As a discipline, medical education has begun to focus on defining competencies that medical students need to master before graduation. In leading this initiative, the Association of American Medical Colleges (AAMC) published in 2013 a shared taxonomy for competencies in medical education.1 As a next step, AAMC convened a working group charged with developing a defined list of competencies: Core Entrustable Professional Activities for Entering Residency: Curriculum Developers’ Guide.2 The document defined entrustable professional activities (EPAs) as “…units of professional practice, defined as tasks or responsibilities that trainees are entrusted to perform unsupervised once they have achieved sufficient specific competencies.” The core of the document was the delineation of 13 EPAs; competencies were developed for each EPA and milestones for each competency.

The ability to accurately interpret electrocardiogram (ECG) abnormalities can be seen as a core competency for a medical school graduate that falls within EPA 3 (“Recommend and interpret common diagnostic and screening tests”) of the AAMC document. Interpretation of cardiograms is critical for graduating seniors entering residencies in internal medicine, emergency medicine, general surgery, family practice, and anesthesiology.3 However, specific guidelines from AAMC, Liaison Committee on Medical Education, and Accreditation Council for Graduate Medical Education (ACGME) regarding ECG training and assessment are lacking.4-7 Prior research in internal medicine and emergency medicine residents has reported a suboptimal ability to accurately interpret ECGs and a low level of self-confidence in ECG reading ability.8,9 We recently completed a series of studies and found that the ability of medical school and physician assistant graduates to correctly interpret basic and critical ECG rhythms is less than predicted.7,10

Given the limitations in ECG interpretation in medical students and housestaff, it is critical to determine where ECG training occurs in medical school and how it is assessed. A national survey performed in 2005 by the Clerkship Directors in Internal Medicine (CDIM) provided data regarding the instruction in and assessment of basic ECG interpretation competency in the third-year internal medicine clerkship at US and Canadian medical schools.1 At that time the CDIM study...
revealed that more explicit and formalized instruction and assessment methods in ECG interpretation were needed.3

As it has been almost a decade since the initial CDIM survey, and given the limitations in ECG interpretation found in our recent studies, we decided to replicate and expand upon the initial CDIM survey. This manuscript addresses the responses to a set of questions included in the 2013 CDIM annual survey. In particular, potential survey questions were developed to enhance focus on ECG instruction and assessment on the clerkship, barriers to teaching ECG interpretation, and the identification of specific ECG patterns that clerkship directors believe all students should master before completion of the third-year internal medicine clerkship.

METHODS

In June 2013, CDIM conducted its annual, online, confidential survey of its US and Canadian member medical schools. The designated clerkship director from each medical school was invited by e-mail to participate. Nonresponders were contacted up to 3 additional times by e-mail and once by telephone. The Institutional Review Board at Case Western Reserve University determined that this study did not require exemption status, Institutional Review Board approval, or further review.

Potential survey questions were submitted in Fall 2012. The authors of the present manuscript submitted to CDIM for consideration an 18-item survey on ECG teaching and assessment in the third-year internal medicine clerkship. The CDIM Research Committee selected topics for inclusion based on the importance of the topic to CDIM as well as on clarity, quality, and appropriateness of the questions posed. The accepted questions were edited, revised, and organized by the CDIM Research Committee before being presented to the CDIM Council, which provided further revisions and final approval. There were 68 total survey items in the 2013 CDIM Survey, of which 13 focused on ECG assessment and interpretation.

RESULTS

The CDIM survey was completed by 94 of the 123 schools to which a survey was sent, for an overall response rate of 76%. The demographic results for the respondents are as follows (note: calculations are based on a denominator of 94, though some respondents did not answer specific demographic or other questions, and so the percentages do not always add up to 100%): mean age was 48 years; the male-to-female ratio was 1:1; and 46% identified themselves as general internists. Institution type included 56% public schools and 34% private schools. The academic rank of respondents was assistant professor, 19%; associate professor, 44%; and professor, 23%.

