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Interactive Multimodal Curriculum on Use and Interpretation of Inpatient Telemetry

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Abstract

Introduction: Inpatient telemetry monitoring is a commonly used technology designed to detect and monitor life-threatening arrhythmias. However, residents are rarely educated in the proper use and interpretation of telemetry monitoring. **Methods:** We developed a training module containing an educational video, PowerPoint presentation, and hands-on interactive learning session with a telemetry expert. The module highlights proper use of telemetry monitoring, recognition of telemetry artifact, and interrogation of telemetry to identify clinically significant arrhythmias. Learners completed pre- and postcurriculum knowledge-based assessments and a postcurriculum survey on their experience with the module. In total, the educational curriculum had three 60-minute sessions. **Results:** Thirty-two residents participated in the training module. Residents scored higher on the posttest (77% ± 12%) than on the pretest (70% ± 12%), $t(31) = -4.3$, $p < .001$. Wilcoxon signed rank tests indicated PGY-3s performed better on the posttest (*Mdn* = 0.86) than on the pretest (*Mdn* = 0.72), $z = -2.19$, $p = .031$. PGY-2s also performed better on the posttest (*Mdn* = 0.86) than on the pretest (*Mdn* = 0.76), $z = -2.04$, $p = .042$. There was no difference between pretest (*Mdn* = 0.66) and posttest (*Mdn* = 0.71) scores for PGY-1s, $z = -1.50$, $p = .142$. The majority of residents reported that the telemetry curriculum boosted their self-confidence, helped prepare them to analyze telemetry on their patients, and should be a required component of the residency. **Discussion:** This module represents a new paradigm for teaching residents how to successfully and confidently interpret and use inpatient telemetry.

Keywords

Cardiac Arrhythmias, Cardiology, Hospital Medicine, Telemetry

Appendices

A. Pretest Instructor Edition .docx
B. Pretest Learner Edition .docx
C. Posttest Instructor Edition .docx
D. Posttest Learner Edition .docx
E. Evaluation of Confidence Pretest.docx
F. Evaluation of Confidence Posttest.docx
G. Educational Video.mp4
H. PowerPoint Presentation .pptx
I. Facilitator's Guide.docx
J. Curriculum Evaluation.docx

All appendices are peer reviewed as integral parts of the Original Publication.

Educational Objectives

By the end of this session, learners will be able to:

1. Identify American Heart Association/American College of Cardiology Class I, II, and III indications for inpatient telemetry monitoring.
2. Systematically interrogate telemetry in order to identify the presence of arrhythmias.
3. Systematically interrogate telemetry in order to identify the type of arrhythmia.
4. Recognize telemetry artifact and distinguish it from real arrhythmias.

Introduction

Inpatient medical telemetry monitoring is a commonly used clinical technology designed to detect a wide range of arrhythmias in a hospitalized population at high risk for cardiac events. Due to its availability, telemetry is also increasingly used in lower risk patient populations, which may lead to inappropriate use of resources, reduced cost-effectiveness, and an adverse impact on patient safety and outcomes from misinterpretation of telemetry data. For these reasons, educating residents about the proper use and interpretation of telemetry monitoring is important from both a clinical care and a high-value care standpoint. However, to our knowledge, there are no widely accepted curricula for medical residents on inpatient telemetry. In particular, interrogation and interpretation of telemetry represent a significant gap in medical education research. The current resource aims to educate learners about two important aspects of inpatient telemetry—indications for use and accurate interpretation—by utilizing a novel program that

incorporates video, PowerPoint presentation, and hands-on teaching. This curriculum represents an improvement over available, published methods because it includes education on telemetry interpretation and interrogation in addition to indications for telemetry. Furthermore, its use of multimedia interventions makes it a novel and engaging component of a residency program.

Indications for Inpatient Telemetry

Inappropriate use of inpatient telemetry monitoring contributes to increased cost of care and errors in patient management due to misinterpretation of false positive findings. For this reason, the Society of Hospital Medicine has identified inappropriate continuous telemetry monitoring as a top five focus of its Choosing Wisely campaign.[1] The American College of Cardiology (ACC) and the American Heart Association (AHA) have issued guidelines to support proper use of telemetry monitoring.[2] However, many recent publications report that up to 50% of patients placed on telemetry monitoring are low risk and do not meet a currently approved indication.[3] Telemetry monitoring in these low-risk patients has a low clinical yield, and detected events are usually benign.[4-8] Furthermore, hypersensitive telemetry monitoring can result in desensitization to floor telemetry alarms, which may cause providers to silence alarms when they are too frequent.[9] Interventions are needed to reduce inappropriate use of telemetry.

