TEACHERS' TOPIC

An Elective Course in Cardiovascular Electrophysiology for Pharmacy Learners

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Objective. To implement an integrated, comprehensive, and learner-centered elective course focused at exposing learners to the interpretation of electrocardiograms and highlighting the mechanisms underlining the abnormal electrophysiological events.

Design. Learners were presented with foundational information on the mechanisms underlying electrophysiological changes associated with the development of arrhythmias. They then discussed the interpretation of electrocardiogram (ECG) recordings and diagnosis of cardiovascular events. Teaching formats included “chalk-talk” and didactic sessions, case-based exercises providing hands-on evaluation of ECG recordings, and high-fidelity simulation presenting cases of arrhythmias. The course design emphasized critical thinking, learner engagement, and development of problem-solving skills. Learners were assessed by formal assignments, examinations, and in-class quizzes.

Assessment. Learner comprehension of the material was assessed using cumulative examinations, in-class quizzes, assignments, and in-class presentations. Learner evaluations showed that the case-based discussions, practice ECGs, review tables, and illustrations enhanced course performance and retention of complex material.

Conclusion. The elective course provided in-depth exposure to the mechanisms underlying electrophysiological aberrations resulting in arrhythmias. It gave learners an opportunity to learn the art of ECG interpretation and to apply their knowledge in simulated scenarios. As clinical teams adopt a multidisciplinary team approach to patient care, acquiring these skills enriches learner experiences and allows them to expand their role and professional opportunities as pharmacists.

Keywords: arrhythmias, channelopathies, electrocardiograms, antiarrhythmic agents, case-based, note-taking

INTRODUCTION

Deaths resulting from cardiovascular diseases remain a concern in the health care field. Despite emergency medicine advances and guideline updates, sudden cardiac death from arrhythmia accounts for several thousand deaths per year.¹ The cause of arrhythmia is multifactorial and can include myocardial ischemia, electrolyte disorders, cardiomyopathies, hypertrophy, several classes of drugs, and channelopathies.² Additionally, the diagnosis and pharmacotherapy of arrhythmia presents its own set of challenges to health care professionals. Further complicating the matter, most agents used in the treatment of arrhythmia can potentially cause arrhythmia. These agents have complex pharmacokinetic profiles, multiple drug-drug interactions, and potential adverse effects other

than precipitating arrhythmias. These challenging factors highlight the role that a pharmacist can play in the management of arrhythmia.

An electrocardiogram (ECG) recording is a diagnostic tool used to assess the overall cardiac health of a patient. They are easy to perform, inexpensive, and provide valuable information regarding the electrophysiological functioning of the heart, and studies indicate the prognostic value of an ECG reading.³ Patients with complicated disease conditions such as arrhythmias are often on multiple medications and need to be monitored continuously. Pharmacists play a key role in fine-tuning patient therapies through interpretation of diagnostic tests. The intention of this course was not only to familiarize learners with ECG interpretation, but to also educate them on mechanisms underlining electrophysiological changes that cause abnormal rhythms. Such a course design would provide a unique skill set for pharmacy learners, which would give them an advantage when actively involved in patient assessment, treatment, and care management.

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The curriculum at Western New England University College of Pharmacy (WNECoP) introduces learners to ECG interpretation as part of the patient assessment course in the fall semester of the second year (P2). The pharmacology of anti-arrhythmic agents and pharmacotherapy of arrhythmia is taught in the P2 spring semester as part of the Integrated Pharmacy Care (IPC) Cardiovascular Care module. Although the module introduces learners to rate and rhythm abnormalities, learners receive limited exposure to the interpretation of ECGs and the underlying mechanisms causing arrhythmias. The elective course, Cardiovascular Electrophysiology: From Bench to Bedside, was developed for third-year (P3) students to complement their knowledge base regarding arrhythmias and diagnosis based on interpretation of ECGs.

The complex language of an ECG can be overwhelming and confusing. The backbone of an ECG recording combines principles of ion channel physiology and concepts of electrophysiology. The aim of the course was to highlight how dysfunctional electrophysiological functions at the molecular level are translated into changes on an ECG. The other aim was to familiarize learners with various types of arrhythmias, with specific emphasis on the interpretation of ECGs. The elective course was developed to include variety of teaching formats including modified “chalk-talk” lectures, learner presentations, and case-based discussions using 12-lead ECG recordings. Specifically, these instructional methods were intended to create an environment that promoted active learning and critical thinking and also helped learners develop problem-solving skills. Additionally, learners were given the opportunity to practice in a high-fidelity simulation (HFS) suite mimicking cardiovascular events such as ST-elevation myocardial infarction (STEMI), heart blocks, and drug-induced overdoses. The objective of this manuscript is to communicate the design of the elective course, the challenges facing the course, and its role in a professional pharmacy program.

