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Original Contributions

EVALUATION OF SPODICK'S SIGN AND OTHER ELECTROCARDIOGRAPHIC FINDINGS AS INDICATORS OF STEMI AND PERICARDITIS

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☐ **Abstract—Background: Patients with ST elevation on electrocardiogram (ECG) could have ST elevation myocardial infarction (STEMI) or pericarditis. Spodick's sign, a downsloping of the ECG baseline (the T-P segment), has been described, but not validated, as a sign of pericarditis. Objective: This study estimates the frequency of Spodick's sign and other findings in patients diagnosed with STEMI and those with pericarditis. Methods: In this retrospective review, we selected charts that met prospective definitions of STEMI (cases) and pericarditis (controls). We excluded patients whose ECGs lacked ST elevation. An authority on electrocardiography reviewed all ECGs, noting the presence or absence of Spodick's sign, ST depression (in leads besides V_1 and aVR), PR depression, greater ST elevation in lead III than in lead II (III > II), abrupt take-off of ST segment (the RT checkmark sign), and upward or horizontal ST convexity. We quantified strength of association using odds ratio (OR) with 95% confidence interval (CI). Results: One hundred and sixty-five patients met criteria for STEMI and 42 met those for pericarditis. Spodick's sign occurred in 5% of patients with STEMI (95% CI 3–10%) and 29% of patients with pericarditis (95% CI 16–45%). All other findings statistically distinguished STEMI from pericarditis, but ST depression (OR 31), III > II (OR 21), and absence of PR depression (OR 12) had the greatest OR values. Conclusions: Spodick's sign is statistically associated with pericarditis, but it is seen in 5% of patients with STEMI. Among other findings, ST depression, III > II, and absence of PR depression were the most discriminating. © 2020 Elsevier Inc. All rights reserved.**

☐ **Keywords—ST elevation myocardial infarction; pericarditis; electrocardiography; chest pain; emergency service; hospital**

INTRODUCTION

Patients with chest pain and ST elevation often provoke a time-sensitive diagnostic dilemma for emergency physicians. On the one hand, the cardiac catheterization laboratory must be activated quickly for patients with ST elevation myocardial infarction (STEMI) to ensure timely reperfusion. Much of the improvement in the mortality rate associated with STEMI has been linked to decreasing door-to-balloon times (1–4). On the other, false activation of the catheterization laboratory can decrease patient trust and staff morale, increase cost, lead to unnecessary procedures, and has been linked to in-hospital mortality (1,4).

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Pericarditis, which frequently causes ST elevation and chest pain, can be mistaken for STEMI. Dr. David Spodick, a pioneer in the study of the pericardium, described the classic four-stage evolution of electrocardiographic changes with pericarditis, including ST elevations and PR depressions (5). Spodick's sign, a downsloping ECG baseline, has been described as being present in 80% of patients with pericarditis (6,7). The frequency of this finding in STEMI is unknown.

Along with Spodick's sign, a number of electrocardiographic findings have been reported as useful in distinguishing STEMI from pericarditis, including PR depression, ST depression, the shape of the ST segment, and the height of ST elevation in lead II relative to lead III (1,8). In this study, we estimate the frequency of these findings in STEMI and validate them by comparing their frequencies in groups of patients with STEMI and pericarditis.

METHODS

Selection and Setting

In this case–control study, which was approved by our Institutional Review Board, we reviewed charts from patients admitted for STEMI (cases) and pericarditis (controls) between 2004 and 2013. We obtained all records from a single, academic, tertiary care center with full capability in interventional cardiology and cardiac surgery and an annual census of approximately 46,000 patients.

To identify STEMI patients eligible for inclusion in this study, we reviewed charts using the third universal definition of MI (9). Those who survived had to meet the following criteria: ST elevation on an electrocardiogram (ECG) preceding a visit to the catheterization suite; a rise or fall of cardiac troponin I with at least one value above the 99th percentile; and symptoms of ischemia, evidence of wall motion abnormalities, or intracoronary thrombus. We further required that an ECG recognized in the chart as showing ST elevation must have been available < 2 h prior to arrival in the catheterization laboratory, unless there was a recorded delay in the laboratory. For patients who did not survive STEMI, we required symptoms, ST elevation, and death occurring before cardiac markers could rise or fall.

