory (CCL) activation are associated with reduced total ischemic time and therefore have become the dominant ST-elevation myocardial infarction referral method in primary percutaneous coronary intervention systems. We sought to determine whether physician oversight was associated with improved diagnostic performance in a prehospital CCL activation system and what effect the additional interpretation has on treatment delay.

RÉSUMÉ

Contexte : Un diagnostic d'infarctus du myocarde avec élévation du segment ST au moment du premier contact avec un professionnel de la santé et l'activation du processus de cathétérisme cardiaque avant l'arrivée à l'hôpital sont associés à une réduction de la durée totale de l'épisode ischémique, et sont donc désormais la méthode de préférence en cas d'infarctus du myocarde avec élévation du segment ST dans les établissements où l'intervention coronarienne percutanée primaire est possible. Nous avons voulu déterminer si la supervision par un médecin était associée à une amélioration de la justesse du

Because shorter treatment delays are associated with better myocardial recovery, survival, and functional status,[1-3] the principle aim of ST-elevation myocardial infarction (STEMI) management systems is to minimize total ischemic time.[4-6] To this end, STEMI diagnosis at first medical contact (FMC) and prehospital cardiac catheterization laboratory (CCL) activation have become the dominant STEMI referral method.[6-19]

Although real-time physician oversight is desirable to ensure the accuracy and appropriateness of prehospital CCL activation,[12,20] the human and technological resources required for this might not be within reach for all health care systems.[9,21] Emergency medical services (EMS)-initiated CCL activation at FMC has emerged as a potential alternative in such circumstances. However, the diagnostic accuracy of EMS electrocardiogram (ECG) interpretation reported in the literature varies considerably.[9,22,23] Prehospital CCL activation solely on the basis of the automated machine interpretation of the ECG in an appropriate clinical context requires minimal additional training of EMS personnel and has been previously shown to have acceptably low proportions of ECG-inappropriate and false positive (FP) activations on par with expert cardiologist ECG interpretation.[24,25]

However, it is not known whether adding real-time physician oversight to such a system could improve the diagnostic performance further or whether the additional interpretation time might negatively affect treatment delays.

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Ethics Statement: The study protocol was consistent with the ethical guidelines of the 1975 Declaration of Helsinki and was approved by local Research Ethics Committees with a waiver of informed consent.

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Methods: Between 2012 and 2015, all patients in 2 greater Montreal catchment areas with a chief symptom of chest paint or dyspnea had an in-the-field electrocardiogram (ECG). A machine diagnosis of "acute myocardial infarction" resulted either in automatic CCL (automated cohort without oversight) or transmission of the ECG to the receiving centre emergency physician for reinterpretation before CCL activation. System performance was assessed in terms of the proportion of false positive and inappropriate activations (IA), as well as the proportion of patients with FMC-to-device times $\leq$ 90 minutes.

Results: Four hundred twenty-eight (428) activations were analyzed (311 automated; 117 with physician oversight). Physician oversight tended to decrease IAs (7% vs 3%; $P = 0.062$), but was also associated with a smaller proportion of patients achieving target FMC-to-device (76% vs 60%; $P < 0.001$). There was no significant effect on the proportion of false positive activation.

Conclusions: Real-time physician oversight might be associated with fewer IAs, but also appears to have a deleterious effect on FMC-to-device performance. Identifying predictors of IA could improve overall performance by selecting ECGs that merit physician oversight and streamlining others. Larger clinical studies are warranted.

Méthodologie : De 2012 à 2015, tous les patients de deux zones desservies du Grand Montréal qui présentaient comme principal symptôme une douleur à la poitrine ou une dyspnée ont subi un électrocardiogramme (ECG) sur le terrain. Un diagnostic d'infarctus aigu du myocarde posé par l'appareil a automatiquement donné lieu à l'activation du processus de cathétérisme cardiaque (cohorte automatisée sans supervision) ou à la transmission de l'ECG à l'urgentologue de l'établissement où le patient était conduit pour la réinterprétation des résultats avant l'activation du processus de cathétérisme cardiaque. La performance du système a été évaluée en fonction de la proportion de faux positifs et d'activations inappropriées, ainsi que de la proportion de patients chez qui le délai entre le premier contact avec un professionnel de la santé et l'intervention était $\leq$ 90 minutes.

