ORIGINAL RESEARCH

Utility of the CORD ECG Database in Evaluating ECG Interpretation by Emergency Medicine Residents

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KEYWORDS: Electrocardiogram, Resident, Teaching, CORD, Evaluation

Abstract

OBJECTIVES:
Electrocardiograph (ECG) interpretation is a vital component of Emergency Medicine (EM) resident education, but few studies have formally examined ECG teaching methods used in residency training. Recently, the Council of EM Residency Directors (CORD) developed an Internet database of 395 ECGs that have been extensively peer-reviewed to incorporate all findings and abnormalities. We examined the efficacy of this database in assessing EM residents' skills in ECG interpretation.

METHODS:
We used the CORD ECG database to evaluate residents at our academic three-year EM residency. Thirteen residents participated, including four first-year, four second-year, and five third-year residents. Twenty ECGs were selected using 14 search criteria representing a broad range of abnormalities, including infarction, rhythm, and conduction abnormalities. Exams were scored based on all abnormalities and findings listed in the teaching points accompanying each ECG. We assigned points to each abnormal finding based on clinical relevance.

RESULTS:
Out of a total of 183 points in our clinically weighted scoring system, first-year residents scored an average of 99 points (54.1%) [91-119], second-year residents 111 points (60.4%) [97-126], and third-year residents 130 points (71.0%) [94-150], $p = 0.12$. Clinically relevant abnormalities, including anterior and inferior myocardial infarctions, were most frequently diagnosed correctly, while posterior infarction was more frequently missed. Rhythm abnormalities including ventricular and supraventricular tachycardias were most frequently diagnosed correctly, while conduction abnormalities including left bundle branch block and atrioventricular (AV) block were more frequently missed.

CONCLUSION:
The CORD database represents a valuable resource in the assessment and teaching of ECG skills, allowing more precise identification of areas upon which instruction should be further focused or individually tailored. Our experience suggests that more focused teaching of conduction abnormalities and posterior infarctions may be beneficial. The CORD database should be considered for incorporation into an ECG curriculum during residency training.

INTRODUCTION:

Rapid and accurate interpretation of electrocardiograms (ECGs) is a vital component of daily emergency medicine (EM) practice. However, few studies have formally evaluated ECG interpretation skills among emergency physicians (EPs). Fewer still have evaluated the ECG interpretation skills of EM residents[1-3]. This is largely due to the difficulty in teaching and assessing ECG interpretation skills in a systematic and rigorous manner. Even among "experts," ECG inter-rater agreement is only 60-70% in published studies[1,4-6]. One study of 716 ECGs demonstrated a high discordance rate of 58% between EPs and cardiologists, of which 25 ECGs (3.5%) were deemed clinically significant[5]. Inter-rater agreement amongst "experts" only is more limited. In one study, agreement amongst cardiologists in the diagnosis of acute infarction in the setting of left bundle branch block was only 81%[7].

In this study we investigated the utility for evaluating ECG interpretation by emergency medicine residents of an Internet database of ECGs recently developed by the Council of EM Residency Directors (CORD). The CORD database is comprised of 395 ECGs that have been formally interpreted by 49 faculty from 45 EM training programs in the United States. Three EM faculty editors reviewed each ECG. All editors were emergency physicians officially certified by

the American College of Cardiology (ACC) in ECG interpretation (ACC-certified), except for one board certified cardiologist who was also EM residency-trained and board certified. Any disagreements in interpretations between editors were forwarded to a second ACC-certified editor. All abnormalities are categorized and summarized in teaching points, together with clinical or interpretation "pearls." The CORD database is fully searchable by various criteria including conduction, rhythm, or infarction abnormalities.

METHODS:

Study Population

The study was performed during the 2001-02 academic year at an urban academic three-year EM residency. The residency has six residents in each class. Institutional Review Board approval was obtained and resident participation was voluntary. Thirteen residents participated. Four residents were unavailable for the testing session, and one of the resident authors was excluded from the analysis.

ECG Selection

Fourteen search terms representing a broad range of commonly encountered clinically relevant ECG abnormalities were used to search the CORD database (Table I). Each search term resulted in multiple ECGs containing the abnormality. ECGs were then randomly selected from each list to select a total of twenty unique tracings from the database for our study. One normal ECG was included as a control.

Testing

The twenty ECGs selected were downloaded from the Internet and displayed in random order using large-screen video projection during a weekly resident education conference. Residents were provided copies of the clinical scenarios accompanying each ECG in the database, as well as an open-ended blank answer form prompting them to note their clinical impression/diagnoses, along with any and all abnormalities in rate, rhythm, axis, waveforms, segments, and intervals. Residents were uniformly provided six minutes per ECG during the two-hour evaluation session. The abnormalities included in the twenty selected ECGs are shown in Table II.