For pericarditis controls, we obtained a list of records of admitted patients with discharge diagnosis. From this list, two reviewers independently reviewed records according to the following criteria: chest pain was a presenting symptom; discharge summary indicated that the treating physician thought that pericarditis was the cause of the patient's chest pain; and no evidence of MI or acute coronary syndrome (ACS) was provided by cardiac marker or other testing. We required chest pain as an indicator of pericarditis because patients who are experiencing it are likely to be considered as having acute coronary syndrome.

For STEMI cases, we obtained a list of records with a discharge diagnosis of STEMI from our medical records department. A research assistant (AAW) who had completed the first year of medical school, reviewed all records. Other research team members (KMH, MDW) reviewed all pericarditis controls and all STEMI cases for which the initial reviewer indicated uncertainty. Additionally, we re-reviewed a random sample of 10% of STEMI eligibility determinations for quality assurance.

Figure 1 displays the selection process for STEMI cases and pericarditis controls.

Data Collection and Processing

We recorded demographic data (age, sex, race/ethnicity) for all patients. For STEMI patients, we recorded whether the patient survived to cardiac catheterization and the results of the procedure. We noted whether thrombus was discovered and whether any arteries were revascularized. We classified arteries as major (left main, left anterior descending, circumflex, and right coronary artery) or minor (other coronary arteries). For pericarditis patients, we noted whether there was any documentation of ECG changes suggesting pericarditis, pericardial rub, pericardial effusion, or pericardial biopsy.

We prepared a set of ECGs from both the STEMI and pericarditis groups. In this set, all clinical and diagnostic information was masked, and we assembled them in random order. For STEMI cases, we chose the first ECG with ST elevation or the one most closely preceding time of catheterization. For pericarditis patients, we reviewed all ECGs obtained during the first 3 days of hospitalization. We included the initial ECG for every patient. For patients who developed greater ST elevation during their stay, we also included the ECG showing the greatest ST elevation. For these cases, we included both ECGs (the initial one and the one with greatest ST elevation) to improve the quality of the masking because we had many more STEMI cases than pericarditis cases.

Three board-certified emergency physicians reviewed all ECGs for the presence of several findings and documented those findings on a standard data collection form. The physicians were: a recognized expert in ECG interpretation (AM), a residency-trained emergency physician and emergency cardiology fellow (ST), and an experienced emergency physician with an average interest in electrocardiography (MDW). ECG reviewers used the following prospective definitions: ST depression of 0.5 mm, comparing the J point to the T-P segment, in

