Electrocardiogram Findings in Emergency Department Patients with Syncope

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Abstract

Objectives: To determine the sensitivity and specificity of the San Francisco Syncope Rule (SFSR) electrocardiogram (ECG) criteria for determining cardiac outcomes and to define the specific ECG findings that are the most important in patients with syncope.

Methods: A consecutive cohort of emergency department (ED) patients with syncope or near syncope was considered. The treating emergency physicians assessed 50 predictor variables, including an ECG and rhythm assessment. For the ECG assessment, the physicians were asked to categorize the ECG as normal or abnormal based on any changes that were old or new. They also did a separate rhythm assessment and could use any of the ECGs or available monitoring strips, including prehospital strips, when making this assessment. All patients were followed up to determine a broad composite study outcome. The final ECG criterion for the SFSR was any nonsinus rhythm or new ECG changes. In this specific study, the initial assessments in the database were used to determine only cardiac-related outcomes (arrhythmia, myocardial infarction, structural, sudden death) based on set criteria, and the authors determined the sensitivity and specificity of the ECG criteria for cardiac outcomes only. All ECGs classified as ''abnormal'' by the study criteria were compared to the official cardiology reading to determine specific findings on the ECG. Univariate and multivariate analysis were used to determine important specific ECG and rhythm findings.

Results: A total of 684 consecutive patients were considered, with 218 having positive ECG criteria and 42 (6%) having important cardiac outcomes. ECG criteria predicted 36 of 42 patients with cardiac outcomes, with a sensitivity of 86% (95% confidence interval [CI] = 71% to 94%), a specificity of 70% (95% CI = 66% to 74%), and a negative predictive value of 99% (95% CI = 97% to 99%). Regarding specific ECG findings, any nonsinus rhythm from any source and any left bundle conduction problem (i.e., any left bundle branch block, left anterior fascicular block, left posterior fascicular block, or QRS widening) were 2.5 and 3.5 times more likely associated with significant cardiac outcomes.

Conclusions: The ECG criteria from the SFSR are relatively simple, and if used correctly can help predict which patients are at risk of cardiac outcomes. Furthermore, any left bundle branch block conduction problems or any nonsinus rhythms found during the ED stay should be especially concerning for physicians caring for patients presenting with syncope.

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Syncope is defined as a transient loss of consciousness resulting in loss of postural tone, followed by spontaneous recovery with return to baseline neurologic function. It is a common clinical problem, accounting for 1.2% of emergency department (ED) visits and up to 6% of acute hospitalizations.[1,2]

The assessment of patients with syncope is challenging because of the heterogeneity of the underlying cause. Many causes of syncope are benign, with neurocardiogenic (vagal) presentations being the most common. However, many patients present to EDs with unclear causes, with 5% to 10% of these patients suffering significant morbidity or mortality. Cardiac arrhythmia and sudden death are the most serious causes of syncope in this group.[3,4] As a result, a large number of patients with benign syncope are admitted for inpatient evaluation, at an estimated cost in the United States of over $2 billion dollars a year.[5] There is a large variation in the number of patients admitted, with the rate in the United States reported to be 50% to 85%, while in

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Canada and Australia the admission rate is between 15% and 30%.[1,2,6–8] There is great potential to improve the efficiency of the admission decision, and numerous studies have attempted to derive predictors or risk factors for those at high risk for serious outcomes. Regardless of the study, cardiac risk and the presenting electrocardiogram (ECG) findings are consistently the most important factors in risk-stratification of syncope patients.[9–14] However, studies vary on what constitutes an ''abnormal'' ECG. Furthermore, failure to apply simple ECG criteria has led to a variety of results when externally validating prediction rules for syncope.[7,15,16] The largest series of prospective consecutive ED patients with syncope examined emergency physician interpretation of ECGs.[2,11] In the derivation of the San Francisco Syncope Rule (SFSR), the definition of an abnormal ECG included any nonsinus rhythm on the 12-lead ECG, during routine cardiac monitoring, and/or any new changes in the ECG compared to a previous ECG. However, the SFSR study considered all serious outcomes and did not distinguish cardiac outcomes from noncardiac serious outcomes. Furthermore, it did not specify which ECG findings were abnormal. In this study, we determined the sensitivity for the ECG criteria of the SFSR for cardiac outcomes and reviewed all the abnormal ECGs in the SFSR study to determine the specific abnormalities and their importance when evaluating patients with syncope.