Résultats : Quatre cent vingt-huit (428) activations du processus ont été analysées (311 automatisées; 117 après la supervision par un médecin). La supervision par un médecin était associée à une baisse non significative des activations inappropriées du processus (7 % vs 3 %; $p = 0{,}062$), mais était aussi associée à une plus faible proportion de patients chez qui le délai visé entre le premier contact avec un professionnel de la santé et l'intervention était respecté (76 % vs 60 %; $p < 0{,}001$). Aucun effet significatif quant à la proportion de faux positifs n'a été observé.

Conclusions : La supervision en temps réel par un médecin pourrait être associée à une réduction des activations inappropriées du processus de cathétérisme cardiaque urgent, mais pourrait également nuire aux résultats quant au délai entre le premier contact avec un professionnel de la santé et l'intervention. L'identification des facteurs prédictifs d'une activation inappropriée du processus pourrait améliorer les résultats globaux en permettant de choisir les résultats d'ECG qui mériteraient d'être passés en revue par le médecin, et en déclenchant le processus habituel pour les autres. Des études cliniques de plus grande envergure sont de mise.

We therefore sought to compare STEMI system performance with and without real-time physician oversight of prehospital CCL activation.

Methods

Prehospital diagnosis and CCL activation system

In January of 2010, a "physician-blind" system of automated prehospital STEMI diagnosis and CCL activation was instituted in one part of the greater Montreal area (246 km^2, population approximately 440,000) because of a recognition of a need to minimize treatment delays and the nonavailability of secure ECG transmission technology at the time (hospital A).[26] As per the CCL activation protocol previously described,[24,25] any patient with a chief symptom of chest pain or dyspnea had an in-the-field ECG performed by an ambulance technician with training in ECG acquisition, but not in ECG interpretation. An automated diagnosis of acute myocardial infarction (Zoll E Series monitor-defibrillator; Zoll Medical Corporation, Chelmsford, MA) led to CCL team activation (simultaneous paging system) by the ambulance technician and direct patient transfer to the CCL without transmission or reinterpretation of the ECG by a physician before patient arrival. On the basis of an initial analysis of referral algorithm performance,[24] patients with tachycardia $>$ 140 beats per minute and left bundle branch block were excluded from the automated activation protocol to minimize the risk of inappropriate activation (IA).[25]

ECG transmission technology, however, has been available since 2014 in another Montreal hospital located 25 km away from hospital A (hospital B; 11,112 km^2 catchment area, population approximately 1,551,000).[26] In this "physician-aware" system (real-time oversight), any patient with a chief symptom of chest pain or dyspnea and an in-the-field ECG automated diagnosis of acute myocardial infarction (using the same ECG acquisition technology) had their ECG transmitted electronically to the local on-duty emergency physician, who, after discussion of the clinical context with the ambulance technician, ultimately decided whether to activate the CCL team (simultaneous paging system). For reasons of patient confidentiality, the emergency physician does not have access to any identifying information before patient arrival at the hospital and, so, does not have access to any previous medical records when deciding to activate the CCL. In either system, during the period of study, the interventional cardiologist typically did not review the ECG before arriving at the hospital

with the CCL team. The interventional cardiologist could choose not to proceed with coronary angiography upon evaluation of the patient and ECG, but only after the patient had arrived at the percutaneous coronary intervention (PCI) centre and the CCL team had already been mobilized. Both CCLs are staffed by the same physician group of interventional cardiologists, ensuring 24-hour STEMI coverage.