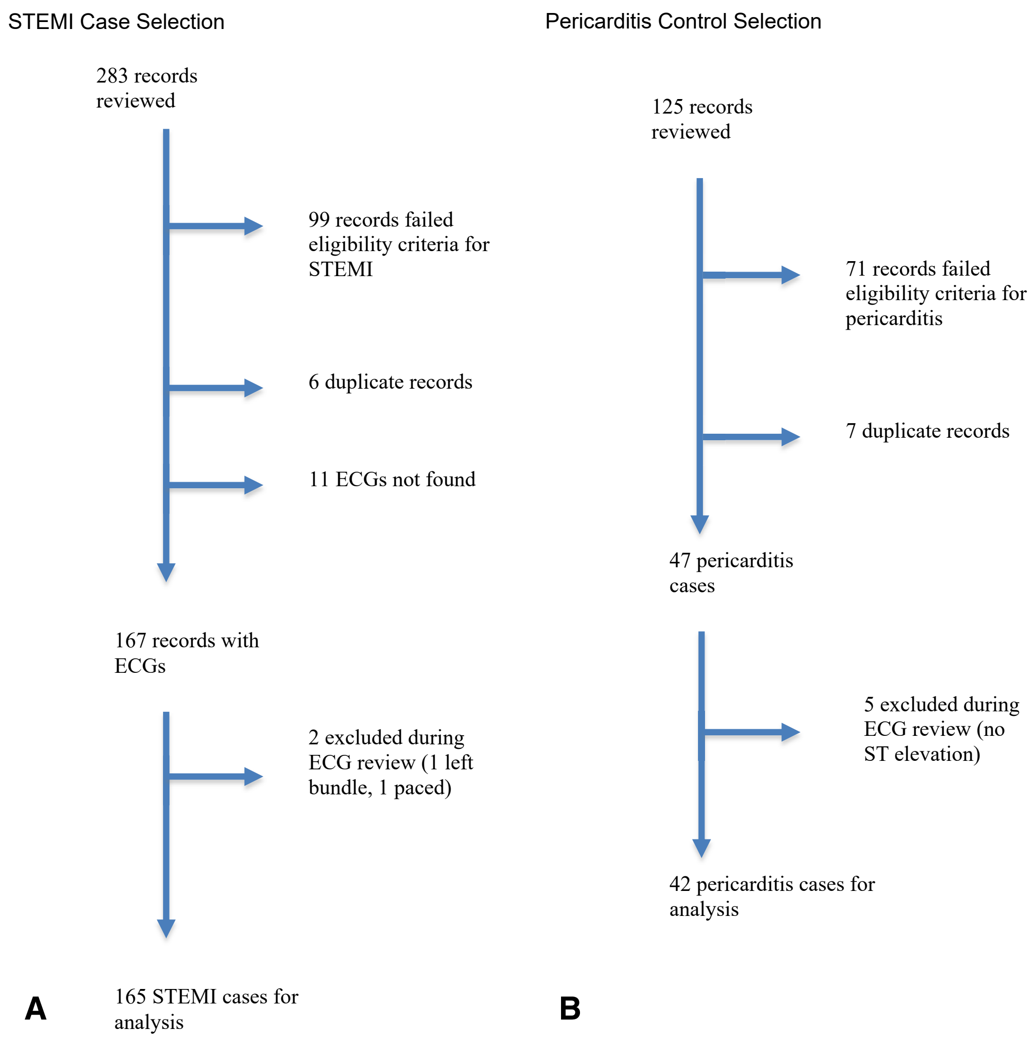

Figure 1. Flow diagram for electrocardiogram selection in ST elevation myocardial infarction (STEMI) cases (A) and pericarditis controls (B). ECG = electrocardiogram.

any lead besides aVR or V_1; ST elevation, measured from the J point, in lead III greater than in lead II (ST elevation III > II); ST convex upward or horizontal except in lead V_1; RT checkmark (ST elevation with abrupt takeoff from end of R wave); and PR depression, measured from the beginning of the P wave to the beginning of the R wave, in multiple leads (1,5,8,10). The RT checkmark has been taught as an indication of STEMI for years by one author (AM) and disseminated via the internet, but it has not yet been described in a peer-reviewed journal (11). Examples of these findings are shown in Figure 2. For Spodick's sign, reviewers noted the number of leads showing a decline of at least 1 mm from the beginning of the T-P segment to the end. Based on the distribution of the number of leads with this finding and a desire to minimize the significance of artifact, we considered an ECG to have Spodick's sign if at least two leads had T-P downsloping of at least 1 mm. Reviewers also noted whether there was a left-bundle branch block pattern (LBBB), a paced rhythm, or the absence of ST elevation in all leads.

