ADVANCES

Diagnostic performance and potential clinical impact of advanced care paramedic interpretation of ST-segment elevation myocardial infarction in the field

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ABSTRACT

Objectives: Most studies of pre-hospital management of ST-elevation myocardial infarction (STEMI) have involved physicians accompanying the ambulance crew, or electrocardiogram (ECG) transmission to a physician at the base hospital. We sought to determine if Advanced Care Paramedics (ACPs) could accurately identify STEMI on the pre-hospital ECG and contribute to strategies that shorten time to reperfusion.

Methods: A STEMI tool was developed to: 1) measure the accuracy of the ACPs at diagnosing STEMI; and 2) determine the potential time saved if ACPs were to independently administer thrombolytic therapy. Using registry data, we subsequently estimated the time saved by initiating thrombolytic therapy in the field compared with in-hospital administration by a physician.

Results: Between August 2003 and July 2004, a correct diagnosis of STEMI on the pre-hospital ECG was confirmed in 63 patients. The performance of the ACPs in identifying STEMI on the ECG resulted in a sensitivity of 95% (95% confidence interval [CI] 86%–99%), a specificity of 96% (95% CI 94%–98%), a positive predictive value (PPV) of 82% (95% CI 71%–90%), and a negative predictive value (NPV) of 99% (95% CI 97%–100%). ACP performance for appropriately using thrombolytic therapy resulted in a sensitivity of 92% (95% CI 78%–98%), a specificity of 97% (95% CI 94%–98%), a PPV of 73% (95% CI 59%–85%) and an NPV of 99% (95% CI 97%–100%). We estimated that the median time saved by ACP administration of thrombolytic therapy would have been 44 minutes.

Conclusions: ACPs can be trained to accurately interpret the pre-hospital ECG for the diagnosis of STEMI. These results are important for the design of regional integrated programs aimed at reducing delays to reperfusion.

Key words: advanced care paramedics; myocardial infarction; thrombolytic therapy

RÉSUMÉ

Objectifs : La plupart des études sur la prise en charge préhospitalière des infarctus du myocarde avec élévation du segment S-T (IMEST) ont été faites dans un contexte où les médecins accompag-

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naient l'équipe d'ambulanciers ou l'électrocardiogramme était transmis à un médecin de la base hospitalière. Nous avons tenté de déterminer si les paramédics des soins avancés (PSA) pourraient identifier avec exactitude les IMEST à l'ECG préhospitalier, ce qui permettrait d'établir des stratégies qui réduiraient les délais jusqu'à la reperfusion.
Méthodes : Un outil IMEST a été conçu pour : 1) mesurer la capacité des PSA de diagnostiquer avec exactitude les IMEST; et 2) déterminer l'économie de temps potentielle si les PSA pouvaient administrer eux-mêmes un traitement thrombolytique. À partir des données des registres, nous avons par la suite estimé l'économie de temps liée à l'administration du traitement thrombolytique sur les lieux de l'incident comparativement à son administration à l'hôpital par un médecin.
Résultats : Entre le mois d'août 2003 et le mois de juillet 2004, un diagnostic exact d'IMEST fondé sur un ECG préhospitalier a été confirmé chez 63 patients. Le rendement des PSA quant à l'identification des IMEST à l'ECG a donné lieu à une sensibilité de 95 % (intervalle de confiance [IC] 95 %, 86 %–99 %), à une spécificité de 96 % (IC 95 %, 94 %–98 %), à une valeur prédictive positive (VPP) de 82 % (IC 95 %, 71 %–90 %) et à une valeur prédictive négative (VPN) de 99 % (IC 95 %, 97 %–100 %). Le rendement des PSA pour avoir utilisé le traitement thrombolytique de façon appropriée a donné lieu à une sensibilité de 92 % (IC 95 %, 78 %–98 %), à une spécificité de 97 % (IC 95 %, 94 %–98 %), à une VPP de 73 % (IC 95 %, 59 %–85 %) et à une VPN de 99 % (IC 95 %, 97 %–100 %). Nous avons estimé que l'administration du traitement thrombolytique par un PSA aurait permis de gagner en moyenne 44 minutes.
Conclusions : Les PSA peuvent être formés pour interpréter avec exactitude l'ECG préhospitalier dans le cadre du diagnostic d'un IMEST. Ces résultats sont importants pour la conception de programmes régionaux intégrés visant la réduction des délais jusqu'à la reperfusion.