Data collection

All consecutive prehospital CCL activations from February 1, 2012, to September 1, 2015, were analyzed at two centres (one in each region), each with a stand-alone CCL (no on-site cardiac surgery). The centre in the "physician-aware" system with real-time oversight was designated a primary PCI centre in 2014 and, so, only contributed data in 2014 and 2015. Data on patient demographics and clinical characteristics, ECGs, procedural data, and subsequent in-hospital clinical events were abstracted from the medical record and prospective CCL registries. The need for informed consent was waived by the local institutional research ethics committee and the study protocol was consistent with the ethical guidelines of the 1975 Declaration of Helsinki.

Definitions

True STEMI (or true positive) was defined as contiguous ($\geq$ 2 leads) ST-elevation ($\geq$ 2 mm in leads V_2 and V_3 in men and $\geq$ 1.5 mm for women in leads V_2-V_3 and $\geq$ 1 mm in other leads) with a significant lesion or alteration of **T**hrombolysis **i**n **M**yocardial **I**nfarction (TIMI) flow in a coronary artery corresponding to the myocardial territory on the ECG.

FP CCL activation was defined as any activation resulting from an accurately identified elevation in the ST segment without a significant lesion in a corresponding artery or alteration in TIMI flow (eg, pericarditis or Takotsubo cardiomyopathy). These CCL activations were considered to be electrographically appropriate in the context of a patient with chest pain (ie, ECG-appropriate).

IA was defined as any activation resulting from a non-diagnostic ECG (ie, ECG-inappropriate).[23-25] A non-diagnostic ECG was defined as any ECG not showing significant ST segment evaluation as evaluated independently by 2 expert readers (among L.-A.B.-P., C.P., A.B.) who reviewed the prehospital ECGs and who were blinded to the results of angiography at the time of review. None of the ECG reviewers performed PCI at either centre. To be considered as a nondiagnostic ECG, both reviewers had to confirm that they would not have activated the CCL on the basis of the prehospital ECG in the clinical setting of chest pain. In case of disagreement, a third reviewer (B.J.P.) independently evaluated the ECG.

IAs were subsequently categorized as either "machine error" or "human error." Machine error was defined as any machine diagnosis of acute myocardial infarction on the basis of an in-the-field ECG of sufficient quality that had been determined not to present any significant ST elevation as previously described. Human error was defined as any failure to observe the established prehospital STEMI diagnosis and referral algorithm at the time of activation. For example, performing and acting on a prehospital ECG for a patient without a chief symptom of chest pain or dyspnea, failure to obtain a prehospital ECG of sufficient quality, as well as referring patients with a heart rate $>$ 140 beats per minute or with a left bundle branch block would all be considered human error (Fig. 1). Instances of an emergency physician choosing to override an automated diagnosis of acute myocardial infarction and not immediately activate the CCL that subsequently was found to indeed be a true STEMI were considered separately.

Door-to-device and FMC-to-device times were defined conventionally as the time intervals between arrival at the hospital or FMC in the field, respectively, and the time of activation of the first intracoronary device (balloon, stent, or thrombectomy catheter) in those who underwent PCI (true STEMI only). FMC-to-door time was defined as the time from FMC to arrival at the PCI centre. Times were abstracted from ambulance technician, emergency room, and CCL reports contained in the patients' medical records. Time pieces were not synchronized.

Procedural success was defined as $\leq$ 10% residual stenosis and final TIMI grade 3 flow.

End points

System performance was evaluated in terms of quality and efficiency. The primary quality outcome was the proportion of IAs. Secondary quality outcomes were the reasons for IAs, categorized as human or machine error, the proportion of FP and the independent predictors of IAs.