DATA ANALYSIS

We excluded data from any patients with LBBB, paced rhythm, or no ST elevation. We also excluded data from the initial ECG for pericarditis patients who developed greater ST elevation during hospitalization. In the remaining data set, we calculated descriptive statistics for both groups. We considered the ECG expert review to be the criterion standard for the presence or absence of electrocardiographic findings and for ECG eligibility determination. Data from other reviewers were used for calculation of inter-rater reliability and effect of reviewer on odds ratio (OR) estimates. We calculated 95% confidence intervals (CIs) for proportions using a normal

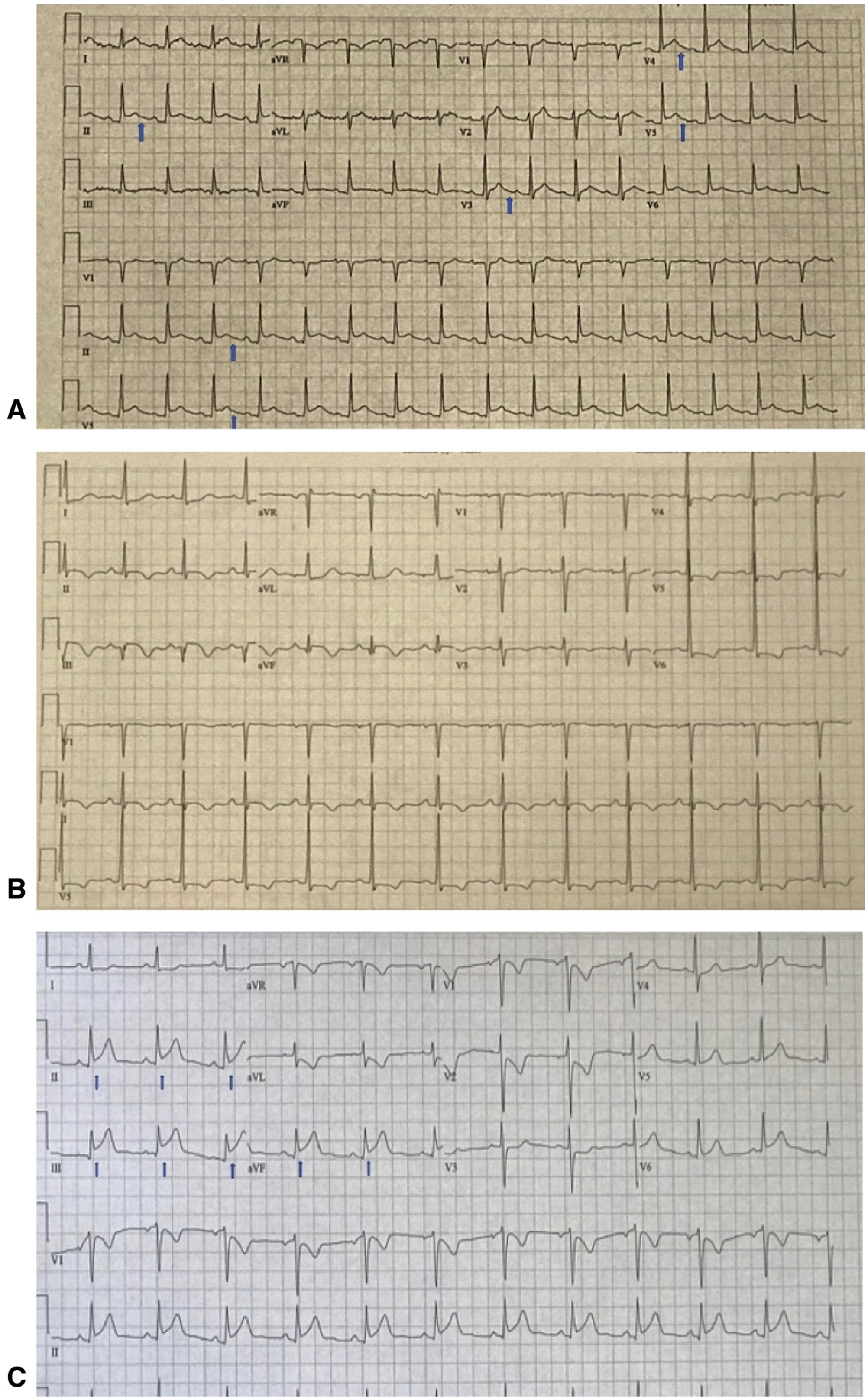

Figure 2. Electrocardiogram (ECG) changes studied. (A) ECG from a patient with pericarditis, showing PR depression (leads I, II, III, aVF, and V3–V6) and Spodick's sign, a downsloping of the T-P segment (see arrows). (B) ECG from a patient with ST elevation myocardial infarction (STEMI), showing ST depression (leads I, aVL, and V4–6), ST elevation in lead III > lead II, and ST convex upward (leads III and aVF) and horizontal (lead aVF). (C) RT checkmark sign, shown in leads II, III, and aVF (see arrows), in a patient with STEMI.

