Defining abnormal electrocardiography in adult emergency department syncope patients: the Ottawa Electrocardiographic Criteria

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ABSTRACT

Background: Previous studies have indicated that the suboptimal performance of the San Francisco Syncope Rule (SFSR) is likely due to the misclassification of the ''abnormal electrocardiogram (ECG)'' variable. We sought to identify specific emergency department (ED) ECG and cardiac monitor abnormalities that better predict cardiac outcomes within 30 days in adult ED syncope patients.
Methods: This health records review included patients 16 years or older with syncope and excluded patients with ongoing altered mental status, alcohol or illicit drug use, seizure, head injury leading to loss of consciousness, or severe trauma requiring admission. We collected patient characteristics, 22 ECG variables, cardiac monitoring abnormalities, SFSR ''abnormal ECG'' criteria, and outcome (death, myocardial infarction, arrhythmias, or cardiac procedures) data. Recursive partitioning was used to develop the ''Ottawa Electrocardiographic Criteria.''
Results: Among 505 included patient visits, 27 (5.3%) had serious cardiac outcomes. We found that patients were at risk for cardiac outcomes within 30 days if any of the following were present: second-degree Mobitz type 2 or third-degree atrioventricular (AV) block, bundle branch block with first-degree AV block, right bundle branch with left anterior or posterior fascicular block, new ischemic changes, nonsinus rhythm, left axis deviation, or ED cardiac monitor abnormalities. The sensitivity and specificity of the Ottawa Electrocardiographic Criteria were 96% (95% CI 80–100) and 76% (95% CI 75–76), respectively.
Conclusion: We successfully identified specific ED ECG and cardiac monitor abnormalities, which we termed the Ottawa Electrocardiographic Criteria, that predict serious cardiac outcomes in adult ED syncope patients. Further studies are required to identify which adult ED syncope patients require cardiac monitoring in the ED and the optimal duration of monitoring and to confirm the accuracy of these criteria.

RÉSUMÉ

Contexte: D'après des études antérieures, le rendement sous-optimal de la règle de San Francisco sur la syncope (RSFS) serait probablement attribuable à une mauvaise classification de la variable «électrocardiogramme (ECG) anormal». Nous nous sommes donc penchés sur certaines anomalies relevées à l'ECG pratiqué au service d'urgence et observées à la surveillance cardiaque, qui permettraient de mieux prévoir l'évolution des troubles cardiaques, au bout de 30 jours, chez les adultes traités à l'urgence pour une syncope.
Méthode: Le présent examen de dossiers médicaux portait sur des patients âgés de 16 ans et plus ayant fait une syncope, à l'exclusion des personnes atteintes d'une altération persistante de l'état mental, des personnes faisant usage d'alcool ou de drogues illicites, faisant des crises épileptiques, ayant subi un trauma crânien qui a entraîné une perte de connaissance ou ayant subi un trauma important qui a nécessité une hospitalisation. Nous avons recueilli des données sur les caractéristiques des patients, 22 variables liées à l'ECG, des anomalies relevées à la surveillance cardiaque, les critères d'«ECG anormal» selon la RSFS, et les résultats cliniques (mort, infarctus du myocarde, arythmie, ou interventions cardiaques). Nous avons eu recours à la partition récursive pour élaborer les «critères électrocardiographiques d'Ottawa».

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Résultats: Sur 505 consultations, 27 (5.3%) se sont soldées par une évolution grave des troubles cardiaques. Nous avons constaté que les patients susceptibles de connaître une évolution défavorable des troubles cardiaques, au bout de 30 jours, présentaient l'une ou l'autre des caractéristiques suivantes: un bloc auriculoventriculaire (BAV) du deuxième degré de type Mobitz II ou du troisième degré; un bloc de branche accompagné d'un BAV du premier degré; un bloc de branche droite, accompagné d'un bloc fasciculaire postérieur ou antérieur gauche; de nouveaux changements ischémiques; un rythme non sinusal; une déviation axiale gauche; ou des anomalies relevées à la surveillance cardiaque au service d'urgence. La sensibilité et la spécificité des critères électrocardiographiques d'Ottawa étaient de 96% (IC à 95% 80–100) et de 76% (IC à 95% 75–76), respectivement.

Conclusions: Nous avons réussi à dégager certaines anomalies relevées à l'ECG pratiqué au service d'urgence et observées à la surveillance cardiaque, désignées sous l'appellation de «critères électrocardiographiques d'Ottawa», qui permettent de prévoir une évolution grave des troubles cardiaques chez les adultes traités à l'urgence pour une syncope. Toutefois, il faudrait mener d'autres études afin de repérer, parmi ces mêmes adultes, ceux qui auraient besoin d'une surveillance cardiaque au service d'urgence, de déterminer la durée optimale de la surveillance et de confirmer la précision de ces critères.