ECG instruction was reported to occur in the third-year internal medicine clerkship in 85% of the schools. Ten percent of the respondents stated that ECG instruction was not taught during the internal medicine clerkship, and 5% of the respondents did not respond to this question. Which ECGs were taught during the clerkship varied widely. Presented in descending order of frequency, responses to who selected the ECG patterns to be taught were 51% clerkship directors, 37% members of the cardiology division, 23% ward attending, and 8% based on ACGME competencies expected of an intern.

The average total amount of time devoted to ECG instruction in the internal medicine clerkship has not changed significantly since the CDIM survey conducted in 2005, at which time most schools reported spending an average of 1-6 hours on formal ECG didactics during the clerkship. The amount of time currently devoted varied widely, however, ranging between 1 and 10 hours. One-third of respondents dedicate 3-4 hours to ECG instruction, 28% of schools spend 5-6 hours, and 18% devote 1-2 hours. A very small minority of schools (4%) spend more than 6 hours on ECG instruction per clerkship (Figure).

Multiple pedagogical techniques were utilized to teach ECGs, including 62% lecture, 55% small group sessions, 30% assigned readings, 22% formal teaching rounds, and 18% Web-based modules.

Whereas 37% of the respondents stated that the average number of ECGs a student was formally asked to interpret during the clerkship was >10, 24% of the respondents noted that they did not know how many ECGs a student at their school formally interpreted during the clerkship. Other respondents indicated 1-2 ECGs 1%, 3-4 ECGs 4%, 5-6 ECGs 9%, and 7-8 ECGs 6%.

ECG instruction has remained constant at 48% of the schools over the last 5 years (15% of respondents did not answer this question) and has undergone changes in

PERSPECTIVES VIEWPOINTS

- Electrocardiogram (ECG) interpretation is an entrustable professional activity.
- Insufficient time is devoted to teaching ECG interpretation skills on the Internal Medicine clerkship.
- Insufficient time is devoted to assessing student ECG interpretation skills.
- Increased teaching time and more practice reading ECGs would be beneficial.
- Sequential assessment of ECG interpretation ability during medical school is necessary.
37% of the schools. Although the majority of responses to specific changes made typically included only one respondent, a variety of changes in ECG instruction have occurred and include new educational models, increased teaching resources, and end-of-clerkship assessment (Appendix). Nearly 50% of clerkship directors report no barriers to teaching ECG interpretation during the clerkship. The most common barriers to ECG instruction encountered are lack of budgeted time (20% of respondents), lack of teaching faculty comfortable in teaching ECG interpretation (12%), and the presence of ECG instruction at other points in the medical school curriculum (6%).

Nearly 100% of respondents reported that by the end of the internal medicine clerkship, every student should be able to recognize the following ECG rhythms/abnormalities: sinus rhythm, sinus tachycardia, sinus bradycardia, atrial fibrillation, atrial flutter, first-degree atrioventricular block, complete heart block, premature ventricular complexes, ventricular tachycardia (monomorphic), bundle branch block, left axis deviation, left ventricular hypertrophy, ST-segment elevation myocardial infarction, acute pericarditis, and hyperkalemia (Table). A majority of respondents (54%) indicated that every student should be able to recognize long QT syndrome. The majority of respondents did not expect students to be able to recognize the following ECG rhythms by the end of the clerkship: torsades de pointes, Mobitz 1 and 2 blocks, myocardial ischemia, pacemaker/paced rhythm, ventricular fibrillation, non-ST elevation myocardial infarction, multifocal atrial tachycardia, polymorphic ventricular tachycardia, electrical alternans, atrioventricular nodal reentrant tachycardia, Wolff-Parkinson-White syndrome, and left anterior fascicular block.

Forty-two percent of respondents stated that their third-year internal medicine clerkship did not include any assessment of ECG interpretation, and 15% of respondents left this question blank. The most common method of assessment of ECG interpretation ability, utilized in the 43% of clerkships where ECG assessment occurred, was a written examination (24%). Other modalities of assessment included ECG assessment embedded within an objective structured clinical examination (14%) or computer-based examination (8%).

Overall, respondents felt that training in ECG interpretation during their clerkship was adequate. Specifically, 65% of clerkship directors (of the 94 respondents) stated that ECG training was adequate, 22% did not respond, and the rest were neutral (indicated neither agreement nor disagreement). There was not a single clerkship director who stated that ECG training at their school was inadequate.