Introduction

Thrombolytic therapy and primary percutaneous coronary intervention (PCI) are the 2 reperfusion strategies currently available for patients presenting with ST-elevation myocardial infarction (STEMI). Since delay to reperfusion of the infarct-related artery is associated with increased mortality,[1,2] strategies are needed that allow earlier identification of patients with STEMI and shorten the time from symptom onset to reperfusion.

The use of the pre-hospital electrocardiogram (ECG) has been found to reduce both door-to-needle time,[3] and door-to-balloon time.[3,4] Paramedics can achieve a high success rate (98.7%) in obtaining diagnostic quality pre-hospital 12-lead ECGs in the majority of patients,[5] and 12-lead ECGs can be transmitted from a moving ambulance using cellular telephones.[6] However,. transmission of an ECG requires additional costly technology, immediate availability of a physician to confirm the diagnosis, and a fault-free line. Transmission of the ECG can be difficult in up to 20% of cases,[7] and significant delays in treatment may result if immediate communication is not available. Computer interpretation of the ECG has not proved to be reliable for the diagnosis of STEMI.[8]

Pre-hospital administration of bolus thrombolytic agents is feasible and results in significant time savings.[9,10] Randomized trials comparing pre-hospital thrombolysis to in-hospital thrombolysis show that the time to therapy can be reduced significantly by administration of the drug in the field.[11–16] Although no such trials were individually powered to evaluate mortality, a meta-analysis found a 2% absolute reduction in in-hospital mortality for patients treated with pre-hospital thrombolysis.[17] In all these trials a physician either accompanied the ambulance crew or approved therapy after reviewing the transmitted pre-hospital ECG. Unfortunately, the availability of physicians to accompany the emergency medical services is not universal, nor has it been shown to be cost-effective. We therefore chose to prospectively evaluate: 1) the feasibility of ACPs (i.e., paramedics who have attained the Advanced Care Paramedic diploma) independently interpreting the pre-hospital ECG; and 2) the potential for ACPs to independently administer thrombolytic therapy in the field.

Methods

The study was conducted in the city of Ottawa between August 2003 and July 2004. Before the study commenced, it was established practice in the study location for ACPs to obtain a pre-hospital 12-lead ECG using a Zoll unit (Zoll Medical Corporation, Burlington, Mass.). None of these units were upgraded to transmit the ECG, and all had the ECG diagnostic function disabled. Up to 42 ambulance units during peak times provided emergency service throughout the study region to a population of approximately 800 000 people. The majority of ambulances were staffed by at least one ACP who had received an additional 8 hours of classroom teaching in the interpretation of