DESIGN

Cardiovascular Electrophysiology: From Bench to Bedside was offered as a 3-credit elective course to P3 pharmacy learners during the fall semester. The course description emphasized understanding the link between aberrant ECG patterns and mechanisms underlying electrophysiological changes causing arrhythmia. The course description also underscored the “hands-on” approach for instruction using case-based exercises, use of simulation, and learner presentations. Objectives were presented during class to help learners study the material, keep the instructor focused on the material, and prevent “over” teaching content. Learning objectives for the course are

listed in Table 1. The retrospective study was approved and deemed exempt by the Western New England University Institutional Review Board.

Because learners were already introduced to cardiovascular pharmacology and therapeutics as P2 students, the elective course was open to P3 learners in the college. To make the experience more conducive to active and interactive learning, the class size was limited to 15. The class met two times during the week: once for a 2-hour session and once for a 1-hour session. Three examinations were administered during the course. The first two contributed 20% to final grade. The cumulative final was 25% of final grade. A portion of the final examination was conducted using the HFS patient simulator. The course also included in-class presentations and write-up worth 20% and unannounced in-class quizzes, which accounted for 15% of the grade. The class was divided into five groups of three learners for an in-class presentation and group write-up for the presentation. The first presentation focused on topics covering the physiological basis of arrhythmias, and for the second presentation, learners discussed topics on ECG interpretation. The main texts for the course were *Cardiac Electrophysiology: from Cell to Bedside* and *12-lead ECG: the Art of Interpretation*.^{4,5}

At this point in the curriculum, learners were already conversant with cardiovascular pathophysiology, laboratory test and valves, pharmacology of anti-arrhythmic agents, and pharmacotherapeutics of most cardiovascular disorders, including arrhythmia, myocardial infarction (MI), and angina. The first two lectures of the course were a review of ion channel conduction, cardiac action potential, and molecular organization of cardiomyocytes. This laid the foundation for higher-level concepts such as channelopathies and signaling pathways involved in the etiology of cardiovascular disorders such as cardiac hypertrophy, cardiac reperfusion-injury, and MI. These topics were presented using a modified “chalk-talk” method. Lecture notes were presented on PowerPoint slides, which were posted on the university’s learning management system (Kodiak). The instructor used a smart-board to fill-in topic details during class. Additionally, the notes also contained “skeletal” outlines of illustrations drawn with ChemDraw (Perkin Elmer, Waltham, MA) or by hand.

The illustrations were used to explain complex material such as mechanisms of arrhythmias and signaling pathways. The document camera was used to explain this content. For example, Figure 1 is the illustration of how calcium-dependent ion channels and proteins contribute to the development of cardiac hypertrophy and ischemia-reperfusion injury. As the instructor explained the pathway and filled in the corresponding missing pieces of the

Table 1. Learning objectives for the Cardiovascular Electrophysiology: From Bench to Bedside elective at the Western New England University College of Pharmacy

Course Learning Objectives After taking this course, the learner should be able to:	WNE COP Core Competencies	Method of Assessments
Explain the biophysics of cardiac ion channels, their role in cardiac impulse conduction, and channelopathies	Knowledge base Thinking and learning	Quizzes, Examination
Describe mechanisms contributing to the development of arrhythmias including molecular pathways, pharmacogenomics and drug-induced arrhythmias	Thinking and learning Patient-centered care Communication	Assignment, In-class presentation, Examinations
Discuss how electrophysiological changes are translated on an ECG recording	Thinking and learning Patient-centered care	In-class exercises, In-class presentation Assignments
Explain and interpret ECG abnormalities associated with certain arrhythmias, drug-induced overdose, and electrolyte imbalance	Patient-centered care Thinking and learning Population based care	In-class exercises, Exercises, Examinations
Demonstrate effective teamwork in simulated environments such as HFS and case-based discussions	Patient-centered care Communication	In-class exercises, Examinations

ECG=electrocardiogram; HFS=high fidelity suite

illustration, learners took notes. With the assistance of provided “skeletal” notes and illustrations, active note taking during class helped learners stay engaged. This teaching format allowed for more in-class feedback, producing learner-led discussions that helped the instructor gain insights into how well learners understood the content.

Learners also gave a 20-minute presentation describing molecular dysfunction, epidemiology, ECG abnormalities, and treatment guidelines for a particular channelopathy. Learners were divided into groups of three, and each learner presented on one subtopic during the presentation. Each presentation was followed by a 10-minute question-and-answer session. The grade for the presentation was based on individual learner evaluation. Additionally, learners submitted a group write-up on the same topic, which was graded as a group.