METHODS

Study Design

This was an analysis of a database of prospectively collected data from consecutive patients with syncope. The original data set was collected under the approval of the University of California San Francisco committee on human research. The Stanford University institutional review board approved the reanalysis of data for this study.

Study Setting and Population

The initial prospective cohort study was conducted at a large university teaching hospital from July 1, 2000, until February 28, 2002, and included patients presenting with acute syncope or near syncope as a reason for their ED visit. Research assistants prospectively screened patients with complaints of syncope, loss of consciousness, fall, collapse, seizure, light-headedness, tachycardia, bradycardia, shortness of breath, and chest pain. Exclusion criteria were persistent altered mental status, alcohol or illicit drug related loss of consciousness, a definite seizure, or transient loss of consciousness caused by head trauma.

Study Protocol

Original Study. A research nurse reviewed daily patient logs and ensured enrollment of all possible patients. Prospective patients were identified and brought to the attention of the attending physician, who made the final decision to enroll the patient. After assessing the patients, physicians completed a structured data form. The physicians assessed 50 predictor variables, including an ECG and rhythm assessment. For the ECG assessment, the physicians were asked to categorize the ECG as normal (completely normal or old changes) or abnormal (any new changes). Specifically, physicians were instructed that they should consider any new change as an abnormal ECG if there was no old ECG for comparison, but were encouraged to use old ECGs from previous visits or serial ECGs in their assessments. Physicians also did a separate rhythm assessment, which was considered as a separate variable.

While monitoring was not mandated, they could use any of the ECGs or available monitoring strips, including prehospital strips, when making this assessment. Physicians marked the rhythm as sinus rhythm, supraventricular tachycardia (SVT), bradyarrhythmia, ventricular ectopy, or other. Where possible, two physicians independently evaluated patients to measure agreement on these two variables. In the derivation study both variables had good agreement and were combined to form the ECG criteria for the SFSR, the ECG criteria for the rule being positive if there were any new ECG changes or any nonsinus rhythm.[2]

Each patient was followed by a study coordinator to determine whether he or she had suffered a serious outcome by day 7. Serious outcomes for the study were death, myocardial infarction (MI), arrhythmia thought to cause the event, pulmonary embolism, stroke, subarachnoid hemorrhage, significant hemorrhage, or any condition causing or likely to cause a return ED visit and hospitalization or therapeutic procedure for a related event.

Current Study. In this reanalysis, we blinded ourselves to the initial assessments in the database and determined only cardiac-related outcomes based on set criteria. This included sudden death, MI (defined as any elevation of troponin or ECG change with an accompanying diagnosis of MI on the discharge diagnosis), any arrhythmia captured on monitoring and thought to have had a temporal relationship to the syncopal event, and any structural heart disease (primarily valvular) thought to have caused the event. We also considered any acute cardiac intervention such as pacemaker insertion and cardiac catheterization as important cardiac outcomes.

All ECGs classified as abnormal by the study criteria were collected. We used the official cardiology reading to determine the following specific findings on the ECG: rhythm abnormalities on the ECG (ventricular tachycardia, heart block, paced, SVT), presence of right branch bundle block (RBBB), left branch bundle block (LBBB), ST-segment changes, nonspecific ST-T wave changes, interval variants (PR, QT), presence of ectopy, and presence of Q-waves. We also reanalyzed the specific rhythm findings obtained during the separate rhythm assessment.

Data Analysis

We completed univariate chi-square analysis on the specific rhythm and ECG findings to determine important relationships for determining cardiac outcomes. Where appropriate we also combined related variables to determine significance and considered them for entry into a direct multivariate logistic regression

model based on statistical significance of $p < 0.2$. When variables were combined or clinically related (for example isolated LBBB vs. any LBBB or nonsinus on ECG vs. nonsinus from any source) we used the most significant variable for entry. Forty outcomes would allow sufficient power to consider up to four variables in our multivariate model.[17] The Hosmer-Lemeshow goodness-of-fit test was used to determine the model fit. Data were entered into an Access database (Microsoft Corp., Redmond, WA) and analyzed using SPSS version 18 (SPSS Inc., Chicago, IL)

RESULTS

A total of 684 consecutive patients were considered during the study period and represented 1.4% of the ED volume. Of the 684 patients, 634 had an ECG and rhythm analysis completed by an attending physician, and 10 had no ECG but a rhythm analysis documented. It was determined that 42 patients (6%) suffered cardiac outcomes, each of whom had both an ECG and a rhythm assessment. Of the 644 patients with ECG criteria, 218 were classified as having positive criteria, with 216 ECGs available for further analysis. Characteristics of all patients, those with abnormal ECGs and those with cardiac outcomes are outlined in Table 1.