14 CORD Database Search Terms

Abnormal finding	ECGs with abnormality	ECGs selected randomly
Anterior MI	41	2
Posterior MI	26	2
Atrial Fibrillation	15	2
Supraventricular Tachycardia	4	1
Ventricular Tachycardia	7	2
Accelerated Junctional Rhythm	5	1
QT Prolongation	21	1
Right Bundle Branch Block	22	1
Left Bundle Branch Block	7	1
Primary ST/T wave changes	14	1
Secondary ST/T wave changes	20	1
T wave inversion	92	2
U wave	23	2
Normal	7	1
	Total ECGs selected:	**20**

Scoring

Scoring of the evaluations was blinded, using the interpretation and teaching points accompanying each ECG in the CORD database as

Table II: All Abnormalities in 20 Selected ECG's

Anterior MI	4
Posterior MI	5
Inferior MI	3
Lateral MI	3
Septal MI	3
Atrial Fibrillation	1
Supraventricular Tachycardia	1
Ventricular Tachycardia	2
Accelerated Junctional Rhythm	1
QT Prolongation	1
Right Bundle Branch Block	3
Left Bundle Branch Block	5
1st Degree AV Block	2
2nd Degree AV Block	2
Left Atrial Enlargement	4
Left Axis Deviation	3
Left Ventricular Hypertrophy	4
Total Abnormalities	47

the gold standard. Exams were scored using a point system weighted by clinical significance, as defined in Table III. Clinical diagnoses including any infarction or dysrhythmias were deemed most clinically significant, while incidental findings (e.g., left atrial enlargement) were deemed clinically less significant. Most of the selected ECGs exhibited multiple abnormalities. These included numerous abnormalities other than the primary abnormality for which the ECG was

Table III
Point Assignments Weighted by Clinical Significance of All Abnormalities Tested

1 pt	Assigned to each notation of abnormal waves or segments, regardless of accuracy of clinical diagnoses or impressions (e.g. nonspecific ST & T changes, ST elevation/depression, T wave changes, U waves) Left Atrial Enlargement (LAE) Left Axis Deviation (LAD)
2 pts	Left Ventricular Hypertrophy (LVH) First Degree AV Block Wandering Atrial Pacemaker (WAP)
3 pts	Right Bundle Branch Block (RBBB) Junctional Tachycardia Second-Degree AV Block
4 pts	Any Acute MI Left Bundle Branch Block Ventricular Tachycardia Atrial Fibrillation Paroxysmal Supraventricular Tachycardia (PSVT)

selected. A total of 183 points was therefore possible.

Data Analysis

Evaluation scores were analyzed utilizing Kruskal-Wallis analysis for comparison of multiple nonparametric groups of unequal size to compare performance among the three residency classes, both with regard to total score and identification of ischemia/infarction.

RESULTS:

Out of 183 possible points, incorporating all abnormalities listed in the CORD database, first-

Table IVa: Infarction Abnormalities

	1st Year	2nd Year	3rd Year	All Residents
Anterior MI (5)	75.0%	87.5%	85.0%	76.9%
Lateral MI (4)	66.7%	41.7%	66.7%	59.0%
Inferior MI(7)	66.7%	75.0%	93.3%	79.5%
Posterior MI (4)	25.0%	25.0%	56.0%	36.9%
Septal MI (5)	58.3%	83.3%	86.7%	76.9%
Any Acute MI (10)	80.0%	72.5%	94.0%	83.8%

Table IVb Rhythm Abnormalities

	1st Year	2nd Year	3rd Year	All Residents
Ventricular Tachycardia (2)	100%	87.5%	80%	88.5%
Atrial Fibrillation (1)	50%	100%	80%	76.9%
Paroxysmal Supraventricular Tachycardia (1)	50%	100%	100%	84.6%
Junctional Tachycardia (1)	0%	100%	80%	61.5%

year residents scored an average of 99 (54.1% correct) [range 91-119], second-year residents averaged 111 points (60.7% correct) [range 97-126], while third-year residents averaged 130 (71.0% correct) [range 94-150], p = 0.12.

Ischemia/Infarction abnormalities

Ten of the twenty (50%) ECGs selected in this study showed acute myocardial infarction (MI). Eight of the ten infarctions (80%) showed acute infarction in multiple anatomic regions, such as antero-septal or infero-lateral. Overall, residents identified 109/130 (83.8%) acute MIs. First-year residents identified 80.0% of all MIs, second-year residents identified 72.5%, and third-year residents identified 94.0%. One second-year resident missed 5/10 (50%) of all acute MIs, while four residents missed none (one first-year and three third-years).