Subsequent sessions were devoted to linking the concepts of molecular electrophysiological abnormalities and their impact on cardiac physiology to ECG recordings. Learners were given a review on the review on abnormalities associated with ECG components (eg, PR interval, ST-segment etc), including a live demonstration of a 12-lead ECG reading using two learner volunteers. The HFS staff member, who was a certified emergency medical technician (EMT), facilitated the demonstration. Learners were given a hands-on opportunity to see the placement of leads, study the ECG grid, and measure heart rate.

As the learner comfort with understanding ECG components grew, the instructor gradually introduced the topic of ECG interpretation. Arrhythmias covered during the course are listed in Table 2. Learners were first presented with arrhythmias covered previously in Integrated Patient Care (IPC) modules and the patient assessment course offered at the college. These included ECG changes associated with common arrhythmias, such as atrial and ventricular fibrillation, sinus bradycardia, and certain heart blocks. To promote discussion and engagement, learners were presented with a case on the arrhythmia, and a 12-lead ECG was embedded within the case. The cases were provided as PowerPoint lecture notes or as class handouts. Learners worked in groups of three and were given 10 minutes to work through the case and identify various abnormalities on the ECG recording. The instructor then gathered feedback from the groups on the interpretation. On the basis of learner discussions, the instructor then explain how to read the ECG recording and arrive at a diagnosis. Along with providing information on ECG interpretation, the instructor explained the underlying cause of the arrhythmias. For example, for the molecular dysfunction behind Andersen-Tawil syndrome, a long-QT disorder was explained as part of the channelopathy section of the course. However, during the ECG interpretation section, the learners were reintroduced to the topic. Then content was presented in a case-based format, and the

Figure 1. Example of Fill-in Illustration Demonstrating the Link between Calcium Channel Channelopathies and Development of Cardiac Hypertrophy and Reperfusion Injury. The figure is provided to the learners as class notes. The illustration is filled-in by the instructor during class using a document camera. (βAR-β adrenergic receptors, PLC-phospholipase C, VOCC- Voltage operated calcium channels, TRPC- Transient receptor potential canonical, IP₃-Inositol 1, 4, 5-trisphosphate receptor.

electrophysiological abnormalities were transcribed on a 12-lead ECG recording.

In some cases, learners were first provided with an ECG with “obvious” rhythm changes; then learners were presented with examples where the changes were subtle and identification was harder. The ECG readings were obtained from the *Art of Interpretation* text, some of which were real-life ECG cases that included artifacts and noise. Learners were provided with summary tables and charts to facilitate quick recall and retention of changes associated with arrhythmias. The questions on in-class quizzes were primarily based on these tables.

The use of ECG as a diagnostic tool in cases of overdoses and electrolyte imbalance was also discussed during the course as pharmacists can play an important role in patient management and treatment in both situations. In most overdose and electrolyte imbalance cases, there is a causal link between dysfunctional ion channel function, and physiological events that underline the abnormality in rhythm observed on the ECG. Case-based format were used for these lectures, during which a clinical practice faculty member specializing in overdoses co-instructed and discussed pharmacotherapy of

overdose treatment. For example, the section on digoxin overdose was broken down into two parts: first, the molecular mechanism behind digoxin overdose, such as delayed afterdepolarizations (DADs) was explained; then the ECG changes associated with digoxin toxicity was discussed. Finally, the clinical practice faculty member presented the treatment and management options for digoxin overdose. The other drug-induced arrhythmias and electrolyte imbalances presented are listed in Table 2. Mnemonics, cartoons, and charts describing overdose toxidromes were also provided to learners to facilitate content retention.

Toward the end of the semester, learners had an opportunity to interpret ECGs in the HFS laboratory. Depending on the case, physiological and vital signs were changed in the patient simulator by the HFS operator. Learners were asked to pay particular attention to changes in ECG readings. Because learners were familiar with interpretation of ECGs, the instructor explained ECGs by asking a series of questions regarding cases, which were based on arrhythmic conditions learners had encountered during the didactic portion of the case. The HFS was used to introduce case-based scenarios based on drug drug-induced arrhythmias.