The primary efficiency outcome of interest was the proportion of patients with FMC-to-device times $<$ 90 minutes according to the recommended FMC-to-device time goal in effect at the time of the study.[27] In 2019, an update of the Canadian guidelines modified the allowable FMC-to-device time to $<$ 120 minutes.[6] A secondary efficiency outcome consisting of the proportion of patients with FMC-to-device $<$ 120 minutes was therefore included, along with the proportion of patients with door-to-device $<$ 90 minutes, median door-to-device times, and FMC-to-device times, and the proportion of procedural success.

Statistical analysis

Baseline characteristics are reported as counts and percent of group total for nominal variables, as means and SDs for normally distributed continuous variables, and medians with interquartile ranges (IQRs) for non-normally distributed continuous data. Two-group comparisons of baseline characteristics were performed using a Fisher exact test or χ^2 test for nominal variables and a t test or Wilcoxon rank sum test for continuous variables as appropriate. The distributions of CCL activation categories in both cohorts were compared using a χ^2 or Fisher exact test as appropriate. FMC-to-device and door-to-device were compared using Fisher exact test for dichotomized outcomes and a log rank test for the continuous outcome. Multivariate analysis of predictors of IAs across all cohorts was conducted using a logistic regression model. Covariates were included on the basis of a combination of expert opinion and results of univariate analyses. Candidate variables included female sex, age $\geq$ 75 years, hypertension,

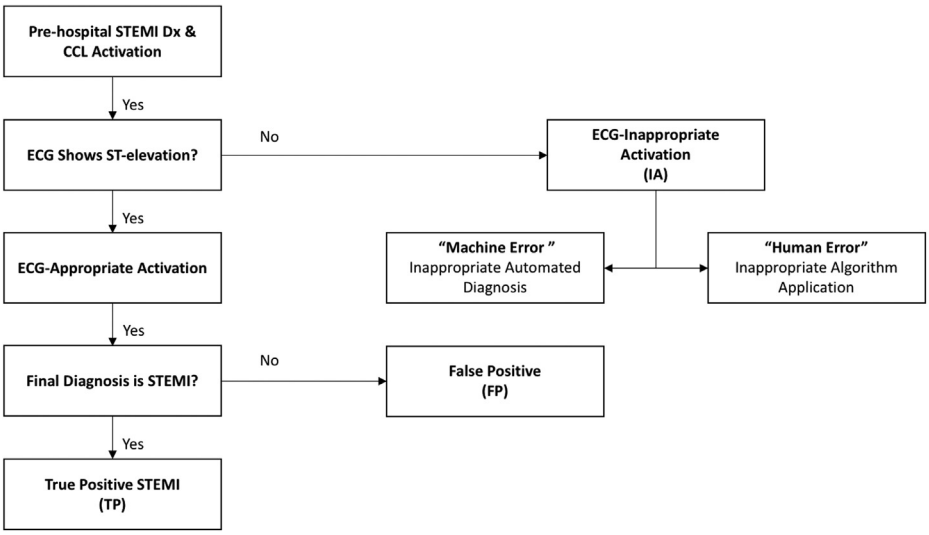

Figure 1. Conceptual schematic of cardiac catheterization laboratory (CCL) activation categories on the basis of a combination of electrocardiographic and clinical criteria. Dx, diagnosis; ECG, electrocardiogram; STEMI, ST-elevation myocardial infarction.

diabetes, history of coronary artery disease (CAD), and a "physician-blind" referral system.

A 2-tailed chance of type I error of 0.05 was considered statistically significant for all analyses. All statistical analyses were performed using SAS version 9.3 (SAS Institute Inc, Cary, NC).

Results

We identified a total of 428 cases in which the prehospital diagnosis and referral system resulted in CCL activation from the field between February 1, 2012 and September 1, 2015 (Fig. 2). Of these, 311 activations comprised the "physician-blind" automated cohort (hospital A) and 117 activations in hospital B had real-time physician oversight ("physician-aware" cohort). Baseline patient characteristics are presented in Table 1. Among patients with true STEMI, in-hospital mortality occurred in 6% of patients in both cohorts (*P* not significant).