The data was further examined for correct identification by specific anatomic cardiac location. Anterior, inferior, and septal ischemia/infarctions were most frequently diagnosed correctly, while posterior and lateral ischemia/infarctions were most frequently missed. (Table IV a). Overall, the percentage of infarctions diagnosed correctly ranged from a low of 36.9% (24/65) for posterior infarctions to a high of 76.9%

Table IVc
Conduction and Miscellaneous Abnormalities

	1st Year	2nd Year	3rd Year	All Residents
Left Bundle Branch Block (5)	25%	45%	40%	36.9%
Right Bundle Branch Block (3)	75%	91.7%	86.7%	84.6%
1st Degree AV Block (2)	0%	37.5%	80%	42.3%
2nd Degree AV Block (2)	50%	37.5%	60%	50%
QT Prolongation (1)	0%	25%	40%	23.1%
Left Ventricular Hypertrophy (4)	43.8%	50%	50%	48.1%
Left Axis Deviation (3)	66.7%	75%	46.7%	61.5%
Left Atrial Enlargement (4)	12.5%	6.3%	80%	18.9%

for anterior infarctions. Posterior infarctions were often mistaken for anterior/septal abnormalities.

Rhythm abnormalities

Rhythm abnormalities most frequently diagnosed correctly included ventricular tachycardia (88.5%), paroxysmal supraventricular tachycardia (PSVT) (84.6%), and atrial fibrillation (76.9%). Junctional tachycardia (61.5%) was most frequently missed. (Table IV b)

Conduction abnormalities

The conduction abnormality most frequently diagnosed correctly was right bundle branch block (84.6%). Left bundle branch blocks (36.9%), first- and second-degree atrioventricular (AV) blocks (42.3% and 50.0%, respectively), and QT prolongation (23.1%) were most frequently missed. (Table IV c)

DISCUSSION:

The CORD ECG database proved valuable in identifying important trends in the ECG interpretation skills of EM residents. ECG skills progressively improved as training progressed from first-year through third-year of residency (54.1%, 60.4%, and 71.0% respectively), although this trend was not statistically significant, $p = 0.12$.

Emergency medicine residents were able to identify the presence of an acute MI in only 83.8% of the ten cases included in this study. Third-year residents successfully identified 94.0% of the acute infarctions, while the performance of first- and second-year residents was considerably lower at 80.0% and 72.5% respectively.

Given the clinical implications of missing an acute MI, additional didactic emphasis on identifying myocardial ischemia and infarction is clearly warranted. Although third-year residents performed the strongest in identifying 94.0% of infarctions, even this level of performance is concerning, as few clinicians would regard missing one in twenty MIs as acceptable.