Table 1. Patients' Characteristics

Characteristic	STEMI (n = 165)	Pericarditis (n = 42)
Age (y), median (IQR)	58 (50–64)	38 (24–49)
Female, n (%)	57 (35)	16 (38)
Race, n (%)		
Black	100 (61)	32 (76)
White	56 (34)	9 (21)
Other	9 (5)	1 (2)
Hospital findings, n	PCI, 144	ECG findings,† 20
	Left anterior descending artery, 62	Effusion,‡ 19
	Left circumflex artery, 14	Rub, 7
	Right coronary artery, 53	Biopsy, 1
	Major,* both right and left, 5	Coronary testing, 21
	Minor* left, 9	
	Minor* right, 1	
	No PCI, 21	
	Died, 2	
	PCI unsuccessful, 3	
	Diffuse disease, 6	
	Lesions minor, 7	
	Notes unclear, 3	

ECG = electrocardiogram; IQR = interquartile range; PCI = percutaneous coronary intervention; STEMI = ST elevation myocardial infarction.
* Left anterior descending, left circumflex, and right coronary arteries are considered major arteries; other branches are minor.
† ECG findings of pericarditis noted in chart records.
‡ Effusion found on imaging.

binomial approximation, and we used a normal approximation for the difference between proportions. We calculated ORs and CIs for ORs using Woolf's method.

We examined the potential for confounding or interaction by sex or race (Caucasian vs. African American) using a stratified analysis, including the Breslow-Day test for interaction. We examined the potential for confounding by age by comparing logistic regression models for each predictor with and without age, defining confounding by age as a > 10% change in coefficient estimates for predictors when adjusted by age.

We chose our sample size with the goal of obtaining precise estimates for the frequency of findings in STEMI. A minimum sample size of 150 cases of STEMI would allow precision around an estimate of 50% within ± 8%.

RESULTS

From 283 STEMI records and 125 pericarditis records, we selected ECGs from 165 confirmed cases of STEMI and 42 pericarditis controls (see Figure 1). Table 1 displays characteristics of these groups. The vast majority of STEMI patients had coronary artery disease noted at catheterization, with a slightly higher frequency of disease in the left coronary distribution. One patient had biopsy-proven pericarditis; electrocardiographic changes or pericardial effusion were documented by treating physicians in a minority of pericarditis patients.

Several electrocardiographic findings distinguished STEMI from pericarditis with statistical significance (Table 2). There was no change in the OR estimates after adjusting for age, sex, or race, and no interaction by sex or race (data not shown). ST depression and PR depression had the largest difference in frequencies between the two groups. ST elevation III > II also predicted STEMI. ST depression was the only sign of STEMI that occurred in the majority of patients with STEMI. The study also statistically validated signs traditionally associated with pericarditis; PR depression had an OR of 0.1 (95% CI 0.07–0.3) and Spodick's sign had an OR of 0.08 (95% CI 0.04–0.2). However, PR depression occurred in 12% of patients with STEMI (95% CI 7–18%) and Spodick's sign occurred in 5% of patients with STEMI (95% CI 3–10%). In patients with T-P downsloping, the median number of leads with T-P downsloping was 4 (range 1–6) in patients with pericarditis and 3 (range 2–4) in patients with STEMI. One patient had T-P downsloping in only one lead and did not meet our criteria for Spodick's sign.

Inter-rater agreement for various electrocardiographic findings is shown in Table 3. Agreement was greater for pairs including the ECG expert than for agreement between the other two investigators (data not shown). ST elevation III > II and ST depression had the highest inter-rater reliability.