Table 2. List of Arrhythmias During the Cardiovascular Electrophysiology: From Bench to Bedside Elective at the Western New England University College of Pharmacy

Arrhythmias	Subtopics
Supraventricular rhythms	Normal sinus rhythm, ^a sinus arrhythmia, ^a sinus bradycardia, ^a tachycardia, ^a sinus pause/arrest, ectopic beats, wandering atrial pacemaker, junctional escape beat, atrial flutter, ^a atrial fibrillation, ^a junctional rhythm
Ventricular rhythms	Premature ventricular contraction, ventricular tachycardia, ^a torsade de pointes, ^a ventricular flutter, ^a ventricular fibrillation ^a
Heart blocks	First degree heart block, ^a Mobitz I, ^a Mobitz II, ^a third-degree heart block ^a
P-wave	P-mitrale, P-pulmonale, biphasic P waves, biatrial enlargement, left and right atrial enlargement
PR interval	PR depression, Wolff-Parkinson-White syndrome
QRS complex	Left and Right ventricular hypertrophy, Osborn waves
Bundle branch blocks	Right and left bundle branch blocks
ST segment and T wave	ST segment elevation and depression
Acute myocardial infarction	Infarct effecting various regions such as lateral wall, anteroseptal AMI, inferior AMI
Electrolyte and drug-induced	Hyperkalemia, hypokalemia, hypocalcemia, Digoxin toxicity, TCA toxicity, CCB and BAA toxicity, antiarrhythmic agents such as sotalolol, quinidine, flecainide, amiodarone

^aContent covered in cardiovascular IPC modules and patient assessment course offered at Western New England University College of Pharmacy

EVALUATION AND ASSESSMENT

Case-based exercises (15-20 minutes in length) gave learners an opportunity to practice and get accustomed to the interpretation of 12-lead ECG recordings. Learners reviewed the recordings and offered their interpretation verbally. For each section of the course, the instructor posted review questions, tables, and practice ECG recordings on the E-board. Questions on the examination and in-class quizzes were based on these review questions. In addition, learning was evaluated with two examinations, a cumulative final, unannounced quizzes, in-class presentations, and write-up of the presentation. Examinations consisted of various formats ranging from multiple-choice, fill-in the blank, matching, short-answer, and case-based questions. The case-based questions were presented along with ECG chart and were used to assess the learners' ability to interpret the ECG and provide a diagnosis. A portion of the final examination was based on two case presentations in the HFS laboratory. Each learner was given 10 minutes time on each case in the HFS laboratory. The mannequin was attached to the cardiopulmonary monitor that displayed the ECG recording along with the patient's vital signs. The HFS staff provided verbal cues as the patient. The average scores on the quizzes ranged from 60-92% while the presentation scores ranged from 96-98%. The average scores on the in-class examination ranged from 72 to 91%. The average grade on the final examination was 84%. The final grade breakdown for the first cohort of learners was seven As, six Bs, and two Cs. The average score for the course was 85%. A

summary of learning objectives mapped to the assessments is presented in Table 1. End-of-semester instructor and course evaluations were above average within the college (instructor and course evaluations are summarized in Table 3). Learner comments for the course were positive. Example comments included: "fun, challenging and very informative," "provided in-depth information regarding ECG," and "tough subject but enjoyed the class."

DISCUSSION

The Center for Disease control estimates that 735 000 Americans per year have heart attacks and that there is a cardiac arrest occurring every 43 seconds in the United States.⁶ In spite of the use of laboratory and serum values to diagnose cardiac events, ECGs remain an important diagnostic tool to identify arrhythmic conditions. The 3-credit elective course was designed for pharmacy learners to interpret ECGs and provide diagnosis, while highlighting the underlying mechanisms of dysfunctional electrophysiology that can potentially lead to the development of cardiac disease states including arrhythmias, MI, and hypertrophy. The course also aimed to provide learners with a case-based "hands-on" approach to study arrhythmic abnormalities not normally encountered within the curriculum at the college.

The 2016 Accreditation Council for Pharmacy Education (ACPE) Standards emphasizes the need to develop elective courses that explore and advance studies in the area of professional interest.⁷ The standards also emphasize the need to develop curricular models that help learners

Table 3. Course and Instructor Evaluations for the Cardiovascular Electrophysiology: From Bench to Bedside Elective at the Western New England University College of Pharmacy (0-5 scale)

Question	Course Evaluation Scores
Course objectives were covered	4.08
Course expectations were met	4.08
Course challenged me intellectually	4.54
Course concepts were presented in a organized manner	4.31
Instructional materials increased my understanding	4.38
Course assignments were interesting and stimulating	4.23
Course helped me develop stronger critical-thinking skills	4.31
Question	Instructor Evaluation Scores
Instructor explained material clearly	4.23
Instructor demonstrated importance of subject matter	4.31
Instructor encouraged learners to ask questions	4.54
Technology improved learning in class	4.31
Instructor was concerned that learners understood material	4.38
Instructor dealt fairly and impartially with all learners	4.38
Instructor was open to comments	4.00
Instructor was available to learners during office hours	4.13

make the connection between scientific understanding and patient care, ultimately evaluating their knowledge-application skills. By linking the importance of understanding molecular and electrophysiological mechanisms underlying arrhythmias for accurate interpretation of an ECG recording, the course connected basic sciences to an important diagnostic tool commonly used in patient care. In addition, the course content complemented the curriculum and helped learners develop a unique skill set.