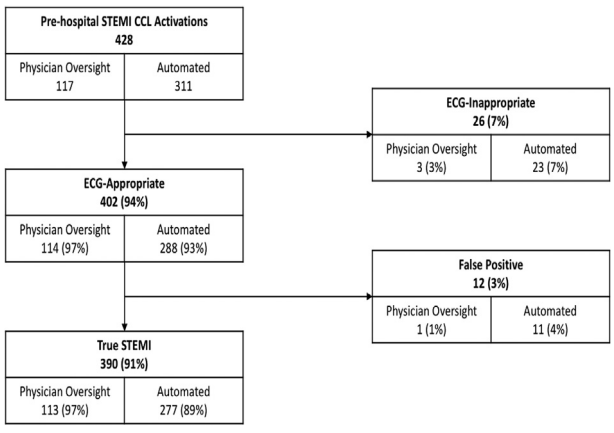

Figure 2. Flow chart of 428 consecutive catheterization laboratory activations using the Physician Oversight and Automated prehospital CCL activation algorithm. CCL, cardiac catheterization laboratory; ECG, electrocardiogram; STEMI, ST-elevation myocardial infarction.

Quality outcomes

Of the 428 activations, 390 (91%) had a final diagnosis of STEMI (true STEMI), 12 (3%) had ST-segment elevation on the presenting ECG, but were determined to be FP activations, and 26 cases (7%) were considered IAs (no ST-segment elevation on the prehospital ECG). Human error was implicated in 19 cases (73% of IAs) and machine error occurred in 7 cases (27% of IAs; Table 2).

In a comparison of referral algorithm performance between the 2 cohorts, the overall proportion of IA was 7% in the automated cohort compared with 3% in the physician oversight cohort (57% lower; $P = 0.062$). The proportion of human error IA was 3% and machine error IA was 0% with physician oversight, compared with 5% and 3% without (*P* not significant). There was no statistically significant difference in FP activations (4% vs 1%; $P = 0.134$). Two instances of the emergency physician incorrectly over-riding an automated in-the-field ECG diagnosis of STEMI were observed in the cohort with real-time oversight.

In the multivariate analysis, age ≥ 75 years and a history of CAD were independent predictors of IA (Table 3).

Efficiency outcomes

Among the 387 true STEMI patients (277 hospital A; 110 hospital B), the median FMC-to-device time was 80 (IQR, 26) minutes. FMC-to-device times of < 90 minutes were achieved in 208 patients (76%) in the automated cohort and in 63 patients (60%) the physician oversight cohort ($P < 0.001$). There was also a statistically significant difference in the FMC-to-device times in the automated cohort and the physician oversight cohort (76 vs 86 minutes) when analyzed continuously ($P < 0.001$; Table 4).

The median FMC-to-door time was 30 (IQR, 16) minutes. There was no significant difference in the FMC-to-

Table 1. Baseline patient characteristics in the physician-blind and physician-aware cohorts

Characteristic	Automated "physician-blind" (2012-2015; n = 311)	Oversight "physician-aware" (2014-2015; n = 117)	*P*
Mean age ± SD, years	64 ± 13	64 ± 12	0.587
Male sex	219 (70)	85 (73)	0.648
Diabetes	53 (17)	23 (20)	0.525
Hypertension	170 (55)	47 (40)	0.007*
Dyslipidemia	179 (58)	47 (40)	0.002*
Tobacco use	146 (47)	45 (38)	0.122
Known CAD or angina history	71 (23)	24 (21)	0.621
Previous revascularization	50 (16)	14 (12)	0.543
Previous stroke/TIA	12 (3)	2 (0)	0.191
Peripheral artery disease	11 (3)	7 (1)	0.026*
CRF (CrCl < 60 mL/min)†	39 (15)	16 (16)	0.901
Dialysis‡	2 (1)	2 (2)	0.435
BMI > 30§	71 (27)	28 (28)	0.978
Killip Class III-IV*,‖	27 (10)	10 (9)	0.821
Mean HR ± SD, bpm	74 ±19	72 ± 25	0.501
Mean SBP ± SD, mm Hg	128 ± 30	130 ± 30	0.479

Data are presented as n (%) except where otherwise stated.