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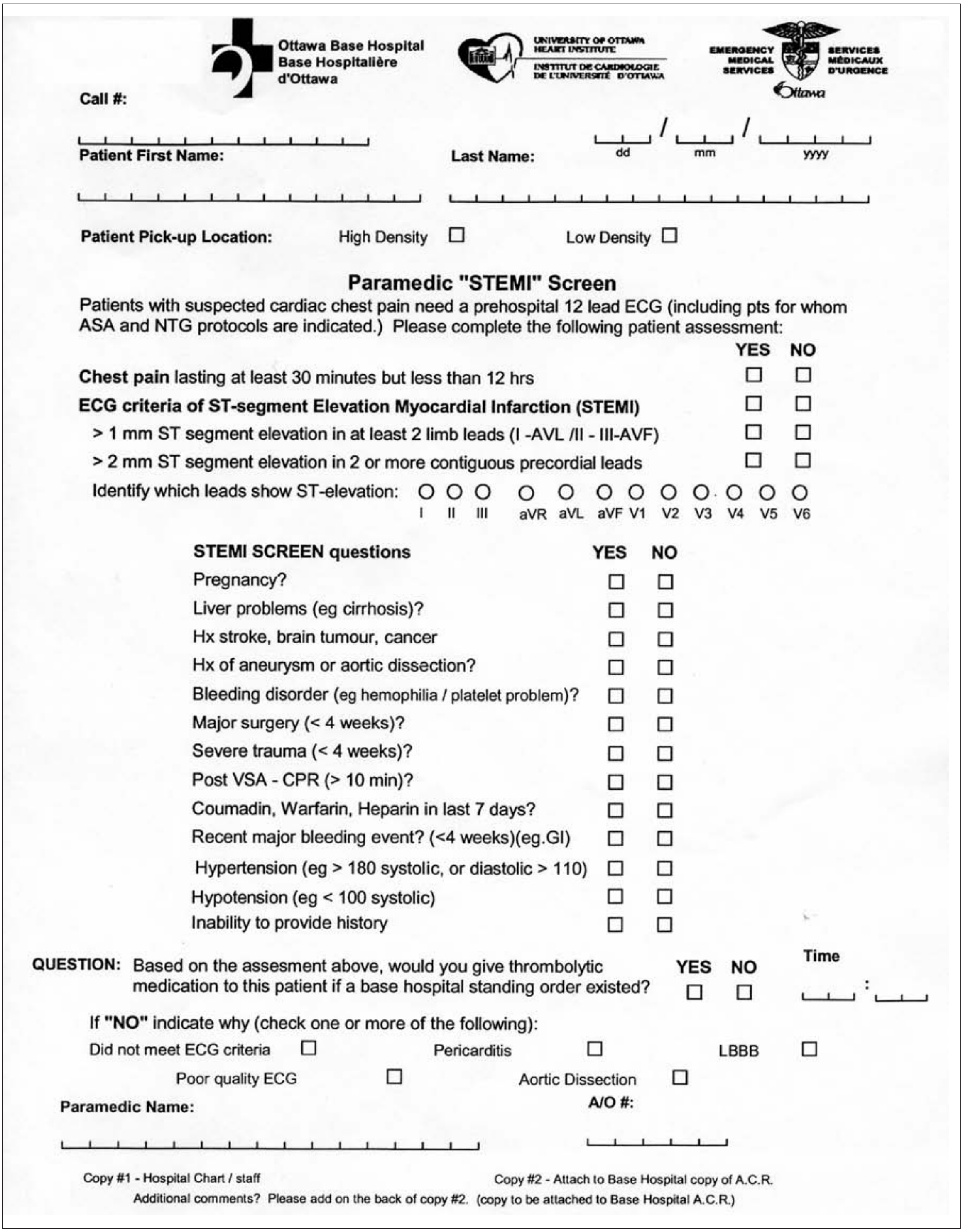
ECGs. The teaching focused on the recognition of ST-elevation consistent with the diagnosis of STEMI, and included supervised training in the field.

A STEMI tool (Fig. 1) was developed before the start of the study to measure the accuracy of ACP diagnosis of STEMI and to determine the potential time saved if ACPs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Call #:

dd / mm / yyyy

Patient First Name: Last Name:

Patient Pick-up Location: High Density ☐ Low Density ☐

Paramedic "STEMI" Screen

Patients with suspected cardiac chest pain need a prehospital 12 lead ECG (including pts for whom ASA and NTG protocols are indicated.) Please complete the following patient assessment:

	YES	NO
Chest pain lasting at least 30 minutes but less than 12 hrs	☐	☐
ECG criteria of ST-segment Elevation Myocardial Infarction (STEMI)	☐	☐
> 1 mm ST segment elevation in at least 2 limb leads (I -AVL /II - III-AVF)	☐	☐
> 2 mm ST segment elevation in 2 or more contiguous precordial leads	☐	☐

Identify which leads show ST-elevation: ○ I ○ II ○ III ○ aVR ○ aVL ○ aVF ○ V1 ○ V2 ○ V3 ○ V4 ○ V5 ○ V6

STEMI SCREEN questions	**YES**	**NO**
Pregnancy?	☐	☐
Liver problems (eg cirrhosis)?	☐	☐
Hx stroke, brain tumour, cancer	☐	☐
Hx of aneurysm or aortic dissection?	☐	☐
Bleeding disorder (eg hemophilia / platelet problem)?	☐	☐
Major surgery (< 4 weeks)?	☐	☐
Severe trauma (< 4 weeks)?	☐	☐
Post VSA - CPR (> 10 min)?	☐	☐
Coumadin, Warfarin, Heparin in last 7 days?	☐	☐
Recent major bleeding event? (<4 weeks)(eg.GI)	☐	☐
Hypertension (eg > 180 systolic, or diastolic > 110)	☐	☐
Hypotension (eg < 100 systolic)	☐	☐
Inability to provide history	☐	☐

QUESTION: Based on the assesment above, would you give thrombolytic medication to this patient if a base hospital standing order existed? **YES** ☐ **NO** ☐ Time __ : __

If **"NO"** indicate why (check one or more of the following):

Did not meet ECG criteria ☐ Pericarditis ☐ LBBB ☐

Poor quality ECG ☐ Aortic Dissection ☐

Paramedic Name: **A/O #:**

Copy #1 - Hospital Chart / staff Copy #2 - Attach to Base Hospital copy of A.C.R.

Additional comments? Please add on the back of copy #2. (copy to be attached to Base Hospital A.C.R.)

Fig. 1. ST-segment elevation myocardial infarction (STEMI) tool used to evaluate the accuracy of the advanced care paramedic's (ACP) interpretation of the 12-lead ECG in a patient presenting with chest discomfort. This tool was also used to evaluate the ACP's decision for the potential administration of thrombolytic therapy in the field. ASA = aspirin; NTG = nitroglycerin; VSA = vital signs absent; GI = gastrointestinal

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were to administer thrombolytic therapy in the field compared with in-hospital administration by a physician. The ACPs were instructed to apply the STEMI tool to all patients with chest pain consistent with myocardial ischemia.

A diagnosis of STEMI was made if patients presented within 12 hours of symptom onset, had symptoms lasting at least 30 minutes, and had ≥1 mm ST-elevation in at least 2 contiguous limb leads, or ≥2 mm in at least 2 contiguous precordial leads on the pre-hospital 12-lead ECG. The time of acquisition of the ECG was recorded. The ACPs indicated the patient's eligibility for immediate thrombolysis based on a STEMI questionnaire, listing exclusions to thrombolytic therapy, and entered the time of the decision to hypothetically administer thrombolytic therapy. We estimated the time that the thrombolytic would have actually been given by adding an additional 10 minutes to the ACP decision time, based on the delay measured from randomization to administration of tenecteplase in the Assessment of the Safety and Efficacy of a New Thrombolytic Regimen (ASSENT)-3 PLUS study.[10] The presence of left bundle-branch block has been reported to reduce the paramedic's ability to diagnose STEMI when compared with a cardiologist.[18] Because of this, our ACPs were instructed to exclude patients with this finding as candidates for pre-hospital thrombolytic therapy.

For the purpose of adjudication, 2 emergency physicians and one cardiologist, blinded to the ACPs' reports, independently reviewed all the pre-hospital ECGs and patients' charts to evaluate the ACPs' diagnoses, using the same diagnostic criteria. The study was approved by the Ottawa Base Hospital Program and the Institutional Review Board at the Ottawa Hospital.