The decision to place a patient on telemetry monitoring occurs in the emergency department at most hospitals and usually requires agreement from a floor team to continue the monitoring once the patient is admitted. At Northwestern Memorial Hospital, like most other institutions, internal medicine residents are responsible for ordering or discontinuing telemetry on a daily basis. However, residents do not receive any education about the indications for inpatient telemetry prior to starting their internships.

A review of existing resources revealed several previously published interventions aimed at promoting proper use of inpatient telemetry, including the implementation of quality improvement electives such as those developed by Weingart, Tess, Driver, Aronson, and Sands,[10] the provision of a guideline-based handout to medicine residents,[11] and the embedding of guidelines in the electronic ordering system. [12] Quality improvement courses, handouts, and electronic ordering system adjustments are all valuable patient care initiatives, but handouts are often misplaced and electronic medical record systems change frequently. We believe that a more focused educational intervention directed specifically at residents will improve telemetry utilization and lead to a more meaningful change in practice patterns.

Interpretation

Once a resident determines that a patient is appropriate for inpatient telemetry, the resident is responsible for interrogating and interpreting telemetry each day. However, residents at most institutions do not receive any formal instruction on how to interrogate and interpret telemetry on their patients, including how to identify and characterize cardiac arrhythmias that have occurred and how to discriminate between therapy-guiding events and artifact. The risks of misinterpreting telemetry are obvious. Telemetry misinterpretation can lead to improper use of anti-arrhythmic medications, unnecessary cardiac catheterizations, and even placement of implantable cardioverter defibrillators.[13]

To our knowledge, there are no published curricula for teaching residents how to interpret telemetry. A number of educational tools have been developed to educate medical students and residents on electrocardiogram interpretation,[14-16] and indeed, at our own institution, we have developed a boot camp that aims to enhance incoming interns' interpretation of common electrocardiogram findings.[17] However, the ability to interpret telemetry is a different skill. There are a handful of resources[18,19] that explicitly attempt to teach telemetry interpretation, but these tend to be geared towards technicians and nurses rather than residents. As medicine residents interrogate and make clinical decisions based on their interpretation of telemetry findings almost every day, we believe that teaching them these skills is of high importance. The curriculum we present here provides a novel program that combines an engaging video- and PowerPoint-based workshop with hands-on practice in telemetry use and interpretation.

Methods

Audience and Timing

The target audience for our telemetry curriculum is internal medicine residency house staff, including senior residents and interns. The audience can include any trainee who is expected to interpret telemetry frequently and may also be suited for first-year cardiology fellows. The curriculum has three 1-hour sessions that can be spaced over time or completed in one 3-hour block. The curriculum can be embedded in any rotation-based conference series or delivered as an independent workshop or as part of a boot camp. We embedded the telemetry curriculum sessions in our existing rotation schedule. Small groups of five to 10 internal medicine interns and residents completed the telemetry curriculum during each monthly rotation for the first half of the 2017-2018 academic year. The Northwestern University Institutional Review Board approved this study, granting exempt status.

Curriculum Overview

The curriculum contained a pretest assessment, a 20-minute educational video, a PowerPoint presentation, a hands-on interactive learning session using telemetry with a facilitator, a posttest assessment, and a curriculum evaluation. The pre- and posttest assessments (Appendices A-D) were constructed by the study team and had 36 and 35 multiple-choice questions, respectively, assessing the resident's knowledge of telemetry use, manipulation, and interpretation. In order to ensure equivalence in content and level of difficulty between the assessments, a bank of questions was administered to 30 PGY-3 residents. This question bank, comprising 71 questions, included several of various levels of difficulty geared toward each learning objective. The distribution of correct responses to each question allowed them to be separated into two separate banks of questions that covered identical material with similar levels of difficulty. This method was supported through a Kuder-Richardson Formula 20 coefficient of .75, which denoted acceptable internal consistency.[20]

A paired-samples *t* test was used to compare scores on the pretest and posttest for the group, while Wilcoxon signed rank tests were used to analyze score differences among each postgraduate year. We administered the surveys using an external survey tool (SurveyMonkey). After the pre- and posttest assessments, residents answered 10 questions that assessed resident confidence in telemetry skills (Appendices E & F, respectively). Answer choices for the confidence questions were presented on a scale from 0 to 100 (0 = *cannot do at all,* 50 = *moderately can do,* 100 = *highly certain can do*).

