Development of a Curriculum for Emergency Physicians to Teach Transesophageal Echocardiography for Cardiac Arrests: A Kern Six-Step Model

Barry Swerdlow[1]

1 Oregon Health Sciences University

Funding: No specific funding was received for this work.

Potential competing interests: No potential competing interests to declare.

Abstract

Background: The Kern model facilitates the development, implementation, and evaluation of successful educational systems in medicine. It involves six steps that link curricular content to health care needs. One such need is the design of a curriculum to teach emergency physicians practical use of focused transesophageal echocardiography employing a limited number of views for management of out-of-hospital cardiac arrests. The objective of this analysis was to describe the components of such a curriculum based on a Kern model that could be employed to train emergency department providers in this diagnostic modality.

Methods: We predicated our analysis on the American College of Emergency Physicians' recommendations and goals for use of transesophageal echocardiography to guide emergency department cardiac arrest resuscitation. We then detailed an asynchronous pre-didactic learning experience followed by a synchronous didactic and simulation-based curriculum to teach emergency physicians how to acquire and interpret images for this purpose based upon steps set forth by a Kern model.

Results: The component steps in designing a curriculum constructed to teach focused transesophageal echocardiography for out-of-hospital cardiac arrests to emergency physicians are rigorously outlined. These components based on a Kern model include problem identification and a general needs assessment, a targeted needs assessment, defining goals and objectives, choosing educational strategies, curricular implementation, and program evaluation.

Conclusions: Use of a six-step Kern model as a template can facilitate the development and dissemination of a curriculum to teach emergency physicians successfully to employ focused transesophageal echocardiography in the treatment of cardiac arrests. In order to promote its widest dissemination, this model should be pursued in a "train-the-trainer" fashion. In so doing, appropriate education of emergency physicians and their use of transesophageal echocardiography to manage cardiac arrests likely can be rapid and impactful, especially among providers with training and experience in transthoracic echocardiography.

Barry Swerdlow, MD[1,2,*]

[1]*Simulation Director, Nurse Anesthesia Program, School of Nursing, Oregon Health & Science University, Portland, OR, USA*

[2]*Adjunct Clinical Assistant Professor, Department of Anesthesiology, Perioperative and Pain Medicine, Stanford University School of Medicine, Stanford, CA, USA*

[*]Corresponding author:
Barry Swerdlow, MD
3440 SW US Veterans Hospital Road, #521
Portland, OR 97239, USA
Email: swerdlow@ohsu.edu
ORCID iD: 0000-0001-9983-2867

Keywords: cardiac arrest, curriculum development, Kern model, transesophageal echocardiography, TEE.

Introduction

The Kern model for curricular development was expressly designed to facilitate the development, implementation, and evaluation of successful educational systems in medicine.[1] The template suggested to achieve this end consists of a six-step approach that links curricular content to health care needs. This creative process has been described as dynamic and interactive and involves distinct steps that often influence and alter one another: problem identification and general needs assessment, targeted needs assessment, definition of goals and objectives, description of educational strategies, curriculum implementation, and evaluation of the program's success.[1] The model has been successfully employed to develop medical educational experiences with multiple applications.[2][3][4]

One such health care need is the design of a curriculum to teach emergency physicians (EPs) practical use of focused transesophageal echocardiography (TEE) to manage out-of-hospital cardiac arrests (OHCAs). Focused TEE represents a point-of-care ultrasound (POCUS) technique where a limited number of TEE views are used to guide patient resuscitation. The value of this technique in the management of emergency room cardiac arrest situations and its relatively low complication rate is well established.[5][6][7] Focused TEE can direct effective cardiopulmonary resuscitation (CPR), identify reversible causes of cardiac arrest, aid in the short-term prognostication of cardiac arrest outcomes, guide extracorporeal membrane oxygenation cannula insertion, and assist with peri-arrest hemodynamic support.[5][6][7][8][9][10][11] As a result of these interventions, it has been shown to alter cardiac arrest management decisions in a large percentage of cases, even when transthoracic echocardiography (TTE) is performed concurrently.[6][7]

TEE offers several advantages over TTE during cardiac arrests. Unlike TTE, it allows continuous monitoring of the heart

during resuscitation and thereby facilitates high quality CPR,[6][12] a condition critical to survival after cardiac arrest.[13] Specifically, TEE can be performed without interruption of chest compressions and is associated with shorter pulse-check pauses versus TTE.[14] Furthermore, this POCUS technique allows assessment of the adequacy of depth of compression and identification of the area of maximal compression.[7]

In addition, compared with TTE, TEE offers superior visualization of many cardiac structures especially when the time available for TTE imaging is circumscribed by interruption of CPR.[6] Despite these advantages, TEE is used infrequently in cardiac arrest situations largely due to lack of applicable EP training. For this reason, we chose to design a curriculum based on a well-established template (the six-step Kern model) that will efficiently teach focused TEE to EPs to allow them to manage cardiac arrest situations in a manner consistent with current American College of Emergency Physicians (ACEP) recommendations.[15] (Table 1)

Table 1. Development of a curriculum based on the Kern six-step model for emergency physicians to teach TEE use during cardiac arrests. Abbreviations: ACEP, American College of Emergency Physicians; ED, emergency department; EP, emergency physician; TEE, transesophageal echocardiography.