DISCUSSION

Previous articles on the electrocardiographic changes of STEMI and pericarditis were based on expert opinion and principles of biology and physics (1,5,10).

Table 2. Frequency of Electrocardiographic Findings in STEMI and Pericarditis

ECG Finding	STEMI, n (%)	Pericarditis, n (%)	Percent Difference (95% CI)	Odds Ratio (95% CI)
No Spodick	156/165 (95)	30/42 (71)	23 (10–40)	7 (3–18)
ST Convex	51/165 (31)	3/42 (7)	24 (9–33)	6 (2–20)
RT Checkmark	64/165 (39)	3/42 (7)	32 (17–41)	8 (2–28)
ST Dep	133/165 (81)	5/42 (12)	69 (53–78)	31 (11–84)
III > II	56/164 (34)	1/42 (2)	32 (18–40)	21 (3–159)
No PR dep	146/165 (88)	16/42 (38)	50 (33–65)	12 (6–27)

CI = confidence interval; ECG = electrocardiogram; III > II = ST elevation greater in lead III than in lead II; No PR Dep = no PR depression; ST Convex = upward ST convexity or horizontal ST segment; ST Dep = ST depression in leads other than V_1 or aVR; STEMI = ST-segment elevation myocardial infarction.

Epidemiologists have learned that theoretical principles often fail when applied to populations. Relatively few studies have examined the epidemiology of electrocardiographic changes indicative of these conditions. In this study, our intention was to validate several findings considered useful in distinguishing pericarditis from STEMI, but we found some signs of pericarditis in patients with STEMI.

Spodick's sign has been described as a decline in the baseline ECG, which can be interpreted broadly to mean a decline from one QRS complex to the next P-R segment or narrowly as an isolated downsloping of the T-P segment (6,7). In the former, ST elevation and PR depression (findings well-characterized by Spodick) would contribute to Spodick's sign; in the latter, changes in the T-P segment (the segment that Spodick recommended as the isoelectric reference point for pericarditis) are independent of other electrocardiographic changes (12). Interestingly, the articles we found by Spodick summarizing the electrocardiographic changes of pericarditis did not describe his eponymous sign (5,10,13,14). We chose the narrow definition for our study because we wished to examine changes in the T-P segment independent from those in the P-R segment. We found that T-P downsloping (29%) and P-R depression (62%) were both statistically associated with pericarditis, but that either could be seen in STEMI. Using either definition, we found a lower prevalence in pericarditis than 80%, the prevalence previously described (6). The difference in prevalence may be related to a difference of spectrum of disease (the author may have been referring to severe or complicated cases, while some of our patients may not have had pericarditis), a difference in definition (they may have included the contribution of the P-R segment to the downsloping between ventricular complexes), or the 80% may have simply been an informal estimate (we were unable to find published data to support it). Importantly, we found that, even using a narrow definition, Spodick's sign may be seen in STEMI.

Table 3. Inter-Rater Agreement for Electrocardiographic Findings

Variable	κ*	% Agreement*	OR Range
No Spodick's sign	0.4–0.5	84–90	3–7
ST Convex	0.3–0.5	66–77	3–6
RT Checkmark	0.2–0.4	74–77	4–30†
ST Dep	0.6–0.8	84–91	8–31
III > II	0.6–0.8	84–91	10–38
No PR Dep	0.5	85–87	12–40

OR = odds ratio; III > II = ST elevation greater in lead III than in lead II; PR Dep = PR depression; ST Convex = upward ST convexity or horizontal ST segment; ST Dep = ST depression in leads other than V_1 or aVR.
* Ranges are for agreement between pairs taken from three reviewers, including a non-expert.
† Odds ratio calculation for one examiner (OR 30) based on substituting 0.5 for 0 to avoid zero denominator.