### DISCUSSION

This manuscript presents the ECG interpretation results of the 2013 CDIM Survey. The reasons for performing the survey were as a follow-up to the 2005 CDIM Survey, which indicated a need for more formalized instruction in ECG interpretation and assessment during the third-year internal medicine clerkship, and to put in perspective recent findings of suboptimal ECG interpretation in graduating medical students and incoming interns. A key focus of medical education innovation in the last decade has been the concepts of milestones and core EPAs. Milestones and EPAs focus on the identification of abilities that a student or resident must master at a certain point in training to ensure patient safety. It is our contention that ECG interpretation is an EPA and that there are distinct milestones in ECG interpretation that a student and resident should master. The major findings of the 2013 CDIM Survey are that there is wide variation among medical schools with regard to the amount of time devoted to ECG interpretation in the third-year internal medicine clerkship, there is a strong consensus among internal medicine
clerkship directors as to which ECGs should be mastered by clerkship end, the majority (42% did not assess and 15% did not respond to the question) of internal medicine clerkships do not assess ECG skills, and little change has occurred in ECG instruction and assessment since the 2005 CDIM Survey.

Interestingly, students are asked to formally interpret a minimum of 9-10 ECGs in only 40% of clerkships that responded. Despite the consensus among nearly all clerkship directors in this study that every student should be able to recognize at least 15 common ECG rhythms by the end of the clerkship, and as echoed in the CDIM-SGIM Core Curriculum Guide, many students may never be asked to formally identify and interpret up to one-third of these abnormalities. This consensus should spark a new focus and discussion among medical educators on how a portion of a core EPA, namely ECG interpretation, could and should be taught and assessed. One logical conclusion would be for clerkship directors to develop a formal ECG curriculum and to test all students on their ability to identify these 15 common ECG findings (Table).

Data from the 2005 CDIM Survey suggested that more explicit and formalized instruction in ECG interpretation was needed. Thirty-seven percent of current respondents reported such changes in the past 5 years; however, nearly one-half of respondents reported no change in the teaching of ECGs in their clerkship over the same period. Newer and innovative techniques of instruction could prove to be as effective as, or more effective than, current methods. For example, simulated patients and Web-based modules appear to be infrequently used, although Web sites such as Maven ECG provide hundreds of varied ECG strips; flexible, independent, and readily accessible learning for students; and are accompanied by clinical cases with explanations. A study by Raupach et al found that small-group peer teaching is more effective than lectures in improving student ECG interpretation skills. More frequent use of innovative methods of ECG instruction could help bridge the gap between the actual measured ability of medical school graduates to accurately interpret ECG abnormalities and their expected ability upon graduation.

Barriers to teaching ECG interpretation during the clerkship exist at approximately 50% of schools surveyed and may account in part for the noted lack of changes in ECG instruction since the 2005 CDIM Survey. The most common barriers were lack of sufficient time, teaching faculty not comfortable in teaching ECG interpretation, and the presence of ECG instruction at other points in the medical school curriculum. Additional barriers include competition from other competencies such as new interprofessional training requirements and the movement of clerkships to earlier in the curriculum (second year). The increased use of Web-based teaching modules, which provide geographic and time flexibility to students, the recruitment of additional cardiology faculty/epidemiologists and fellows, increased faculty development in ECG interpretation for general internists, and the development of a more vertically integrated ECG curriculum throughout the 4 years of medical school could help address these barriers and improve student ECG interpretation skills.

The ability to master ECG interpretation depends on frequent repetition of skills learned and repeated exposure to the same or similar ECG strips. Given that teaching time devoted to ECG interpretation during the internal medicine clerkship has not significantly changed since 2005, it is not surprising that many students are not able to identify common ECG abnormalities.

Despite the limited time devoted to ECG instruction and the lack of focus on ECG assessment, it is noteworthy that clerkship directors were nearly unanimous that third-year students at the completion of the internal medicine rotation should be able to identify a multitude of ECG abnormalities. It is possible that the limiting of teaching of ECG interpretation and the lack of assessment of ECG ability at clerkship completion may inadvertently convey the message to medical students that ECG interpretation is not an important skill to master during the internal medicine clerkship.