Syncope is a common emergency department (ED) problem and accounts for 1 to 3% of ED visits and 2% of hospital admissions from the ED.[1–5] Cardiac outcomes (death from cardiac or unknown causes, myocardial infarction, arrhythmias, or need for cardiac procedural interventions) constitute a substantial proportion of the serious outcomes in these patients.[4–7] Among the published risk stratification instruments for predicting serious outcomes in ED syncope patients, only the San Francisco Syncope Rule (SFSR) has been prospectively derived and validated according to the methodological standards for clinical prediction rules.[8–10] The SFSR performed either suboptimally or poorly in all external validation studies due to substantial miss rates for serious cardiac outcomes.[6,7,11] In a validation study conducted by our group, the SFSR performed with a slightly lower sensitivity but significantly poorer specificity due to the poor performance of the "abnormal electrocardiogram (ECG)" variable.[11] In this study, we found that the addition of cardiac monitor abnormalities to the SFSR improved its sensitivity.[11] We also found that variable application of the poorly defined "abnormal ECG" variable could potentially explain the heterogeneity in performance of the SFSR between validation studies.[11]

All published ED syncope studies have arbitrarily defined the abnormal ECG variable. The SFSR classified an abnormal ECG as any nonsinus rhythm or any new changes, whereas other studies compiled a list of characteristics to define the ECG as abnormal.[4,12–14] The presence of any new changes in the ECG makes the SFSR ECG criteria difficult to implement and has led to variability in interpretation of this variable. This is evident from the wide variation in the

proportion of patients deemed to be positive for this variable across different studies.[6,7,11,15] No study has investigated the association between specific ECG characteristics or cardiac monitor abnormalities and serious cardiac outcomes in adult ED syncope patients.

The primary aim of this study was to derive the "Ottawa Electrocardiographic Criteria": clinically important and specific ED ECG and cardiac monitor abnormalities that would predict serious cardiac outcomes within 30 days in adult ED syncope patients. The criteria were derived only for serious cardiac outcomes, not for the many noncardiac outcomes that can occur in ED syncope patients. This study was carried out as a component of developing an improved clinical prediction rule by either refining the SFSR or deriving a new rule for adult ED syncope patients.

METHODS

Study design and setting

This was a retrospective health records review of consecutive adult syncope patients presenting to the ED of The Ottawa Hospital Civic Campus (an urban adult academic ED with 60,000 patient visits annually) from August 1, 2005, to January 30, 2007. The hospital research ethics board approved the protocol without the need for informed consent.

Study population

We identified potentially eligible patients by searching for the terms "syncope," "presyncope," "fainting," "blackout," "loss of consciousness," "fall," "collapse,"

"seizure," or "lightheadedness" in the presenting complaint or primary or secondary discharge diagnosis fields of The Ottawa Hospital health records database. Our hospital database is part of the Canadian National Ambulatory Care Reporting System (NACRS), which captures data on all patients visiting Canadian EDs. We used a consecutive sampling method to select potentially eligible records for review. We included patients who were 16 years of age or older, had a local residential address, and had syncope as defined by the sudden transient loss of consciousness followed by prompt spontaneous complete recovery. We excluded patients with a duration of loss of consciousness over 5 minutes, confusion, mental status changes from baseline, seizure, loss of consciousness related to alcohol or illicit drug use, or head or significant trauma and those who were not Ottawa residents. During the pilot phase of the study, we determined that we were unable to reliably differentiate presyncope from symptoms of dizziness, lightheadedness, or feeling unwell from hospital records. Because of this, we excluded presyncope patients in an effort to reduce contamination by nonsyncope patients. We photocopied the history and clinical examination portion of all ED records of treatment (physician, nurse, and paramedic) related to a syncopal episode visit. Using these, the principal investigator assessed all patients' study eligibility blinded to their outcome status. We included patients regardless of their admission or discharge disposition.

Study protocol and data abstraction

We defined an "index visit" as the first visit of a patient during the study period or any visit after 30 days of an index visit. We defined a "return visit" as any visit within 30 days of an index visit. As the risk for adverse outcomes likely varies with each visit, we included all index visits by the same patient and used patient visits as the unit of analysis. Using photocopies of the ED record of treatment and all ECGs performed during the visit, the principal investigator and a trained research assistant, blinded to patient outcome, abstracted patient demographics, medical history, ECG characteristics, details of ED cardiac monitoring, and disposition of the patient for included patient visits. We used standardized data abstraction forms, which were piloted prior to conducting the review. It is standard practice in the study hospital for all ECGs performed in the ED to be reviewed by a cardiologist.

The ECG characteristics were abstracted by reviewing all ECGs obtained during the visit along with the cardiologists' interpretation printed on the ECG. Each specific ECG variable was deemed to be present if it was detected on any of the ECGs during the ED visit. We abstracted 19 binary ECG variables (primary predictor variables) and 3 continuous variables (pulse rate, QRS duration, and corrected QT [cQT] interval). The ECG characteristics abstracted and their definitions are provided in the Appendix. The research assistant abstracted the first 10% of the data in the presence of the principal investigator, and the quality of the remaining data was ensured by twice-weekly meetings. To calculate the interobserver agreement for ECG interpretation, all ECGs on 10% of included patient visits (50 patient visits) were randomly selected by a computer number generator for review by a second emergency physician (E.P.H.) and assessment for the 19 ECG variables. Disagreements were resolved by consensus, and the consensus determinations were used in the analysis. We abstracted details of any abnormalities detected on an ED cardiac monitor that were not evident on the ECG and could potentially explain the cause of syncope. These included nonsinus rhythm, second- or third-degree atrioventricular (AV) block, ST-T wave changes (including dynamic changes) consistent with ischemia, sinus pause > 3 seconds, sinus bradycardia < 50 bpm, and sinus tachycardia > 100 bpm. We also abstracted details on any abnormalities detected on an ED cardiac monitor that required interventions or treatment (such as dialysis for hyperkalemia, pacemaker insertion, or electrical cardioversion) and any symptoms (such as dizziness, lightheadedness, loss of consciousness) associated with these abnormalities.