BMI, body mass index; bpm, beats per minute; CAD, coronary artery disease; CrCl, creatinine clearance; CRF, chronic renal failure; HR, heart rate; SBP, systolic blood pressure; TIA, transient ischemic attack.

* True ST-elevation myocardial infarction cases only.

† Overall 32 missing (25 physician-blind, 8 physician-aware).

‡ Three missing (3 physician-blind).

§ Three missing (3 physician-aware).

‖ Overall 20 missing (10 physician-blind, 10 physician-aware).

door times in the automated cohort compared with the physician oversight cohort (median, 29 [IQR, 13] vs 35 [IQR, 20] minutes; $P = 0.900$; Table 4). The median door-to-device time was 47 (IQR, 24) minutes. There was no significant difference in door-to-device times in the automated cohort compared with the physician oversight cohort when analyzed continuously (46 vs 52 minutes; $P = 0.264$; Table 4). Door-to-device times of < 90 minutes were achieved in 263 patients (97%) in the automated cohort and 100 patients (95%) in the physician oversight cohort ($P = 0.138$). FMC-to-device times of < 120 minutes were achieved in 258 patients (95%) in the automated cohort and in 97 patients (89%) the physician oversight cohort ($P = 0.040$).

The proportion of off-hours presentation (ie, weekdays from 16:00 to 08:00 and weekends and holidays) was similar whether considering all activations (65% vs 71%; $P = 0.242$) or just true STEMI patients (67% vs 72%; $P = 0.338$).

Procedural success was achieved in 95% of patients without any difference between cohorts ($P = 0.908$).

Discussion

Our study shows that although the diagnostic performance of the "physician-blind" prehospital STEMI activation systems results in what could be considered acceptable FP and IA proportions, ECG reinterpretation by an emergency physician appears to reduce the proportion of ECG-IA further (from 7% to 3%), but is associated with a cost in terms of longer system delays with a smaller proportion achieving target FMC-to-device. Somewhat predictably, real-time physician oversight had no effect on the proportion of ECG-appropriate FP CCL activations. There appears therefore to be an important tradeoff in the minimization of IAs beyond what can be achieved with a "physician-blind" automated system alone and the minimization of treatment delays that has been shown to improve clinical outcomes.

Although there is broad agreement that prehospital CCL activation should be the cornerstone to addressing treatment delay shortfalls in STEMI activation systems, there is an ongoing debate regarding the necessary level of and appropriate means of physician oversight. Although the proportion of IA and FP activation are both important concerns, a certain proportion of FP STEMI diagnoses is commonly deemed acceptable and even necessary to minimize the proportion of false negative activations,[24,25,28] whereas IAs have not typically been associated with any patient benefit. To the contrary, Henry et al. reported that CCL cancellations are economically costly, suggesting that IAs might also have a deleterious health-economic effect.[29] IAs might also lead to distrust in the

Table 2. Types of error in 428 consecutive prehospital cardiac catheterization laboratory activations with and without real-time physician oversight

Type of error	Automated "physician-blind" (2012-2015; n = 311)	Oversight "physician-aware" (2014-2015; n = 117)	*P*
False positive activation	11 (4%)	1 (1%)	0.134
Inappropriate activation	23 (7%)	3 (3%)	0.062
Machine error	7 (2%)	0 (0%)	–
Human error	16 (5%)	3 (3%)	0.248

Table 3. Adjusted odds ratio of predictors of inappropriate activations across cohorts.