The abnormal ECG criteria predicted 36 of the 42 patients with cardiac outcomes, giving a sensitivity of 86%, a specificity of 70%, and a negative predictive value of 99% (see Table 2 for confidence intervals [CIs]). Of the six patients not predicted by the criteria, three were diagnosed with non-Q-wave MI, one of whom died during cardiac catheterization. All were felt to have ECGs that were unchanged from previous readings. One had an exacerbation of CHF resulting in eventual death during hospitalization with an unchanged ECG on ED evaluation, and two were felt to have completely normal ECGs but were subsequently diagnosed with SVT.

Considering specific ECG findings, isolated LBBB, or any LBBB partial or complete, were associated with serious cardiac outcomes. The presence of Q-waves, RBBB, ST-segment changes, and sinus rhythm were not.

Table 1
Clinical and Demographic Characteristics

	All (N = 684)	Abnormal ECG Criteria (n = 216)	Cardiac Outcomes (n = 42)
Mean age (yr)	62.1 (±23)	72.5 (±17)	78.6 (±9.5)
Female	402 (58.9)	201 (48.6)	17 (40.1)
Admitted	376 (54.9)	165 (76)	41 (98)
Mean admission length (days)	1.6 (±2.4)	2.2 (±3)	4.9 (±4.2)
7-day serious outcomes	79 (11.5)	49 (23)	
Cardiac outcomes	42 (6.1)	36 (17)	
Arrhythmia	30 (4.4)	28 (13)	
Ischemic	9 (1.3)	6 (2.8)	
Structural	3 (0.4)	1 (0.1)	

Values are given as n (%) or mean (±SD).

Table 2
Sensitivity and Specificity of SFSR ECG Criteria for Detecting Cardiac Outcomes

	Criteria Positive	Criteria Negative
Cardiac outcome	36	6
No cardiac outcome	180	422
Total	216	428

Sensitivity = 86% (95% CI = 71% to 94%); specificity = 70% (95% CI = 66% to 74%); negative predictive value = 99% (95% CI = 97% to 99%); LR positive = 2.9 (95% CI = 2.4 to 3.4); LR negative = 0.2 (95% CI = 0.1 to 0.4).
ECG = electrocardiogram; LR = likelihood ratio; SFSR = San Francisco Syncope Rule.

On separate rhythm assessment (using all ED information including monitoring), a significantly greater number of patients were found to have nonsinus rhythms compared to the rhythm assessment using only the ECG reading (72% vs. 34%, $p = 0.001$), and this rhythm variable was significant on univariate analysis (Table 3). On the multivariate logistic regression analysis, the Hosmer-Lemeshow goodness-of-fit statistic was not significant ($p = 0.86$), indicating that the model prediction did not significantly differ from the observed. Only two variables met criteria for entry: any nonsinus rhythm from any source and any left bundle conduction problem (any LBBB, left anterior fascicular block, left posterior fascicular block, or QRS widening), which were 2.8 and 3.2 times more likely, respectively, associated with significant cardiac outcomes (see Table 4 for CIs).

DISCUSSION

An ECG is currently recommended in almost all patients with syncope, as it is consistently the most

Table 3
Univariate Analysis of Specific ECG and Rhythm Findings

Finding	Cardiac Outcome (n = 36)	No Cardiac Outcome (n = 180)	p-value
ECG			
Isolated complete LBBB	5 (14)	7 (4)	0.03
Any LBBB	15 (42)	49 (27)	0.01
RBBB	4 (11)	16 (9)	0.68
Q-waves	7 (19)	36 (20)	0.94
Ventricular ectopy	4 (11)	16 (9)	0.67
Sinus on ECG only	23 (64)	133 (74)	0.19
ST segment changes	4 (11)	11 (6)	0.23
Rhythm			
Sinus	7 (19)	67 (37)	0.04
SVT	1 (3)	1 (0.1)	0.20
Bradyarrhythmia	9 (25)	45 (25)	1.0
PVC	2 (6)	5 (3)	0.58
Other	17 (47)	61 (34)	0.13
Any nonsinus	29 (81)	113 (63)	0.04

Values are reported as n (%)
ECG = electrocardiogram; LBBB = left branch bundle block; PVC = premature ventricular contraction; RBBB = right branch bundle block; SVT = supraventricular tachycardia.