SAS-based data entry screens with built-in range and logic checks were designed for data entry (SAS Institute, Cary, NC). We further verified the accuracy of data collection and entry by regular review of frequency reports.

Outcomes

We defined serious cardiac outcomes as a composite variable that included death due to a cardiac or unknown cause, myocardial infarction, arrhythmia, or cardiac procedural interventions occurring within 30 days of the ED visit. We defined myocardial infarction as an elevation in troponin (as defined by the hospital

laboratory; ≥ 0.1 μg/L) or ECG changes consistent with infarction or ischemia confirmed in the patient's chart by the emergency physician, the cardiology service, or the most responsible physician. Arrhythmia was defined as any abnormality on an ECG or cardiac monitor that could potentially cause syncope and was associated with symptoms or that required treatment. We considered interventions such as coronary angiography ± angioplasty, electrical cardioversion, and pacemaker ± defibrillator insertion to treat a cardiac cause of syncope to be significant procedural interventions. Serious outcomes that had a noncardiac primary etiology were classified as negative for cardiac outcomes (e.g., ventricular fibrillation in a patient with massive gastrointestinal bleeding or bradycardia in a patient with a brain tumour). As cardiology follow-up within 7 days is not routinely available in our practice setting, we selected 30 days as the timing of outcome assessment.

We assessed outcomes by reviewing all records related to the ED visit (emergency medical service, nurses, emergency physician, and consultant) and in-patient records for admitted patients. We also reviewed the charts for prehospital and ED cardiac monitor abnormalities attributable to the cause of syncope. We searched for evidence of return visits to any of the local adult hospitals (to ED, outpatient clinics, or inpatient admission) using a computerized hospital patient tracking system. We reviewed the records from return visits and the death records from all local hospitals and the provincial coroner's office. A second emergency physician blinded to the predictor variables independently confirmed outcomes. In the event of disagreement, a third emergency physician adjudicated the outcome. We also collected the place of occurrence of cardiac outcomes, inside or outside the ED, the latter as an in-patient or in the community. Ethics approval was obtained from all local hospitals and the Office of the Chief Coroner before study commencement.

Data analysis

Continuous data are presented as means with standard deviation and categorical data as percent frequency of occurrence. Interobserver agreement for the primary predictor variables was assessed with the Cohen unweighted kappa (κ) coefficient. Univariate analysis was performed to determine the strength of any association between the various ECG characteristics and cardiac outcomes. For nominal variables, we used the chi-square test with continuity correction or the Fisher exact test as appropriate and report the relative risk with 95% confidence intervals (CIs). For continuous variables, we used an unpaired two-tailed t-test using separate or pooled variance estimates as appropriate and report the difference in the values with 95% CIs between groups with and without outcomes. We used SAS version 9.1 software for descriptive statistics, κ coefficient, and univariate analysis.

Variables with a p value < 0.2 on univariate analysis and κ > 0.5 were selected for chi-square recursive partitioning analysis to develop a highly sensitive model with the maximum possible specificity. We performed recursive partitioning using Knowledge SEEKER version 5 software (Angoss Software, Toronto, ON) to derive the final model. We included only patients who had at least one ECG done during the ED visit for univariate and multivariate analyses.

We calculated the sensitivity, specificity, predictive values, and likelihood ratios with 95% CIs for the model. Publicly available software was used for calculating test characteristics.[16] We performed the primary analysis by including only patients who had at least one ECG performed. We also conducted a sensitivity analysis by including all patient visits and assuming that those with no ECG performed were either positive or negative for the Ottawa Electrocardiographic Criteria.

RESULTS

There were 87,508 patient visits to the study hospital ED during the 18-month study period. Of these, 505 visits by 490 patients met the inclusion criteria and did not have exclusion criteria. The demographic and clinical characteristics of included patients are shown in Table 1. Numerous characteristics of patients who did not have an ECG performed during the ED visit were different from those who did, including (respectively) mean age (35 years v. 60 years), history of coronary heart disease (3% v. 21%), history of arrhythmia (3% v. 12%), history of cardiomyopathy or valvular heart disease (0% v. 3%), and final ED diagnosis of vasovagal syncope (49% v. 25%). All patients who suffered cardiac outcomes had at least one ED ECG performed.

There were 49 serious outcomes, including 27 cardiac outcomes (Table 2). The cardiac outcomes

Table 1. Characteristics of study cohort (N = 505)

Characteristic	Patient visits, n (%)
Demographics	
Age, yr mean (SD)	58.5 (23)
Range, yr	16–101
Female	254 (50.3)
Medical history, n (%)	
Congestive heart failure	30 (5.9)
Coronary artery disease	99 (19.6)
Arrhythmia	58 (11.5)
Valvular heart disease	14 (2.8)
Cardiomyopathy	5 (1.0)
Diabetes	65 (12.9)
Hypertension	174 (34.5)
Cerebrovascular accident	29 (5.7)
Transient ischemic attack	27 (5.3)
Management, n (%)	
ECG obtained	470 (93.1)
Cardiac monitoring during the ED visit	285 (56.4)
Any abnormality on cardiac monitor not detected on ECG*	39 (13.7)
Symptomatic abnormalities that explained the cause of syncope*	6 (2.1)
Admitted	62 (12.3)
Outcomes, n (%)	
Serious cardiac outcomes[†]	27 (5.3)
Death	2 (0.4)

ECG = electrocardiogram; ED = emergency department.
*Percentage calculated as a proportion of 285 patients monitored in the ED.
[†]The 27 serious cardiac outcomes are described in Table 2.