Teaching pharmacology of antiarrhythmic agents and pharmacotherapy of cardiac arrhythmia was challenging. Studies propose various pedagogical tools and methods to improve content delivery, but many pharmacy learners struggle with the arrhythmia section of cardiology.^{8,9} Traditional lecture delivery, especially of such complex subject matter, has poor retention and does not allow the development of critical-thinking and problem-solving skills.¹⁰ The use of “chalk-talk” using document cameras and smart boards improves learner attention and retention of content.¹¹ In this course, a modified “chalk-talk” method proved suitable for content delivery. The fill-in illustrations describing signaling pathways and lecture notes only containing outlines promoted active note-taking during class.

Moreover, learners who record notes during class increase retention and perform better on examinations.¹⁰ The “skeletal” nature of the notes/outlines allows the learner to pay attention and stay engaged in the classroom, while eliminating the need to transcribe everything during class.¹² However, note taking can be demanding on learners. Moreover, students’ note-taking abilities or the instructor’s presentation could contribute to inefficient and inaccurate note-taking. Additionally, if

the material with dense content was presented quickly, learners may not process the information correctly, leading to incorrect recording.^{13,14} Whether students learn better by transcribing lectures in their own words is debatable, learner evaluations for the course indicated they appreciated the method used by the instructor. Learners commented that the figures or illustrations provided an easy way to understand difficult concepts and helped them retain the material.

A combination of “chalk-talk” and case-based presentation facilitated teaching ECG interpretation. The use of case-based learning is well documented in various settings in most pharmacy programs.¹⁵ In this course, case-based exercises helped students engage and provided feedback of learning to the instructor. More importantly, the exercises helped learners focus on key points of a case, allowed for critical thinking and reasoning, and helped integrate the knowledge of physiology and pharmacology and apply it to practice. These exercises provided an opportunity for the students to actively work on a clinical problem as a group, which helped them learn on their own. Additionally, feedback to the instructor helped the teaching process, as inaccurate information was corrected immediately. The “hands-on” practice during the case-based exercise sessions allowed learners to get comfortable with recording and helped improve their interpretation skills. This allowed for self-learning, improved problem-solving ability among learners, and allowed the instructor to explain content. However, group discussions and exercises could also mean that not all individuals were participating in the group. Smaller group size did help deter this issue, as the instructor participated in all discussion sessions. Moreover, individualized

quizzes, which were based on the in-class exercises, helped address this issue.

High-fidelity simulation provides “hands-on” experience for learners to practice skills without risk to any patients. The use of HFS during the course allowed for demonstration of critical life threatening arrhythmic conditions, drug-induced overdoses, and fluid electrolyte imbalances. Because the HFS content was at the end of the course, it allowed learners an outlet to apply their skills and knowledge. However, according learner evaluations, learners would have liked more incorporation of simulation during the course. In the future, the instructor plans to expand the HFS and “live demonstration” section of the class and develop additional ideas for learner participation.

It is unlikely that a pharmacist would be called upon to make a primary diagnosis based on an ECG; however, pharmacists are a critical part of the health care team and are can be consulted to provide feedback on cardiovascular disease management. Given the complexity of arrhythmic conditions, a knowledgeable pharmacist can play an important role in patient care management. Educating learners on accurate interpretation of ECGs provides them with a unique skill set, adding depth to their professional portfolios.

SUMMARY

This elective course provided pharmacy students the opportunity to learn, understand, and master the challenges of ECG interpretation. Because learners must be able to extrapolate their understanding of physiology to interpret ECGs, significant emphasis was placed on learners applying their knowledge and becoming problem solvers. Teaching learners ECG interpretation requires that they understand the fundamentals of cardiac physiology and associated electrophysiological changes. Building on this foundation allows the learners to not only appreciate the complexity of an ECG recording, but also assists them in reading and interpreting ECGs. Didactic instruction combined with real-time practice gave learners an opportunity to acquire and apply their ECG interpretation skills. The course complemented the curriculum and provided the learners with a unique skill set to potentially expand their knowledge base and professional opportunities.

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