The 20-minute video (Appendix G) was developed internally by local experts and shot using videographers from the Northwestern Simulation Center. The video detailed the AHA/ACC Class I, II, and III indications for telemetry and visually guided the learner through the steps involved in correct interrogation of telemetry and accurate interpretation and identification of arrhythmias versus artifact. The PowerPoint presentation (Appendix H) reinforced concepts described in the educational video through an interactive case-based approach. The presentation highlighted key concepts from the pretest to provide the learner with additional feedback on the first assessment.

The hands-on practice session at the telemetry machine required only one facilitator who was knowledgeable about appropriate telemetry use and interpretation. The facilitator conducted an interactive session with the learners at the telemetry machine. Each learner was assigned a hospitalized patient and instructed to systematically interrogate the patient's telemetry using the skills acquired via the curriculum, with the assistance of a facilitator's guide (Appendix I). Each resident was asked to identify any arrhythmias recorded by the telemetry machine and to discuss each arrhythmia's etiology with the facilitator. Facilitators were encouraged to ask learners follow-up questions to reinforce use of learner skills and prepare for more advanced interaction with the telemetry monitor. For example, a facilitator might have asked, "If we are concerned that the patient had ventricular tachycardia at midnight last night, what would be the most efficient way to find this?" Residents systematically interrogated patients' telemetry in the method that they were taught in the other educational materials. If unable to perform any of the following tasks—find a patient on the telemetry, systematically interrogate telemetry, identify any

arrhythmia recorded within the telemetry machine, and discuss the arrhythmia's etiology—the resident was asked to repeat them with the assistance of real-time feedback until able to successfully complete them.

Residents were asked to answer multiple survey questions about their experience after completing the telemetry curriculum (Appendix J). Questions addressed residents' perception of the curriculum's usefulness and its impact on their clinical readiness and self-confidence using a 5-point Likert scale.

Time Line

The telemetry curriculum can be spaced over weeks or condensed into a single 3-hour session, with an extra hour allotted across the three sessions in the event that a group of learners requires extra discussion or training.

We implemented the curriculum according to the following time line:

Week 1:

- Time required: 60 minutes.
- Location: a classroom or meeting room with appropriate audiovisual equipment or a computer on which learners were able to view a video. This session could accommodate as many residents as were able to fit in the conference room.
- Facilitator: no skill required. This session required only a coordinator able to administer the pretest assessment and play the video.

Residents arrived at the session and completed the pretest assessment (Appendix B). This was administered using an online survey tool (residents were instructed to bring their own laptops) but could also be administered in paper form. This assessment took approximately 35 minutes to complete.

After finishing the pretest, the residents completed the pretest confidence evaluation (Appendix E), again on their own laptops. This took approximately 5 minutes.

The facilitator then played the educational video (Appendix G) for the learners. The video was 20 minutes long.

Week 2:

- Time required: 60-90 minutes.
- Location: near a telemetry monitor. This session was best completed with smaller groups of residents (six to eight) in order to facilitate learning and limit the amount of time spent on this component.
- Facilitator: should be knowledgeable about telemetry, prepared to present the PowerPoint presentation, and able to walk learners through telemetry interrogation.

The facilitator first guided the residents through the PowerPoint presentation (Appendix H), which was displayed on a laptop or desktop computer. Ideally, this presentation should be reviewed near a telemetry machine so that the concepts and buttons presented in the PowerPoint can be reviewed in real time on the telemetry machine. Residents were encouraged to sequentially read and answer each question out loud. If a resident did not acquire a concept, the facilitator reviewed the concept in depth for the group. The presentation also covered the various functions of the telemetry monitor. Facilitators reviewed the presentation while they were sitting at a telemetry monitor so that the various functions described in the presentation could be reviewed in real time on telemetry. The PowerPoint presentation took approximately 30-40 minutes.

After the presentation, the group spent approximately 30-60 minutes interrogating patient data on telemetry depending on how many learners were present and what challenges were encountered with

the deliberate practice. The facilitator assigned each resident a patient on the telemetry monitor. Residents interrogated the patient's telemetry according to the script (Appendix I) while the rest of the group observed. If a resident did not take an appropriate step as part of the interrogation, the facilitator would guide the resident through the correct interrogation techniques and then ask the resident to complete the interrogation again. This continued until all residents had interrogated one patient's telemetry and all questions were answered.

Week 3:

- Time required: 60-90 minutes.
- Location: a classroom or meeting room with appropriate audiovisual equipment or a computer on which learners were able to view a video. This session could accommodate as many residents as were able to fit in the conference room.
- Facilitator: should be knowledgeable about telemetry so that posttest answers can be reviewed.