Table 2. Serious outcomes and place of outcome occurrence (inside or outside the ED)

Nature of outcomes*	All outcomes	Inside ED	Outside ED
Cardiac outcomes	27	12	15
Death	2	0	2
Profound bradycardia	2	1	1
New/uncontrolled atrial fibrillation	4	2	2
Sinus node dysfunction	7	3	4
Third-degree atrioventricular block	6	3	3
Acute coronary syndrome	1	1	0
Coronary angiogram/CABG	2	1	1
Pacer insertion	18	8	10
Ventricular tachycardia/fibrillation	1	1	0
Arrhythmia unspecified[†]	1	0	1
Noncardiac outcomes	22	9	12
Death	3	2	1
Gastrointestinal hemorrhage	8	5	3
Pulmonary embolism	4	1	3
Stroke	1	0	1
Brain tumour	1	1	0
Sepsis	1	0	1
Hospitalization on return visit	5	0	5
Other conditions requiring intervention[‡]	2	2	0

CABG = coronary artery bypass grafting; ED = emergency department.
*Some had > 1 outcome.
[†]Unspecified arrhythmia was found to be the cause of death in this patient by coroner's investigation.
[‡]Other noncardiac conditions include one patient with a large pleural effusion and another with a large pneumothorax, both of whom required chest tube insertion.

included two deaths, both of which were unexpected and occurred after the patient left the ED to a long-term care residential facility. The cause of death was not known in one patient and occurred 48 hours following the ED presentation. The cause of death for the second patient was reported as arrhythmia by the coroner's office and occurred 12 days later. Table 2 also lists the nonfatal cardiac and the noncardiac outcomes that occurred in study patients. There were three noncardiac deaths: two patients with massive gastrointestinal bleeding who died in the ED and one patient with sepsis who died as an in-patient. Symptomatic ED cardiac monitor abnormalities that explained the cause of syncope were evident in six patient visits and included three cases of sinus pause: one of dynamic ST-T wave changes consistent with ischemia, one of ventricular fibrillation leading to cardiac arrest, and one short run of paroxysmal atrial

fibrillation followed by a 4-second pause. The duration of cardiac monitoring ranged from 34 to 395 minutes among included patients.

Table 3 shows the univariate associations between specific ECG predictor variables and serious cardiac outcomes. We evaluated 19 primary predictor ECG variables and 10 created variables (2 combination variables: left anterior or posterior fascicular block in the presence of right bundle branch block, right or left bundle branch block in the presence of a first-degree atrioventricular block, and 8 variables based on QRS duration and cQT interval using various cutoffs). We did not further analyze the pulse rate as it was not significantly associated with serious cardiac outcomes on univariate analysis. Table 3 also shows the κ statistic for the primary predictor ECG variables. There were

Table 3. Univariate association and interobserver agreement of ECG predictor variables and serious cardiac outcomes

ECG predictor variable	Cardiac outcome n = 27 (%)	No cardiac outcome n = 443 (%)	Relative risk (95% CI)	κ statistic
Nonsinus rhythm*	7 (26)	31 (7)	4.0 (1.6–9.1)	0.84
Second- or third-degree AV block*	3 (11)	0	16.7 (5.3–19.5)	0.76
Premature atrial contractions*	4 (14)	23 (5)	2.9 (0.9–7.7)	0.88
Premature ventricular contractions	3 (11)	19 (4)	2.5 (0.6–7.6)	0.48
Intraventricular conduction defect	0	7 (2)	1.0 (0.0–8.7)	—†
Right bundle branch block (RBBB)*	9 (32)	29 (7)	5.7 (2.5–12.2)	1.0
Left bundle branch block (LBBB)*	5 (18)	13 (3)	5.7 (2.0–13.0)	1.0
Left anterior fascicular block (LAFB)*	3 (11)	10 (2)	4.4 (1.1–11.8)	1.0
Left posterior fascicular block (LPFB)*	1 (4)	1 (0.2)	9.0 (0.5–18.2)	1.0
Left ventricular hypertrophy	4 (14)	50 (11)	1.3 (0.4–3.8)	0.65
Right ventricular hypertrophy	1 (4)	5 (1)	3.0 (0.2–12.5)	—†
Left axis deviation*	5 (18)	36 (8)	2.4 (0.9–6.1)	0.57
Right axis deviation	0	11 (2)	0.7 (0.0–6.5)	0.24
Old myocardial infarction	4 (14)	36 (8)	1.9 (0.6–5.2)	0.55
Ischemic ST-T changes	4 (14)	39 (9)	1.7 (0.5–4.9)	0.58
New ischemic ST-T changes*	3 (11)	7 (2)	5.8 (1.4–14.1)	0.51
Secondary ST-T changes	3 (11)	9 (2)	4.8 (1.2–12.5)	0.14
Repolarization ST-T changes	0	6 (1)	1.2 (0.0–9.5)	1.0
Nonspecific ST-T changes	3 (11)	49 (11)	1.0 (0.2–3.3)	0.63
RBBB + (LAFB or LPFB)*	4 (14)	5 (1)	8.9 (2.8–17.6)	—
First-degree AV block + (RBBB or LBBB)*	4 (14)	3 (0.7)	11.5 (3.7–20.0)	—
			Difference between groups (95% CI)	
Mean pulse rate (beats/min)	69	70	−1 (−5 to 8)	—
Mean QRS duration (ms)*	121	95	25 (16 to 35)	—
Mean corrected QT interval (ms)*	455	434	21 (7 to 33)	—