Problem Identification and General Needs Assessment	Stakeholders: EPs, EDs, hospitals, and patients Needs: EP TEE skill set to meet ACEP guidelines Current State: Most EPs are untrained in use of TEE consistent with ACEP guidelines.
Targeted Needs Assessment	Core content should involve development of a focused TEE skill set for cardiac arrest management and encompass TEE fundamentals, including limitations, pitfalls, and contraindications, and acquisition and use of images from ACEP-defined views to optimize cardiopulmonary resuscitation performance, identify cardiac activity and rhythm, evaluate left and right ventricular function, and assess for specific cardiac arrest pathologies. [6][7][15][16]
Goals and Objectives	Upon completion of this curriculum, the EP will be prepared to: • Employ a focused TEE skill set to optimize management of ED cardiac arrests; • Retain this skill set for subsequent management of ED cardiac arrests at a later date; and • Teach other EPs to employ and retain this skill set in a comparable manner.
Educational Strategies	*Asynchronous pre-didactic education*: Allows subsequent "flipped classroom" didactic education. *Didactic education*: Structured training to meet predetermined core content consistent with ACEP guidelines. *Simulation education*: Training in real-time scanning techniques to acquire and interpret imaging views of the ACEP focused TEE skill set. *Formative and summative evaluation*: Simulation-based assessment of the ACEP TEE skill set by a credentialed TEE provider using hypothetical cardiac arrest scenarios.
Implementation	Prior to implementation, curricular developers should: • Produce curriculum and core content; • Define a timeline with dates for notification and selection of EP applicants; • Secure personnel, TEE simulator(s), and necessary associated funding; and • Pilot the curriculum with EPs and in an ED desiring to acquire this skill set.
Program Evaluation	EP graduates of the program should be assessed at intervals over time regarding their frequency of use of TEE for ED cardiac arrests, their relative success with such use as judged both by successful image acquisition and interpretation and by alteration of cardiac arrest strategies, and TEE instruction of other EPs for management of cardiac arrests. Program outcomes to be assessed include: • EP evaluations of the program; • EP graduation rate; and • EP graduate initiation of new ED TEE programs.

Problem Identification and General Needs Assessment

The purpose of the ACEP guidelines referencing TEE use by EPs is "to assist practitioners performing emergency ultrasound studies of the heart using TEE during cardiac arrest" by providing training standards.[15] These standards include completion of:

- 2-4 hours of TEE-specific didactic training;
- A minimum of 10 proctored TEE examinations either on patients or via simulation that involve a minimum of three imaging views – midesophageal four chamber view (ME 4C), midesophageal long-axis view (ME LAX), and transgastric midpapillary short-axis view (TG MP SAX); and

- A "standardized assessment by a credentialed TEE provider."[15]

It is the perspective of the ACEP that closing the gap between the current state of affairs where the large majority of ED cardiac arrests are managed without TEE and use of TEE to appropriately direct such management is largely an issue of providing adequate training for EPs.[15] This training has the potential to significantly alter OHCA strategies[6][7] and thereby potentially to affect outcomes. Given that currently approximately 356,000 individuals suffer non-traumatic OHCA annually in the United States,[17] these changes may significantly impact clinical care. As such, the stakeholders in this problem are first and foremost patients, but also include EPs, EDs, and hospitals. (Table 1)