	Univariate analysis		Multivariate analysis	
Variable	OR (95% CI)	*P*	OR (95% CI)	*P*
Female sex	0.90 (0.37-2.19)	0.812	–	–
Age ≥ 75 years	2.74 (1.21-6.17)	0.015	2.98 (1.27-6.95)	0.012*
Diabetes	0.92 (0.30-2.76)	0.954	–	–
Hypertension	2.44 (0.99-6.01)	0.052	–	–
Previous CAD	3.20 (1.39-7.41)	0.006	3.02 (1.29-7.06)	0.011*
Physician-blind	3.03 (0.89-10.31)	0.075	–	–

CAD, coronary artery disease; CI, confidence interval; OR, odds ratio.
* Statistically significant at $P < 0.05$.

prehospital CCL activation system with possible adverse effects on patient care (ie, "STEMI fatigue")[23-25,30] and might be associated with unnecessary angiography.[24] It remains a matter of debate, however, how to best relate the avoidance of these IA costs to the costs of ensuring additional physician oversight in an automated system. Although the financial costs of IA and physician oversight might be readily comparable, the conceptual cost of "STEMI fatigue" vs a possible loss of mortality benefit due to treatment delays with additional oversight are not so easily related. (We would argue that the best objective metric for the effect of mistrust and STEMI fatigue might in fact be treatment delays.) As such, it is perhaps not surprising that there is currently no clear consensus in the literature regarding the acceptable rate of FP and IA. However, an FP rate of 5% has been shown to be achievable in a real-world STEMI program[25] and we estimate that an IA rate of 10% or less should minimize the risk of STEMI fatigue. Ultimately, however, a national consensus on the acceptable rate of FP and IA in a STEMI system is required to guide future quality of care initiatives.

Comparing the results of this analysis and previous analyses of "physician-blind" automated systems with other studies is not straightforward, because of differences in diagnostic category definitions,[7,16,31,32] eligibility criteria, and STEMI diagnosis algorithms.[12] The proportion of IAs reported in the literature is highly variable, ranging from 3% to 36%.[22,31-36] However, this disparity seems largely explained by the inclusion of only cancelled activations on one end of the spectrum to the inclusion of any "unwanted" activation (sometimes termed the "total FP" proportion; a combination of IA and FP) on the other, with variable inclusion of relative or social contraindications, such as extreme old age or very poor baseline functional status, in the IA definition. In addition, differences in the design of STEMI referral systems and the extent of training of ECG interpreters and CCL activators[22,35,36] and whether they are supported by automated or other decision aids[16] might also play a role. Because the causes and consequences of FP and IA differ, we and others contend that FP and IA proportions should be analyzed separately.[23-25]

Although a number of studies have reported the IA proportion separately, definitions again vary between studies. Garvey et al. reported an emergent angiography cancellation proportion of 25% with EMS-initiated and 15% with emergency physician-initiated CCL activation.[22] Mixon et al., who used a definition of IA on the basis of ECG criteria as we did, similarly reported a proportion of IA of 21% with EMS activation and 10% with emergency physician CCL activation.[23] Lu et al., in contrast, did not find a difference in the IA proportion using an ECG-based definition (4% vs 2%), but reported a higher FP proportion with emergency physician-initiated compared with EMS-initiated activations (17% vs 11%; $P = 0.01$).[32] The emergency physician-initiated IA proportion was similarly low (5%) in a report by Tanguay et al.[34] These last 2 Canadian studies,[32,34] combined with our previous work[24,25] and the present results, have all shown similarly low IA proportions. Moreover, irrespective of who initiates CL activation, ECG-IA has never been associated with a final diagnosis of STEMI,[23-25,34] reinforcing the appropriateness of using ECG criteria as the basis for defining IA.[23,24]