AV = atrioventricular; ECG = electrocardiogram.
*Predictor variables with $p < 0.2$ on univariate analysis and κ > 0.5 were considered for recursive partitioning.
†Kappa statistic could not be calculated as the ECGs reviewed by the second reviewer did not contain these characteristics.

nine primary predictor variables: two combination variables and seven variables with varying cutoffs of QRS duration and cQT interval (QRS durations > 100, 110, and 120 ms; cQT intervals > 460, 475, 500, and 525 ms) that met our eligibility criteria for recursive partitioning ($p < 0.20$ and κ > 0.5).

Figure 1 shows the recursive partitioning decision tree to select the variables that separate patients with and without cardiac outcomes. The following variables remained in the model and constitute the Ottawa Electrocardiographic Criteria: second-degree Mobitz type 2 or third-egree AV block, bundle branch block + first-degree AV block, right bundle branch with either left anterior or posterior fascicular block, new ischemic changes, nonsinus rhythm, left axis deviation, or ED cardiac monitor abnormalities (Table 4).

Table 5 shows the classification performance of the Ottawa Electrocardiographic Criteria for identification

of serious cardiac outcomes. The Ottawa Electro-cardiographic Criteria failed to identify only one patient with a serious cardiac outcome. This patient suffered recurrent sudden syncope, had a normal ECG, and underwent empirical pacemaker insertion. Figure 2 shows the receiver operator characteristic (ROC) curve for the Ottawa Electrocardiographic Criteria for predicting serious cardiac outcomes within 30 days.[17] The area under the curve for this ROC curve was 0.89 (95% CI 0.82–0.95).

LIMITATIONS

Our results must be considered with the inherent limitations of a retrospective health records review. We only included patients with a local address in an effort to maximize follow-up; however, this may increase the risk of selection bias. We elected to exclude
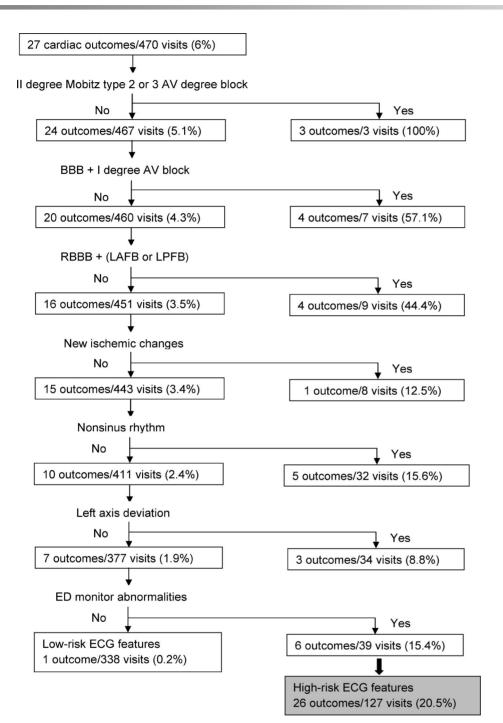
Figure 1. Derivation of the Ottawa Electrocardiographic Criteria by recursive partitioning analysis. AV = atrioventricular; BBB = bundle branch block; ECG = electrocardiographic; LAFB or LPFB = left anterior or posterior fascicular block; RBBB = right bundle branch block.

presyncope patients as we found it very difficult to differentiate presyncope from symptoms such as dizziness and lightheadedness during the pilot phase of the chart review.[4,5] We used cardiologists' interpretation of the ECG as it was easily available and routinely performed at our centre. The variations in κ values for the different ECG characteristics in our study may be due to the very small number of patients, with some characteristics in the ECGs randomly selected for dual

extraction. In this study, we sought to better define the "abnormal ECG" variable rather than develop a rule for predicting cardiac outcomes. Because of this, we did not include other clinical variables in our analysis. We intend to use important clinical variables such as congestive heart failure when we refine the SFSR or explore the feasibility of developing a new rule.[17] Our study cohort did not have any patients with congenital heart disease or conduction abnormalities, leading to

Table 4. The Ottawa Electrocardiographic Criteria to identify syncope patients at high risk for serious cardiac outcomes within 30 days

Patients are at risk for serious cardiac outcomes within 30 days if any of the following are present:

1. Blocks:
   a. Second-degree Mobitz type 2 or third-degree AV block
   b. Bundle branch block + first-degree AV block
   c. Right bundle branch + left anterior or posterior fascicular block
2. New ischemic changes
3. Nonsinus rhythm
4. Left axis deviation
5. ED cardiac monitor abnormalities

AV = atrioventricular; ED = emergency department.

absence of these conditions in the final model. We included only patients who had at least one ECG performed during the ED visit in the univariate and multivariate analyses. We would expect that most patients on whom ECG was not performed would have had a normal ECG given the young age of this cohort and proportion deemed to have vasovagal syncope. As with all chart reviews, the information in the patient's chart may have been incomplete or misinterpreted by the extractors, and serious outcomes might have been missed. Because the ECG criteria were objectively defined, the potential for abstraction error was minimized.