Every clerkship director in the present study noted that ECG interpretation at his or her school was adequate. Yet despite this perception, a series of recent, potentially generalizable studies conducted at the George Washington School of Medicine found that the ability of many medical school graduates, both from GW and other medical schools in the US (the latter were incoming interns), to correctly interpret basic and critical ECG rhythms was significantly less than predicted. Data from the current survey suggest several factors that may account for this discrepancy, the primary one being a lack of assessment. Nearly one-half of clerkships do not assess ECG interpretation at the end of the rotation. Given this lack of evaluation during the internal medicine clerkship, instructors and deans cannot be certain that students have the ability to identify common ECG abnormalities.

LIMITATIONS

Our study has several limitations. We did not ask if or where ECG instruction or assessment takes place in other parts of the medical school curriculum. Our set of survey questions did not query how often cases are attached to the ECGs used during instruction, although such a practice has been shown to improve teaching/retention. Furthermore, respondents were not asked to rate the perceived effectiveness of specific ECG teaching methods or to rank current vs ideal methods of ECG instruction and skills assessment. Our study also has several strengths. The overall response rate was 76%, and respondents represented the majority of internal medicine clerkships in the US and
Canada. Furthermore, barriers to teaching ECG interpretation were identified, and core ECGs that the vast majority of clerkship directors believed that students should master by the completion of the internal medicine clerkship were identified.

CONCLUSIONS
AAMC has identified 13 EPAs that medical school graduates should be able to perform on the first day of internship. The publication Core Entrustable Activities for Entering Residency “serves as a guide for curriculum developers, faculty, and learners to better prepare students for roles as clinicians.”

We believe that ECG interpretation is such an EPA, because ECG misinterpretation can result in inappropriate clinical decisions, unnecessary treatments, and significant morbidity and mortality.

Nevertheless, although nearly all internal medicine clerkship directors of varied backgrounds and from across the US and Canada unanimously believe that students should master a set of 15 key ECG rhythms/abnormalities, minimal time is devoted to its teaching, and even less to assessment. Based on our earlier study, there appears to be a disconnect between the assessment of student ECG interpretation ability at graduation and what clerkship directors believe students should master by the end of the internal medicine clerkship.

Wider adoption of newer instructional methods coupled with increased teaching time, more practice reading ECGs, increased faculty development in teaching ECG interpretation, and sequential and systematic assessment of ECG interpretation ability based on a core set of ECG rhythms/abnormalities during medical school should help bridge this gap and better prepare medical school graduates for their roles as physicians.

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References

SUPPLEMENTARY DATA
Supplementary appendix table accompanying this article can be found in the online version at http://dx.doi.org/10.1016/j.amjmed.2015.10.034.
Appendix

Changes in ECG Instruction
Condensed formal dedicated time by 50%
Increased number of simulated patients used to provide a clinical application to ECG findings
Increased dedicated faculty support
ECG of the week to be addressed by clerkship students and their residents
Introduction of ungraded assessment of ECG interpretation skills
Introduction of Cardiology faculty in teaching of ECGs
More structured and interactive ECG session
Implemented an ECG teaching module
Introduction of pass/fail ECG interpretation quiz at end of clerkship; increased required number of formal ECGs interpreted;
addition of formal ECG interpretation conferences
Changed to a 4-hour introductory course at clerkship orientation followed by ECG review in small groups at individual clerkship sites
Introduced a structured curriculum
Formal workshop and ECG examination as part of grade
2 1-hour teaching sessions per clerkship rotation added/increased time dedicated to teaching ECG interpretation
Have a formal teaching schedule and dedicated time by a cardiology faculty member interested in teaching
Introduced on-line quiz/teaching
Internist replaced cardiologist due to better teaching skills
Eliminated ECG test
Added ECG reading to OSCE
Introduced 1:1 mentor sessions
Modification of didactic content and methods of delivery; modification of ECG cases
Created an ECG examination to ensure minimal competence

ECG = electrocardiogram; OSCE = Objective Structured Clinical Examination.