Further scrutiny of the anatomic location of missed

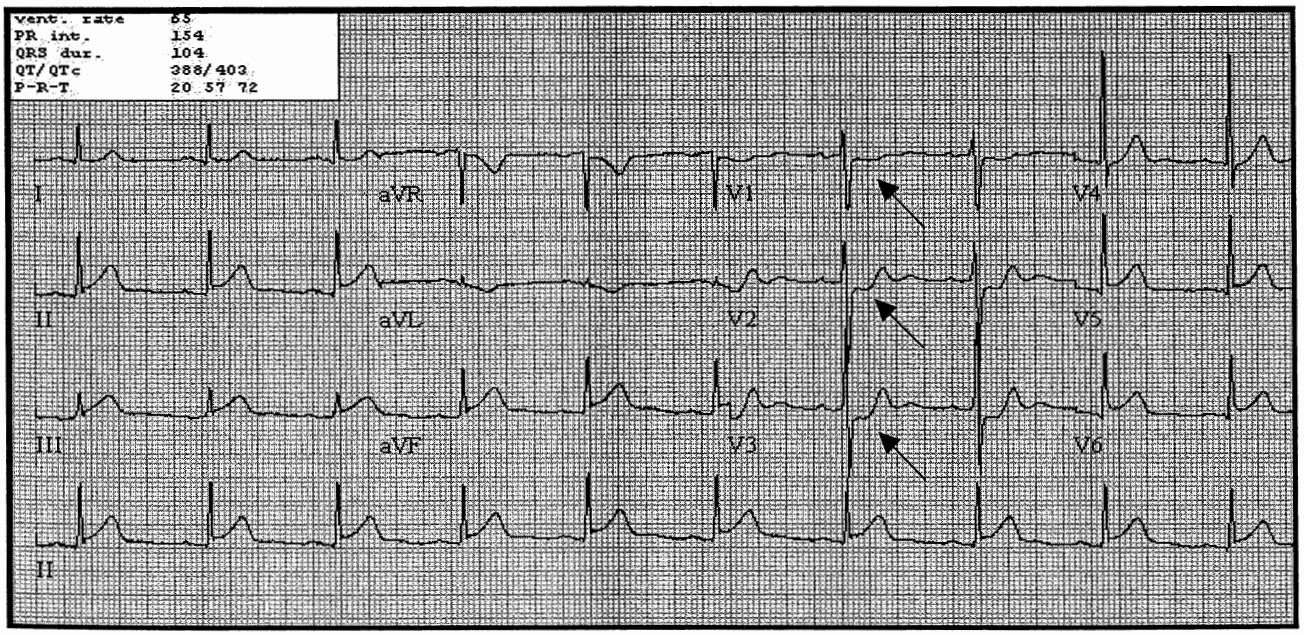

Figure I. Acute Posterior-Inferior-Lateral Infarction. Six out of thirteen residents (46.1%) missed the posterior infarction.

acute MI, revealed that residents most frequently failed to identify posterior infarctions, correctly diagnosing only 36.9% of the five cases in our study. Residents frequently correctly noted ST depression in the early pre-cordial leads (V1, V2) but misdiagnosed the cases as anterior-septal ischemia (Figure I). Such errors may have significant clinical implications should the patient be a candidate for thrombolysis.

In numerous cases residents correctly identified an acute infarction but misdiagnosed the anatomic location of the myocardium involved. In particular, lateral infarctions, of which only 59.0% were properly identified, were commonly diagnosed as anterior infarctions. While such errors may arguably be of less clinical significance from a treatment and disposition perspective, further didactic emphasis on anatomic ECG interpretation appears indicated.

The CORD ECG database also helped identify several useful findings in resident interpretative skills in diagnosing conduction and rhythm abnormalities. Residents identified less than 50% of all cases of left bundle branch block, first- and second-degree AV block, and QT prolongation. Although performance in identifying rhythm abnormalities was higher, overall residents only identified 88.5% of the two ventricular tachycardia cases in our study. Similarly, 76.9% of atrial fibrillation cases and 84.6% of PSVT cases were correctly identified (Table IVb).

Limitations

Clearly, the small number of participants in this study limits our power to detect clinically significant differences between the three classes of emergency medicine residents. While a clear trend of improving score was noted amongst first-year through third-year residents, the small group of participating residents limited the power to achieve statistical significance. Further studies are warranted and may benefit from multi-center residency participation.

Of note, in scoring the evaluations, residents were required to not only identify all clinical diagnoses, but also rigorously document all supporting waveform, segment, and interval abnormalities. Residents frequently identified the correct clinical diagnosis but did not document specific abnormalities, resulting in lower scores. Residents frequently identified the acute inferior wall MI, for instance, but did not also document the corresponding ST elevations in leads II, III, and aVF. Residents also received no points for misidentifying the location of myocardial infarctions.

Many residents also did not document numerous abnormalities of lesser clinical significance (e.g., left atrial enlargement or left axis deviation). It is unclear whether participants did not identify the abnormalities or simply did not document them.

Although the residents were provided copies of clinical scenarios accompanying each ECG, it remains possible that their interpretations of ECGs may have been affected by the lack of live clinical correlation, although the impact of this on their diagnostic accuracy in unknown. In any examination setting, a resident's motivation may be difficult to assess, and performance on this exam may not be reflective of true clinical skill.

The results of this study may be difficult to apply to other residency programs, even within EM. EM residency programs vary greatly in terms of hospital resources, residency size, and didactic organization. Any one of these factors may influence the utility of the CORD database in assessing EKG skills amongst residents.

The timing of the study should also be considered in interpreting the results of the study and for future investigations. The testing session was conducted during the middle of the academic year in February. At our institution we were able to utilize the study as a mid-year assessment that allowed more focused instruction for residents in all three classes. We feel the CORD database provides a unique opportunity as a generally available standardized evaluation and teaching tool that can be duplicated at other centers for further assessment of resident ECG skills.

Future Directions

The findings of this study underscore the need for a rigorous and standardized didactic approach during residency training. We found the CORD database to be a valuable resource in the assessment and teaching of ECG skills. It allowed more precise identification of areas upon which instruction should be further focused or individually tailored. Our experience suggests that more focused teaching of posterior infarctions and conduction abnormalities may be particularly beneficial. The CORD database should be considered for incorporation into an ECG curriculum in EM residency training.

Due to the rich collection of pathology available in the CORD ECG database, numerous teaching sets may be assembled for further instruction and review. The database can further be utilized, as it has been in our program, to construct pre- and post-tests of the efficacy of ECG instruction. The database is continually expanding, and holds much promise as a standardized platform for ECG teaching.

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