We took steps to minimize the potential biases of retrospective studies by using accepted chart review methodology, including clear objectives, appropriate case selection, unambiguous a priori definitions of the predictor variables and outcomes, use of standardized abstraction forms, training and mentoring the research assistant, regular meetings with the research assistant, blinding of the abstractors for outcomes at the data

Table 5. Classification performance of the Ottawa Electrocardiographic Criteria

Ottawa ECG criteria	Cardiac outcomes	
	Yes	No
Positive	26	106
Negative	1	337

ECG = electrocardiographic.
Sensitivity = 96% (95% CI 80–100); specificity = 76% (95% CI 75–76); negative predictive value = 99.7% (95% CI 98–100); positive predictive value = 19.7% (95% CI 16–20); negative likelihood ratio = 0.05 (95% CI 0.0–0.3); positive likelihood ratio = 4.0 (95% CI 3.2–4.2). Sensitivity analysis showed that the specificity decreased to 71% if all patients without ECG performed during the emergency department visit were assumed to be positive for the Ottawa Electrocardiographic Criteria and the specificity improved to 78% if they were all assumed to be negative. The sensitivity remained the same.

collection phase, independent outcome assessment by at least two reviewers, interrater reliability assessment, appropriate sample size calculation, ethics approval, review of records in all local adult hospitals and the coroner's office for occurrence of serious outcomes, and funding source declaration.[18–21]

The number of patients with serious cardiac outcomes is relatively small in our study. Because of this, the Ottawa Electrocardiographic Criteria might not perform as well with prospective testing and may prove to be less specific when more patients with cardiac monitor abnormalities would be detected. The optimal duration of cardiac monitoring of ED syncope patients remains undefined.

DISCUSSION

This study identified a set of clinically important ED ECG and cardiac monitor abnormalities that predict serious cardiac outcomes within 30 days in ED syncope patients, the Ottawa Electrocardiographic Criteria, composed of any of the following: type 2 second-degree or higher atrioventricular block; combined first-degree and bundle branch block; right bundle branch block with one left fascicle block; new ischemic changes; nonsinus rhythm; left axis deviation; or ED monitor abnormalities. The Ottawa Electrocardiographic Criteria do not predict noncardiac outcomes associated with ED syncope patients. Use of these criteria would have missed only one serious cardiac outcome in our study cohort.

Cardiac causes comprised the major proportion of serious outcomes in our study, and this is comparable to other ED-based syncope studies, which report a cardiac outcome prevalence of 4 to 9%.[4–7] The two combined variables that are part of our criteria have been identified as important in previous studies. In 1968, Lasser and colleagues, in a case series, identified that patients with right bundle branch block and marked left axis deviation (due to left anterior fasicular block, described as left anterior parietal or peri-infarction block) were at risk for complete heart block.[22] In a small prospective study with 27 patients, Tabrizi and colleagues reported that bifascicular block in syncope patients was highly predictive of third-degree AV block within 24 months.[23] Although perhaps intuitive, the associations of other ECG predictor variables with cardiac outcomes observed in our study have not been previously reported. Previously
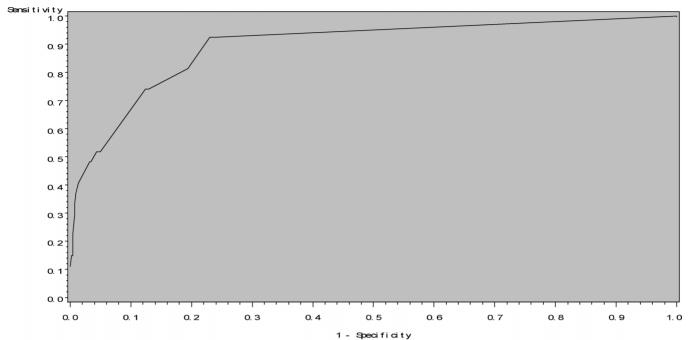
Figure 2. Receiver operating characteristic curve for the Ottawa Electrocardiographic Criteria. Area under the curve for the Ottawa Electrocardiographic Criteria: 0.89 (95% CI 0.86–0.92).

published risk stratification studies or guidelines have compiled a list of characteristics that define an ECG as abnormal.[4,12,13,24–27] The SFSR rule defined an abnormal ECG variable as any new change in the ECG or presence of a nonsinus rhythm. The difficult application of this broadly inclusive variable in the SFSR is evident from the varying proportion of patients (21–56%) who tested positive for this variable in the original study and in the external validation studies.[4,6,7,11,15] Studies have also reported only modest to fair interobserver agreement for application of the SFSR abnormal ECG variable.[6,7,28,29] The first risk stratification study by Martin and colleagues and the later studies by Colivicchi and colleagues and Reed and colleagues listed nonsinus rhythm; frequent repetitive premature ventricular contractions; conduction disorders including intraventricular conduction delay, bundle branch block, and AV blocks (except first degree); ventricular hypertrophy; left axis deviation; and old or new ischemic changes in their definition of abnormal ECG.[12,13,27] The 2009 European Society of Cardiology guidelines and Reed and colleagues additionally include bifascicular block; QRS duration ≥ 0.12 seconds; bradycardia < 50 bpm; sinus pause > 3 seconds; ST elevation in V_1-V_3 (Brugada syndrome); and negative T waves in the right precordial leads, epsilon waves, or ventricular late potentials (arrhythmogenic