Table 4
Multivariate Analysis of Important ECG and Rhythm Findings

	Adjusted OR	95% CI
Any LBBB	3.2	1.4–6.9
Any nonsinus rhythm	2.8	1.1–6.8

ECG = electrocardiogram; LBBB = left branch bundle block.

important risk stratification tool as recommended by most society guidelines.[18,19] In this study we determined the sensitivity and specificity of the SFSR ECG criteria when considering cardiac outcomes in patients with syncope and determined that the likelihood of a significant cardiac outcome in a patient with normal SFSR ECG criteria was very low. We further defined specific ECG findings for patients with abnormal ECGs and found nonsinus rhythms any time during an ED evaluation and left bundle branch conduction problems on ECG to be important specific ECG findings.

Almost every study attempting to risk stratify patients with syncope has found the ECG to be an important predictor for adverse events.[2,9,12,13,20] However, there has been no agreement on what an abnormal ECG is in the setting of syncope. Definitions for significant ECG findings are generally long descriptions often defined by consensus specialty groups. Furthermore, there is no evidence regarding whether these findings can be determined and applied by physicians evaluating these patients at the bedside.[18] In one of the initial risk stratification studies by Martin et al.,[12] their definition was broad. They acknowledged that ventricular arrhythmias, bradycardia associated with symptoms, atrial–ventricular (AV) blocks (Mobitz II and complete heart block), and pacemaker malfunction were considered significant. However, ectopic beats, brief SVT, and atrial dysrhythmias were not considered abnormal, unless the patient was symptomatic. They excluded any nonspecific ST-T wave abnormalities as being significant. This definition was significantly different from that used by Colivicchi et al.[20] in their risk stratification. Their definition included any rhythm abnormalities, significant AV blocks, significant bundle branch blocks, right or left ventricular hypertrophy, left axis deviation, old MI, or any ST segment or ST-T wave abnormalities possibly consistent with myocardial ischemia. In the EGSYS trial, the definition of an abnormal ECG was comprehensive but nonspecific, including evaluation of the 12-lead ECG, as well as cardiac monitoring, electrophysiology studies, and ECG stress testing.[14]

When determining variables for the SFSR we kept a simple, broad, nonspecific definition that was subjective but tested for physician agreement for both the ECG findings and the rhythm assessment. The subsequent combining of the rhythm finding into the ECG criteria has seemed to confuse people. Many have failed to understand the origin of the rhythm assessment and in simplifying the rule have assumed the rhythm criteria applies only to one ECG and not all sources, as it was derived.[16] This had led to difficulty applying the criteria and validating our findings.[7,15] In the first external validation of the SFSR, Sun et al.[15] note in their limitations that they did not follow the ECG definition used in the SFSR, instead using a separate non-validated criteria ''any rhythm other than sinus, any bundle branch block, left-axis deviation, mono- or biventricular hypertrophy, any abnormal conduction interval except for first degree atrioventricular block, any Q/ST/T change consistent with ischemia (acute or chronic), or isolated, nonspecific ST/T abnormalities.'' In a separate validation study by Birnbaum et al.,[7] the cardiology overread of ECGs was used when applying the criteria and appeared to ignore any monitoring abnormalities when applying the rhythm criteria. In a recently published study, a group from the University of Ottawa looked at the sensitivity of the SFSR with and without the use of monitoring findings when defining rhythm abnormalities.[8] When using the same ECG criteria as the initial SFSR studies, they were able to externally validate the results with the same sensitivity.[8] In this study, we showed that over half of abnormal rhythms will be missed if only one ECG during the ED visit is used as the only source for rhythm determination.

LIMITATIONS

This was an observational cohort study that did not mandate care or specific standardized testing including monitoring in the ED. There were a significant number of cases where the ECG showed sinus rhythm, but in those same 216 patients, the number with a sinus rhythm decreased substantially when all sources were used to determine the rhythm (Table 3). So while we cannot make recommendations on who should be monitored or for how long, it is clear that when monitoring occurs, the findings should not be ignored.