Somewhat surprisingly, very little has been published on predictors of IA.[22,23,32,34] Lange et al. reported that age, peak troponin, and initial ECG findings were factors that discriminated emergent coronary angiography vs cancellation.[37] However, of these, only age and the ECG are knowable at the time of CCL activation and case cancellation and IA are not necessarily synonymous. In an earlier report of the initial experience with automated CCL activation,[24] our analysis of predictors of IA led to the exclusion of rapid supraventricular tachycardias and left bundle branch block from the automatic referral algorithm. In the present analysis, after exclusion of these cases, older age and a history of CAD were independent predictors of IA, most of which were due to human error, suggesting that actors in the prehospital system

Table 4. Door-to-device and FMC-to-device time among 390 true STEMIs from 428 consecutive prehospital cardiac catheterization laboratory activations

	Automated (2012-2015; n = 277)	Physician Oversight (2014-2015; n = 113)	*P*
Median FMC-to-device time, IQR	76, 20	86, 25	< 0.001*
Median FMC-to-door time, IQR	29, 13	35, 20	0.900
Median door-to-device time, IQR	46, 24	52, 13	0.264

FMC, first medical contact; IQR, interquartile range; STEMI, ST-elevation myocardial infarction.
* Statistically significant at $P < 0.05$.

might have been unduly swayed by these considerations in a small proportion of cases. Because of the small number of IAs overall, it is not possible to comment on any differential effect of these predictors with or without real-time physician oversight.

Ensuring such oversight in a prehospital activation system might possibly come at a cost. In addition to the human and financial resources required, we observed longer treatment delays in the "physician-aware" system in terms of longer median FMC-to-device times and a lower proportion of patients achieving guideline-recommended treatment delays. Whether ensuring physician oversight is desirable therefore likely depends on the baseline diagnostic and treatment delay performance of a given STEMI referral system. Although not the situation described in this report, one could reasonably conclude that a "physician-blind" system that had an unacceptably high proportion of IA, but very good treatment delay performance, would stand to benefit from the addition of a real-time oversight mechanism (while maintaining adequate treatment delays overall). However, the usefulness of physician oversight when the IA proportion in a "physician-blind" system is low, such as in the system described in this report, would appear more dubious.

The present analysis has certain limitations because of its retrospective nature. This was a nonrandomized dual-centre study. Although there is the possibility of differential case mixes among the centres, the populations were similar in terms of their measured characteristics. Disparate geography between the 2 catchment areas is also a consideration that could potentially affect treatment delays. However, the STEMI catchment areas of both centers were designed to achieve target FMC-to-device in all patients. This is supported by the fact that FMC-to door times were not significantly different in the 2 cohorts. It should also be stressed that both centres are staffed by the same physician group of interventional cardiologists and both institutions apply similar STEMI pathways internally. As such, the risk of care differences upstream of the first device activation unrelated to the presence or absence of physician oversight should be minimal. Both systems also relied on the same in-the-field ECG equipment, increasing internal validity. However, this might also limit the generalizability of our results to systems using other technologies or automated referral exclusion criteria.[38] Finally, because the present analysis was based on CCL databases from both centres, we lack data on prehospital ECGs not resulting in CCL activation. We therefore cannot comment on the overall sensitivity, specificity, and false negative proportion of either referral system. Similarly, data on true STEMI patients who were not sent to the CCL could not be systematically collected. The 2 cases of the emergency physician incorrectly over-riding the prehospital ECG diagnosis were identified because they ultimately went to the CCL. Others might have been appropriately managed conservatively because of other considerations, but could not be identified from our CCL databases. Collaboration with prehospital emergency services in the greater Montreal region is ongoing to address this shortcoming with a regional prehospital data set.

In conclusion, adding real-time physician oversight to an automated prehospital STEMI diagnosis system had no effect on the FP proportion, but might be associated with fewer IAs at an apparent cost of negatively affecting FMC-to-device performance. Further research into the predictors of IA might lead to a hybrid algorithm in which ECGs at risk of being IAs would be selected for secondary assessment by the emergency physician, with high-likelihood automated STEMI diagnoses directly transferred to the CCL.

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Disclosures

The authors have no conflicts of interest to disclose.

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