right ventricular dysplasia) as abnormal ECG features.[25,27] The other features that contribute to abnormal ECG listed in these studies are abnormal PR interval (< 0.1 or > 0.2 seconds), long or short QT intervals (short QTc not defined, long QTc defined either as > 450 or > 500 ms), isolated nonspecific ST-T abnormalities, and early repolarization.[7,13,25–27] The 2007 American College of Emergency Physicians' clinical policy identifies acute ischemia, dysrhythmias, and significant conduction abnormalities as notable abnormal ECG findings but failed to define dysrhythmias or list which conduction abnormalities are significant.[24] Our study cohort did not have any patients with hypertrophic cardiomyopathy, Brugada syndrome, or arrhythmogenic right ventricular dysplasia, but the presence of ECG features suggestive of these disorders should be considered as high risk in the appropriate clinical setting in adult ED syncope patients.

We previously reported that a robust clinical decision rule is needed to risk stratify adult ED syncope patients as emergency physicians in our setting failed to predict 30% of serious outcomes occurring within 30 days of the ED visit and implementation of the SFSR in our setting would increase admission rates five- to sixfold.[11] If prospectively confirmed, the Ottawa Electrocardiographic Criteria have the potential to

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improve emergency physicians' ability to identify patients at risk for cardiac outcomes without a substantial increase in admission rates.

We identified some abnormalities that were captured only by cardiac monitoring and explained the cause of syncope. This has not been previously reported. These cardiac monitor abnormalities occurred within 8 hours of presentation to the ED. Due to limited availability of monitored beds in the ED, further studies are needed to identify which adult ED syncope patients need monitoring and the duration of cardiac monitoring for these patients.

CONCLUSIONS

We successfully identified specific ED ECG and cardiac monitor abnormalities we term the Ottawa Electrocardiographic Criteria that predict serious cardiac outcomes in adult ED syncope patients. Further studies are required to identify which adult ED syncope patients require cardiac monitoring in the ED and the optimal duration of monitoring and to confirm the accuracy of these criteria. Our new criteria are the first step toward exploring the feasibility of deriving a new risk stratification strategy. If confirmed prospectively in other patient populations, our criteria have the potential to improve the prognostic accuracy of current prediction tools for ED syncope patients, help emergency physicians better identify patients at risk for cardiac outcomes, and lead to more efficient use of health care resources.

REFERENCES

1. Blanc JJ, L'Her C, Touiza A, et al. Prospective evaluation and outcome of patients admitted for syncope over a 1 year period. *Eur Heart J* 2002;23:815-20, doi:10.1053/euhj. 2001.2975.

2. Sarasin FP, Louis-Simonet M, Carballo D, et al. Prospective evaluation of patients with syncope: a population-based study. *Am J Med* 2001;111:177-84, doi:10.1016/S0002-9343(01)00797-5.

3. Sun BC, Emond JA, Camargo CA Jr. Characteristics and admission patterns of patients presenting with syncope to U.S. emergency departments, 1992-2000. *Acad Emerg Med* 2004;11:1029-34.

4. Quinn JV, Stiell IG, McDermott DA, et al. Derivation of the San Francisco Syncope Rule to predict patients with short-term serious outcomes. *Ann Emerg Med* 2004;43:224-32, doi:10.1016/S0196-0644(03)00823-0.

5. Quinn J, McDermott D, Stiell I, et al. Prospective validation of the San Francisco Syncope Rule to predict patients with serious outcomes. *Ann Emerg Med* 2006;47:448-54, doi:10.1016/j.annemergmed.2005.11.019.

6. Birnbaum A, Esses D, Bijur P, et al. Failure to validate the San Francisco Syncope Rule in an independent emergency department population. *Ann Emerg Med* 2008;52:151-9, doi:10.1016/j.annemergmed.2007.12.007.

7. Sun BC, Mangione CM, Merchant G, et al. External validation of the San Francisco Syncope Rule. *Ann Emerg Med* 2007;49:420-7, doi:10.1016/j.annemergmed. 2006.11.012.

8. Wasson JH, Sox HC, Neff RK, et al. Clinical prediction rules. Applications and methodological standards. *N Engl J Med* 1985;313:793-9, doi:10.1056/NEJM198509263131306.

9. Stiell IG, Wells GA. Methodologic standards for the development of clinical decision rules in emergency medicine. *Ann Emerg Med* 1999;33:437-47, doi:10.1016/S0196-0644(99)70309-4.

10. Laupacis A, Sekar N, Stiell IG. Clinical prediction rules. A review and suggested modifications of methodological standards. *JAMA* 1997;277:488-94, doi:10.1001/jama.1997. 03540300056034.

11. Thiruganasambandamoorthy V, Hess EP, Alreesi A, et al. External validation of the San Francisco Syncope Rule in the Canadian setting. *Ann Emerg Med* 2010;55:464-72, doi:10.1016/j.annemergmed.2009.10.001.