Residents arrived at the session and completed the posttest assessment (Appendix D). This was administered using an online survey tool (so the residents brought their own laptops) but could also be administered in paper form. This assessment took approximately 35 minutes to complete.

After the residents completed the posttest, they completed the posttest confidence evaluation (Appendix F), again on their own laptops (but this could also be administered in paper form). This took approximately 5 minutes.

After all residents had completed the posttest, the facilitator pulled it up on the classroom computer and reviewed the answers. All questions were answered. This took approximately 30 minutes but could take up to 60 minutes depending on the number of questions asked by learners.

Finally, residents completed the curriculum evaluation (Appendix J) on their laptops (the evaluation could also be completed in paper form).

Results

A total of 32 residents (13 PGY-1s, 12 PGY-2s, and seven PGY-3s) completed the rotation during the 6-month pilot study. Although participation in the telemetry curriculum was a mandatory component of resident education, participants could decline to participate in research. All 32 residents consented to having their data used for program evaluation as part of this study.

Overall, residents scored significantly higher on the posttest (77% ± 12%) than on the pretest (70% ± 12%), $t(31) = 4.3$, $p < .001$. A prespecified analysis of scores among different postgraduate years was completed using Wilcoxon signed rank tests. PGY-3s performed better on the posttest (*Mdn* = 0.86) than on the pretest (*Mdn* = 0.72), $z = -2.19$, $p = .031$. PGY-2s also performed better on the posttest (*Mdn* = 0.86) than on the pretest (*Mdn* = 0.76), $z = -2.04$, $p = .042$. There was no difference between pretest (*Mdn* = 0.66) and posttest (*Mdn* = 0.71) scores for PGY-1s, $z = -1.50$, $p = .142$.

Residents also rated their degree of confidence in performing a number of telemetry tasks before and after the curriculum by recording a number ranging from 0 to 100. Average confidence scores before and after the educational curriculum was completed for a number of statements are listed in the Table. All confidence improvements were statistically significant with $p < .0001$. In addition, a composite index of all domains of confidence increased from a mean of 48 before the curriculum to 79 after the curriculum ($p < .0001$).

Table. Confidence Scores Pre- and Postcurriculum

Statement	*M* ± *SD* Score (0-100) Precurriculum	Postcurriculum	*p*
Naming the AHA/ACC guideline indications for proper initiation and discontinuation of inpatient telemetry monitoring.	34 ± 23	70 ± 18	<.0001
Categorizing current AHA/ACC guidelines for proper initiation of inpatient telemetry monitoring by strength of indication (Class I/II/III).	16 ± 18	65 ± 24	<.0001
Utilizing the various functions on the telemetry monitor, including FD page, FD strip, calipers, events tab, and graphical trends.	58 ± 25	84 ± 16	<.0001
Manipulating the telemetry display to identify both the onset and termination of an arrhythmia.	53 ± 29	87 ± 16	<.0001
Identifying which arrhythmia is most likely based on the graphical trend display.	60 ± 20	80 ± 17	<.0001
Distinguishing true ventricular tachycardia from telemetry artifact.	64 ± 24	83 ± 16	<.0001
Using the functions on the telemetry monitor to determine what type of AV block is present.	40 ± 27	76 ± 20	<.0001
Distinguishing atrial fibrillation from all other arrhythmias based on the graphical trend display.	57 ± 30	87 ± 14	<.0001
Systematically reviewing a patient's telemetry to determine if any clinically significant arrhythmia has taken place.	62 ± 28	84 ± 16	<.0001
Explaining the etiology of any arrhythmia identified on a patient's telemetry.	41 ± 25	72 ± 21	<.0001
Composite index of all confidence domains.	48 ± 29	79 ± 19	<.0001

Abbreviations: ACC, American College of Cardiology; AHA, American Heart Association; AV, atrioventricular.

Finally, participant satisfaction with the module was high. Following the completion of the telemetry curriculum, residents filled out a survey regarding their experience with the curriculum using a 5-point Likert scale (1 = *strongly disagree,* 5 = *strongly agree*). All 32 residents provided feedback for this session (100% response rate). The majority of residents agreed (indicated by a 4 on the Likert scale) or strongly agreed (indicated by a 5 on the Likert scale) with the following survey statements after completion of the curriculum:

- "The telemetry curriculum boosted my self-confidence" (*M* = 3.6, *SD* = 0.8).
- "The telemetry curriculum helped prepare me to analyze telemetry on my patients" (*M* = 4.1, *SD* = 0.6).
- "The telemetry curriculum should be a required component of residency at Northwestern" (*M* = 3.8, *SD* = 0.8).