Another limitation in this and the original derivation study for the SFSR was that some of the predictor variables could have been defined as outcomes. For example, if a patient had an ''arrhythmia thought to cause the event'' (one of the outcome definitions), it could have been the same arrhythmia that was seen on the initial ECG. We also only reviewed specific changes in those ECGs that were considered abnormal, and it is possible that some of the ECGs meeting ''normal'' criteria had some old changes that may have been important. However, that would have pertained to only four such ECGs, and including all other normal ECGs without outcomes in our analysis would have yielded little information but added background noise to our analysis. Finally, we may not have considered all specific findings that could have been important, such as right or left ventricular hypertrophy.

CONCLUSIONS

There are many factors that go into evaluating the patient with syncope. ECG and rhythm findings from all sources (multiple ECGs and rhythm strips) are important. The ECG criteria from the San Francisco Syncope Rules are relatively simple and if used correctly can predict which patients are at risk of cardiac outcomes. Furthermore, any left branch bundle block conduction problems or any nonsinus rhythms found during the ED evaluation of patients with syncope should be particularly concerning.

References

1. Blanc JJ, L'Her C, Touiza A, Garo B, L'Her E, Mansourati J. Prospective evaluation and outcome of patients admitted for syncope over a 1 year period. Eur Heart J. 2002; 23:815–20.
2. Quinn JV, Stiell IG, McDermott DA, Sellers KL, Kohn MA, Wells GA. Derivation of the San Francisco Syncope Rule to predict patients with short-term serious outcomes. Ann Emerg Med. 2004; 43:224–32.
3. Kapoor WN. Syncope. NEJM. 2000; 343:1856–62.
4. Soteriades ES, Evans JC, Larson MG, et al. Incidence and prognosis of syncope. N Engl J Med. 2002; 347:878–85.
5. Sun BC, Emond JA, Camargo CA Jr. Direct medical costs of syncope-related hospitalizations in the United States. Am J Cardiol. 2005; 95:668–71.
6. Cosgriff T. External Validation of the San Francisco Syncope Rule in the Australian context. CJEM. 2007; 9:157–61.
7. Birnbaum A, Esses D, Bijur P, Wollowitz A, Gallagher EJ. Failure to validate the San Francisco Syncope Rule in an independent emergency department population. Ann Emerg Med. 2008; 52:151–9.
8. Thiruganasambandamoorthy V, Hess EP, Alreesi A, Perry JJ, Wells GA, Stiell IG. External validation of the San Francisco Syncope Rule in the Canadian setting. Ann Emerg Med. 2010; 55:464–72.
9. Costantino G, Perego F, Dipaola F, et al. Short- and long-term prognosis of syncope, risk factors, and role of hospital admission: results from the STePS (Short-Term Prognosis of Syncope) study. J Am Coll Cardiol. 2008; 51:276–83.
10. Reed MJ, Newby DE, Coull AJ, Prescott RJ, Jacques KG, Gray AJ. The ROSE (risk stratification of syncope in the emergency department) study. J Am Coll Cardiol. 2010; 55:713–21.
11. Quinn J, McDermott D, Stiell I, Kohn M, Wells G. Prospective validation of the San Francisco Syncope Rule to predict patients with serious outcomes. Ann Emerg Med. 2006; 47:448–54.
12. Martin TP, Hanusa BH, Kapoor WN. Risk stratification of patients with syncope. Ann Emerg Med. 1997; 29:459–66.
13. Sarasin FP, Hanusa BH, Perneger T, Louis-Simonet M, Rajeswaran A, Kapoor WN. A risk score to predict arrhythmias in patients with unexplained syncope. Acad Emerg Med. 2003; 10:1312–7.
14. Del Rosso A, Ungar A, Maggi R, et al. Clinical predictors of cardiac syncope at initial evaluation in patients referred urgently to a general hospital: the EGSYS score. Heart. 2008; 94:1620–6.
15. Sun BC, Mangione CM, Merchant G, et al. External validation of the San Francisco Syncope Rule. Ann Emerg Med. 2007; 49:420–7.
16. McDermott D, Quinn J. Response to ''failure to validate the San Francisco Syncope Rule in an independent emergency department population'' [letter]. Ann Emerg Med. 2009; 53:693.
17. Hsieh FY, Bloch DA, Larsen MD. A simple method of sample size calculation for linear and logistic regression. Stat Med. 1998; 17:1623–34.
18. Brignole M, Alboni P, Benditt DG, et al. Guidelines on management (diagnosis and treatment) of syncope-update 2004. Executive Summary. Eur Heart J. 2004; 25:2054–72.
19. 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.
20. Colivicchi F, Ammirati F, Melina D, Guido V, Imperoli G, Santini M. 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.