Statistical analysis

Values for binary outcomes are reported as frequencies and percentages, with 95% confidence intervals (CIs) where appropriate; values for continuous outcomes are reported as medians with interquartile ranges. Analyses were performed with SYSTAT v. 11.0.

Results

The ACPs evaluated 967 patients with chest pain. A pre-hospital ECG was available in 97% of these patients, and the tracing was suboptimal in 1% of cases. The STEMI tool was applied to 411 (43%) of these patients. Non-compliance with the protocol was the main reason for the tool not being applied in eligible cases.

A correct diagnosis of STEMI on the pre-hospital ECG by ACPs was confirmed in 63 patients. The ACPs failed to diagnose STEMI in 3 patients (false negatives) and incorrectly identified STEMI in 13 patients (false positives). This performance in identifying STEMI on the ECG resulted in a sensitivity of 95% (95% CI 86%–99%), a specificity of 96% (95% CI 94%–98%), a positive predictive value (PPV) of 82% (95% CI 71%–90%) and a negative predictive value (NPV) of 99% (95% CI 97%–100%) (Table 1).

Were it possible for the ACPs to independently decide and administer thrombolytic therapy, 49 patients would have received treatment; 13 of these should have been excluded based on the inclusion and exclusion criteria. The performance of the ACPs in their decision regarding the patient's eligibility for thrombolytic therapy resulted in a sensitivity of 92% (95% CI 78%–98%), a specificity of 97% (95% CI 94%–98%), a PPV of 73% (95% CI 59%–85%) and an NPV of 99% (95% CI 97%–100%) (Table 1).

The median time intervals in patients with STEMI on the pre-hospital ECG are shown in Table 2. The median time from the ACPs' potential administration of pre-hospital thrombolytic therapy to hospital arrival was 3 minutes (interquartile range –5 min to 10 min). Our registry data indicates that the median hospital door-to-needle time for patients with STEMI arriving by ambulance during the study period was 41 minutes (interquartile range 30 min to 51 min). Therefore we estimate that the median time saved by the ACPs' administration of thrombolytic therapy would have been 44 minutes.

Discussion

The pre-hospital ECG can influence the management of patients with STEMI through faster utilization of reperfusion strategies.[3] Few studies have evaluated protocols allowing paramedics to diagnose STEMI and independently activate a well-defined management plan. Whitbread and colleagues showed that training paramedics to recognize STEMI on a 12-lead ECG is feasible and suggested that radio transmission may not be necessary to pre-alert the hospital.[19]

The concept that paramedics can independently make the diagnosis of STEMI and transfer the patient to a specialized centre may reduce the time to reperfusion. This was demonstrated in Derbyshire, UK, with a protocol whereby paramedics bypassed the emergency department and independently transferred patients directly to the coronary care unit resulted in the more expeditious administration of thrombolytic therapy.[20]

Two studies evaluated the feasibility of paramedics interpreting the ECG and deciding autonomously on the administration of thrombolytic agents.[21,22] The first was a small pilot study performed in rural Wales, where paramedics were trained to recognize STEMI on the 12-lead ECG, independently determining the eligibility for thrombolysis before hospital arrival.[21] When compared with treatment subsequently received in hospital, there was a potential reduction in call-to-needle time of 41 minutes, and the study concluded that paramedic selection of patients for the pre-hospital administration of thrombolytic therapy was both feasible and safe. A second study from the United Kingdom reached the same conclusion and reported a potential time savings of 48 minutes if the paramedics were to administer thrombolytic therapy in the field.[22] In the latter study the paramedics' sensitivity and specificity in identifying patients with STEMI was 71% and 97%, respectively, compared with 90% and 94% for doctors. Our findings are in keeping with these previous studies and further support the suggestion that a significant reduction in time to reperfusion could be achieved by paramedic administration of thrombolytic therapy. As in the 2 prior studies, we did not evaluate the safety of paramedics acting independently to actually administer thrombolytic agents. The NPV we found indicates that ACPs rarely miss STEMI; however, the PPV suggests that they would have administered thrombolytic therapy to a significant number of