12. Colivicchi F, Ammirati F, Melina D, et al. OESIL (Osservatorio Epidemiologico sulla Sincope nel Lazio) Study Investigators. Development and prospective validation of a risk stratification system for patients with syncope in the emergency department: the OESIL risk score. *Eur Heart J* 2003;24:811-9, doi:10.1016/S0195-668X(02)00827-8.

13. Martin TP, Hanusa BH, Kapoor WN. Risk stratification of patients with syncope. *Ann Emerg Med* 1997;29:459-66, doi:10.1016/S0196-0644(97)70217-8.

14. Sarasin FP, Hanusa BH, Perneger T, et al. A risk score to predict arrhythmias in patients with unexplained syncope. *Acad Emerg Med* 2003;10:1312-7, doi:10.1111/j.1553-2712. 2003.tb00003.x.

15. Cosgriff TM, Kelly AM, Kerr D. External validation of the San Francisco Syncope Rule in the Australian context. *CJEM* 2007;9:157-61.

16. Pezzullo JC. Interactive statistics page. 2-Way contingency table analysis. Available at: http://www.statpages.org/ctab2x2. html.

17. Hanley JA, McNeil BJ. A method of comparing the areas under receiver operating characteristic curves derived from the same cases. *Radiology* 1983;148:839-43.

18. Gilbert EH, Lowenstein SR, Koziol-McLain J, et al. Chart reviews in emergency medicine research: where are the

methods? *Ann Emerg Med* 1996;27:305-8, doi:10.1016/S0196-0644(96)70264-0.

19. Worster A, Bledsoe RD, Cleve P, et al. Reassessing the methods of medical record review studies in emergency medicine research. *Ann Emerg Med* 2005;45:448-51, doi:10.1016/j.annemergmed.2004.11.021.

20. Badcock D, Kelly AM, Kerr D, et al. The quality of medical record review studies in the international emergency medicine literature. *Ann Emerg Med* 2005;45:444-7, doi:10.1016/j.annemergmed.2004.11.011.

21. Lowenstein SR. Medical record reviews in emergency medicine: the blessing and the curse. *Ann Emerg Med* 2005;45:452-5, doi:10.1016/j.annemergmed.2005.01.032.

22. Lasser RP, Haft JI, Friedberg CK. Relationship of right bundle-branch block and marked left axis deviation (with left parietal or peri-infarction block) to complete heart block and syncope. *Circulation* 1968;37:429-37.

23. Tabrizi F, Rosenqvist M, Bergfeldt L, et al. Time relation between a syncopal event and documentation of atrioventricular block in patients with bifascicular block: clinical implications. *Cardiology* 2007;108:138-43, doi:10.1159/000096038.

24. Huff JS, Decker WW, Quinn JV, et al. Clinical policy: critical issues in the evaluation and management of adult patients presenting to the emergency department with syncope. *Ann Emerg Med* 2007;49:431-44, doi:10.1016/j.annemergmed.2007.02.001.

25. Moya A, Sutton R, Ammirati F, et al. Guidelines for the diagnosis and management of syncope (version 2009). *Eur Heart J* 2009;30:2631-71, doi:10.1093/eurheartj/ehp290.

26. Grossman SA, Fischer C, Lipsitz LA, et al. Predicting adverse outcomes in syncope. *J Emerg Med* 2007;33:233-9, doi:10.1016/j.jemermed.2007.04.001.

27. Reed MJ, Newby DE, Coull AJ, et al. The Risk stratification Of Syncope in the Emergency department (ROSE) pilot study: a comparison of existing syncope guidelines. *Emerg Med J* 2007;24:270-5, doi:10.1136/emj.2006.042739.

28. Byrt T. How good is that agreement? *Epidemiology* 1996;7:561.

29. Landis JR, Koch GG. The measurement of observer agreement for categorical data. *Biometrics* 1977;33:159-74, doi:10.2307/2529310.

APPENDIX: SPECIFIC ELECTROCARDIOGRAPHIC CHARACTERISTICS (PREDICTOR VARIABLES) ABSTRACTED FROM STUDY PATIENTS

a. Rhythm (sinus or nonsinus; if nonsinus specifically, if it is supraventricular tachycardia, multifocal atrial tachycardia, atrial fibrillation or flutter, ventricular tachycardia—sustained or nonsustained, ventricular fibrillation, junctional or idioventricular rhythm);

b. Presence of atrioventricular block and its type if present; paroxysmal atrial contractions or paroxysmal ventricular contractions and their frequencies; presence of intraventricular conduction delay, right bundle branch block, left bundle branch block, or left anterior/posterior fascicular block;

c. Presence of left ventricular hypertrophy, right ventricular hypertrophy, left axis deviation, right axis deviation, old myocardial infarction, ST segment and T wave changes consistent with ischemia and if present whether they are new, secondary ST-T wave changes (defined as ST-T wave changes that are not consistent with ischemia but secondary to causes such as medications, electrolyte imbalances, conduction defects, arrhythmias, or pulmonary disease), repolarization abnormalities, or nonspecific ST-T wave changes (defined as ST-T wave changes that are not consistent with ischemia or secondary ST-T wave changes);

d. Rate;

e. QRS duration in milliseconds;

f. Corrected QT interval in milliseconds; and

g. Is the electrocardiogram abnormal as per the San Francisco Syncope Rule criteria (any nonsinus rhythm or any new changes)?