Besides Spodick's sign, all of the findings we reviewed distinguished STEMI from pericarditis statistically. In fact, the best discriminators, based on strength of association (odds ratio), difference in proportions, and inter-rater reliability, were ST depression, PR depression, and ST elevation III > II. However, a similarly designed study by Henning et al examined ST elevation in II > III as a sign of pericardial disease in patients with pericardial disease vs. inferior STEMI, and found a weaker association (OR 2; 95% CI 1–5), based on our calculations from their data, than we did (OR 21; 95% CI 3–159) (8). The difference in the estimates is unclear, and further study is needed, but one reason may be that the Henning data were limited to patients with inferior MI. Inferior MI from left circumflex disease can cause ST elevation in II > III, so while III > II can be considered a sign of STEMI, II > III may lack specificity for pericarditis (15). Another study found that ST depression was a predictor of true-positive trips to the cardiac catheterization laboratory among patients with ST elevation (16).

Limitations

One limitation of our study is that some patients in the pericarditis group might not have had pericarditis. The criterion standard test for pericarditis—biopsy—is invasive and applied infrequently. Although biopsy was not done, pericardial pathology was suggested by the fact that the majority of patients in our pericarditis group did have electrocardiographic changes (ST elevations and PR depression, as assessed by our reviewers), effusions, or pericardial rubs. Also, many patients in the pericarditis group had testing for coronary disease, as deemed appropriate by the treating team, so they can be considered true negatives for STEMI. The limited number of pericarditis controls limits the precision of our estimates and also may limit generalizability of our findings.

The case–control design allows estimation of ORs, but it does not allow calculation of predictive values, which depend on disease prevalence. The case–control design does allow accurate calculation of the statistics we presented (OR, difference in proportions).

A feature of the study is that we had an ECG expert available to review ECGs. The findings of our expert may not generalize to settings without real-time ECG expert review. Computerized interpretation would be a generalizable alternative, but computer algorithms for ECG interpretation lack accuracy (17–19). If the ECG findings we studied truly discriminate between STEMI and pericarditis, expert review would bias toward more extreme ORs than readings by less-accurate observers or methods. Less-accurate observation leads to nonsystematic misclassification and a bias toward OR of 1. Indeed, we noted generally less-extreme OR when using observations from our experienced emergency physician with an average interest in electrocardiography. Our study design allowed for a quantification the effect of ECG expertise on OR estimates. Many findings discriminated STEMI from pericarditis, even for a nonexpert reviewer.

An additional limitation is that data were from a single site. This may limit generalizability, geographically and otherwise, of our findings.

CONCLUSIONS

In patients with ST elevation, Spodick's sign and other findings statistically distinguish STEMI from pericarditis. We found ST depression, PR depression, and ST elevation III > II to be the best discriminators. However, no sign was pathognomonic for STEMI or pericarditis. In fact, some patients with STEMI had traditional ECG indicators of pericarditis—5% had Spodick's sign and 12% had PR depression.

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ARTICLE SUMMARY

1. Why is this topic important?

Emergency physicians must rapidly decide whether to activate the cardiac catheterization team in patients with chest pain and ST segment elevation. Prior findings purported to distinguish ST elevation myocardial infarction (STEMI) from pericarditis, including Spodick's sign, require validation.

2. What does this study attempt to show?

This study estimates the frequency of Spodick's sign and other important findings in patients with STEMI and those diagnosed with pericarditis. Comparing these frequencies provides validation of these signs as discriminators of these conditions.

3. What are the key findings?

The following findings distinguish STEMI from pericarditis: Spodick's sign, ST depression (in leads besides aVR or V_1), ST elevation in III > II, ST convex upward or horizontal (except in lead V_1), RT checkmark, and PR depression conditions. In patients with STEMI, 12% had PR depression and 5% had Spodick's sign.

4. How is patient care impacted?

In patients with ST elevation, emergency physicians can consider that ST depression (in leads besides aVR or V_1), ST elevation in lead III > lead II, and ST convex upward or horizontal (except in lead V_1) suggest the presence of STEMI, and PR depression and Spodick's sign are evidence of pericarditis.