Table 1. Sensitivity, specificity and predictive value of ACPs in the interpretation of STEMI on the ECG and on the hypothetical decision to administer thrombolytic therapy

		STEMI on ECG Adjudicated by MD: +	−	
STEMI on ECG interpreted by ACP	+	60 (TP)	13 (FP)	Positive predictive value = TP/(TP+FP) 60/73 = 82% (95% CI 71%–90%)
	−	3 (FN)	335 (TN)	Negative predictive value = TN/(FN+TN) 335/338 = 99% (95% CI 97%–100%)
		Sensitivity = TP/(TP+FN) 60/63 = 95% (95% CI 86%–99%)	Specificity = TN/(FP+TN) 335/348 = 96% (95% CI 94%–98%)	

		Appropriate decision to use thrombolysis Adjudicated by MD: +	−	
Decision to use thrombolysis by ACP	+	36 (TP)	13 (FP)	Positive predictive value = TP/(TP+FP) 36/49 = 73% (95% CI 59%–85%)
	−	3 (FN)	359 (TN)	Negative predictive value = TN/(FN+TN) 359/362 = 99% (95% CI 97%–100%)
		Sensitivity = TP/(TP+FN) 36/39 = 92% (95% CI 78%–98%)	Specificity = TN/(FP+TN) 359/372 = 97% (95% CI 94%–98%	

ACP = Paramedic who has attained the Advanced Care Paramedic diploma; STEMI = ST-elevation myocardial infarction; TP = true positive; FP = false positive; TN = true negative; FN = false negative; CI = confidence interval

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patients without STEMI. In addition, the opportunity for the ACPs to give thrombolytic therapy before hospital arrival would have been limited because in many cases the distance to the nearest hospital was relatively short. Patients with STEMI using the emergency medical services to reach the hospital are likely older than patients using self-transport, and therefore are at a higher risk of intracranial hemorrhage with thrombolytic therapy.[23] An alternative strategy would be to transfer patients with STEMI directly to a catheterization facility.

Limitations

This was a pilot study that evaluated the accuracy of trained ACPs to interpret the ECG in patients presenting with possible STEMI. The relatively low compliance in the application of the STEMI tool is a limitation that should be considered when interpreting our results. Although our study reports the potential time saved by ACPs independently administering thrombolytic therapy in the field, this strategy was only evaluated hypothetically, and greater delays could be encountered if ACPs were actually required to administer this treatment. Finally, our results do not apply to jurisdictions where ACPs are not available. Future studies are needed to evaluate the ability of primary care paramedics to interpret ECGs in the field.

Conclusion

Paramedics who have attained an Advanced Care Paramedic diploma can be trained to accurately interpret the pre-hospital ECG for the diagnosis of STEMI. These results are important for the design of regional integrated programs aimed at reducing delays to reperfusion and consequently improving clinical outcomes.

Table 2. Median time intervals between events for patients with ST-elevation myocardial infarction who were evaluated by advanced care paramedics (ACPs)*

Event	Median time interval, min (25th and 75th percentiles)
Symptom onset to 911 call	41 (15, 185)
911 call to ACP arrival	8 (6, 11)
ACP arrival to ECG	11 (8, 15)
ACP arrival to departure	19 (16, 24)
ECG to decision to administer thrombolytic therapy	3 (0, 11)
ECG to potential administration of thrombolytic therapy	13 (10, 21)
ECG to hospital arrival	19 (14, 24)
Potential administration of thrombolytic therapy to hospital arrival	3 (–5, 10)

*Paramedics who have attained the Advanced Care Paramedic diploma

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