Discussion

We describe a novel multimodal curriculum that combines didactic and hands-on experiences to teach internal medicine residents correct use and interpretation of inpatient telemetry monitoring. Residents gained both competence and confidence in telemetry interpretation skills from the hands-on and engaging curriculum. The intervention doubled residents' confidence in the indications for use and discontinuation of telemetry, which may have an impact on future cost savings. Over 70% of residents reported that the telemetry curriculum should be a required component of the residency experience, suggesting that medicine residents are eager to learn this clinical skill. We believe the telemetry curriculum and its materials can be used to better educate internal medicine residents about a clinical technology they use daily.

We chose to include residents from all postgraduate years in this curriculum. We did so because we believe that although there is likely significant variability in clinical skills and knowledge between postgraduate years, the skills taught in the curriculum are unique and not reliant on baseline clinical abilities. PGY-3s may not necessarily know the appropriate way to scroll through telemetry or how to

distinguish between atrial flutter and atrial fibrillation based on the graphical trend line, even though they have completed more than 2 years of residency. Furthermore, a needs assessment that we conducted prior to developing this curriculum showed that none of our residents (PGY-1 through PGY-3) had had any formal curriculum in this skill. Therefore, we felt that the curriculum was broadly applicable to all class years with the same learning objectives.

Interestingly, PGY-2s and PGY-3s showed significant improvement in posttest scores after the curriculum, but PGY-1s did not. There are a few possible explanations for why the curriculum was less successful with PGY-1s. The most likely reason is due to the small sample size, and this study may benefit from testing the curriculum on a larger cohort. Second, although we feel that many of the skills taught in the curriculum were not dependent on clinical knowledge, it is possible that some of the material was more complex and required additional clinical knowledge that PGY-1s did not yet possess. As such, PGY-1s may require more exposure to the curriculum to truly digest the skills presented. Finally, it is possible that younger trainees were just not as receptive to the curriculum; however, research involving simulation-based education does not suggest that this is true.[21-22]

Some fine-tuning was required in order to incorporate the curriculum into our residency. The greatest challenge was determining when to administer the curriculum so that the residents were engaged, motivated, and not distracted by patient care responsibilities. We first pilot tested the program during the cardiac intensive care unit rotation, but we found that it was too difficult to schedule. After eliciting informal feedback from residents, we ultimately decided to implement the curriculum during an elective month, when residents were not actively caring for patients and could devote more of their efforts to it. Once we made this switch, we found the residents to be much more engaged. This scheduling modification was very important in the implementation of this educational tool.

The telemetry curriculum has several limitations. First, implementation at a single site limits the generalizability of findings and the program. The curriculum elements (video, PowerPoint session, hands-on session, and test questions) are all based on Northwestern Memorial Hospital's telemetry system. Other health care settings may use different software, screens, or interfaces. Our materials and methods may not apply as well to other residency programs. We believe, however, that the curriculum is generally applicable because most of our educational objectives can be taught regardless of the telemetry system used. A second limitation is that our pre- and posttest assessments are in multiple-choice format. The multiple-choice test is able to discern resident knowledge of certain domains, such as indications for telemetry, distinguishing artifact from arrhythmia, and identifying arrhythmias based on waveforms. The test measures skill using brief vignettes and questions asking learners to interrogate various screens from the telemetry machine. We believe that residents derive great benefit from the hands-on teaching session at the telemetry machine with a facilitator. However, these observations have not been captured in our assessment and are grounds for future work. Finally, it is difficult to determine the individual impact of each of the educational interventions (video, PowerPoint, practice at the telemetry machine) used in this curriculum. However, we do suspect that the inclusion of varied and novel elements in this curriculum made it more engaging and effective.

The curriculum has several future directions. Knowledge and skill retention at 6 and 12 months will be measured to determine if the curriculum has lasting impact. Repeat exposure of the residents to the curriculum at additional times throughout the year will reinforce the concepts and facilitate skill retention. Measuring the effect of this curriculum on telemetry use and interpretation in actual patient care settings will also be valuable. Additionally, we believe the telemetry curriculum could be offered to a broader group of learners, including residents in the emergency department, who often make initial decisions about the propriety of telemetry. Mid-level providers and other groups of residents who frequently use telemetry are potential curriculum consumers. Finally, these results were obtained using a standard amount of training time. Next steps include development of a mastery standard that represents the judgment of expert faculty regarding what knowledge internal medicine residents should achieve after

training. Imposing a mastery model on future cohorts of trainees would allow varying training times and thus achievement of maximal learning outcomes.

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Ethical Approval
The Northwestern University Institutional Review Board approved this study.

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