Targeted Needs Assessment

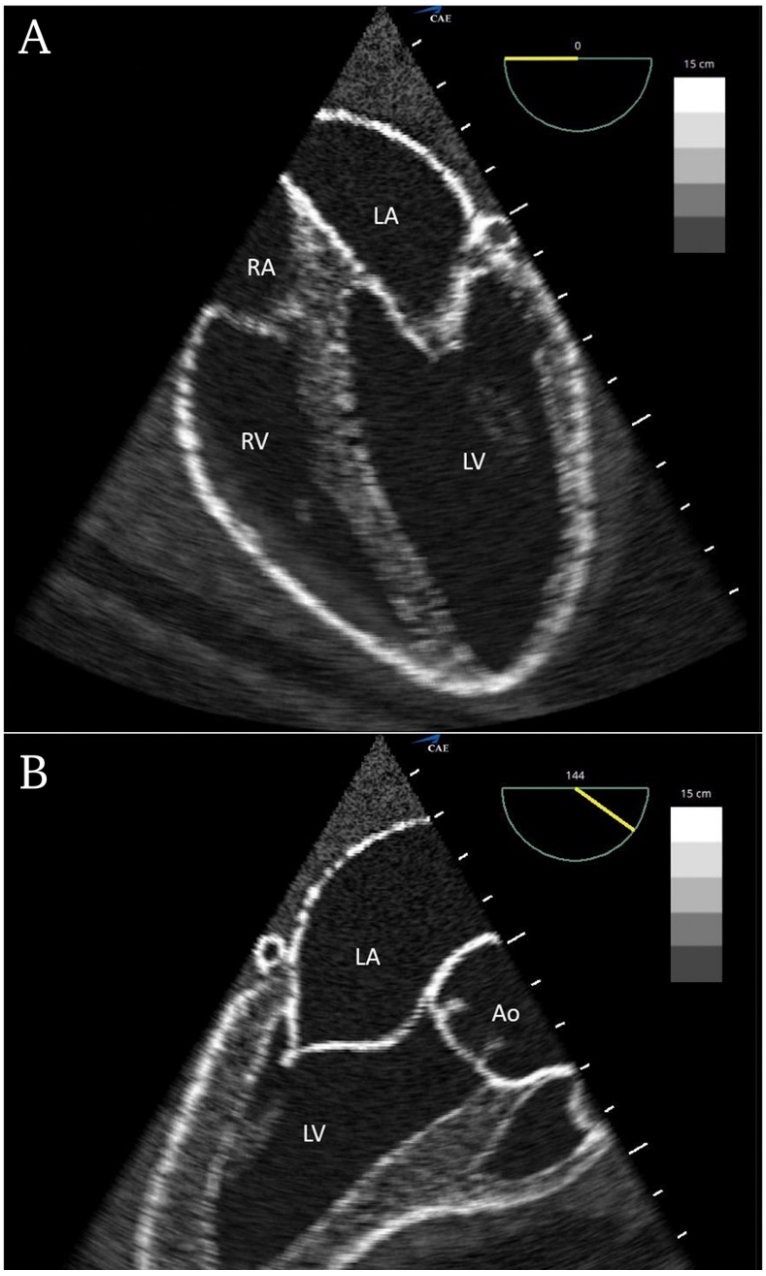
The above general needs assessment can be used as a rough guide for formulation of a targeted needs assessment. Many EPs are proficient in the use of TTE (but not TEE) for OHCAs.[6] As such, it is the opinion of the ACEP that TEE credentialing for EPs is solely a question of "technical ability and image acquisition,"[15] since TEE images are largely simple inversions of TTE images, and correspondingly that teaching TEE image interpretation is unnecessary.[16] As such, after delivery of a limited didactic content, the ACEP decided in its 2017 consensus statement that the cornerstone of learning and credentialing should involve the development of appropriate psychomotor skills either with patients or with high-fidelity simulators to allow accurate image acquisition of specific focused TEE views.[15][16] This decision may be based on a recently trained segment of EPs that is TTE-adept,[6] and as such may not apply to the broader EP population.

In this context, several studies have demonstrated the feasibility of teaching TEE image*acquisition* skills to EPs. Furthermore, didactic and simulation-based curricula have successfully taught *acquisition* of multiple views consistent with ACEP guidelines.[11][18][19][20] The suggestion, however, that EPs do not require training in TEE image*interpretation* is inconsistent with data showing significant discrepancies between TEE image acquisition skills (relatively high) and TEE image interpretation skills (lower) of EPs after brief, combined didactic and simulation sessions.[21]

Byars and colleagues did show that emergency medicine residents can successfully acquire two views (the ME 4C view and the midesophageal two chamber [ME 2C] view) AND *identify* a small number of simulated cardiac arrest pathologies following a brief didactic and simulation-based curriculum.[22] ACEP guidelines, however, recommend three views (one of which is NOT the ME 2C view), and despite its ease of acquisition the ME 2C view does not provide widely different information than the ME 4C view for resuscitation purposes. Furthermore, by excluding the other two ACEP views (ME LAX and TG MP SAX views), data regarding the left ventricular (LV) outflow tract, the proximal ascending aorta, segmental ventricular wall motion resulting from all coronary artery territories, and redundant views of the right ventricle (RV) and other cardiac structures critical for evaluation during resuscitation is lost. The latter point is particularly important and represents part of the rationale for the ACEP's design of its three-view protocol ("minimum standards"): "the need for redundancy to corroborate important findings across multiple planes of interrogation."[16]

As such, the targeted needs curricular content of EPs with respect to TEE education for OHCAs that is consistent with

ACEP guidelines (and the gap in the current state of curricula in this context) involves *both* image acquisition and image interpretation of the three most informative TEE views for this purpose (ME 4C, ME LAX, and TG MP SAX views) (Figure 1). Specifically, this curriculum should focus, not only on TEE fundamentals including its limitations, pitfalls, and contraindications, but also on acquisition *and* interpretation of images using these views to optimize CPR performance, identify cardiac activity and rhythm, evaluate LV and RV function, and assess for specific common OHCA pathologies including myocardial ischemia, type A aortic dissections, pulmonary embolism, and cardiac tamponade.[6] In so doing, this curriculum not only can address the general needs associated with underuse of TEE in OHCAs but also will be relevant and applicable to the specific needs of EPs who require training and credentialing with practical aspects of TEE in OHCAs consistent with ACEP guidelines. Furthermore, by limiting teaching to three TEE views, this curriculum (and the ACEP) provides a functional approach to such education that values brevity and respects most EPs' limited time availability. (Table 1)



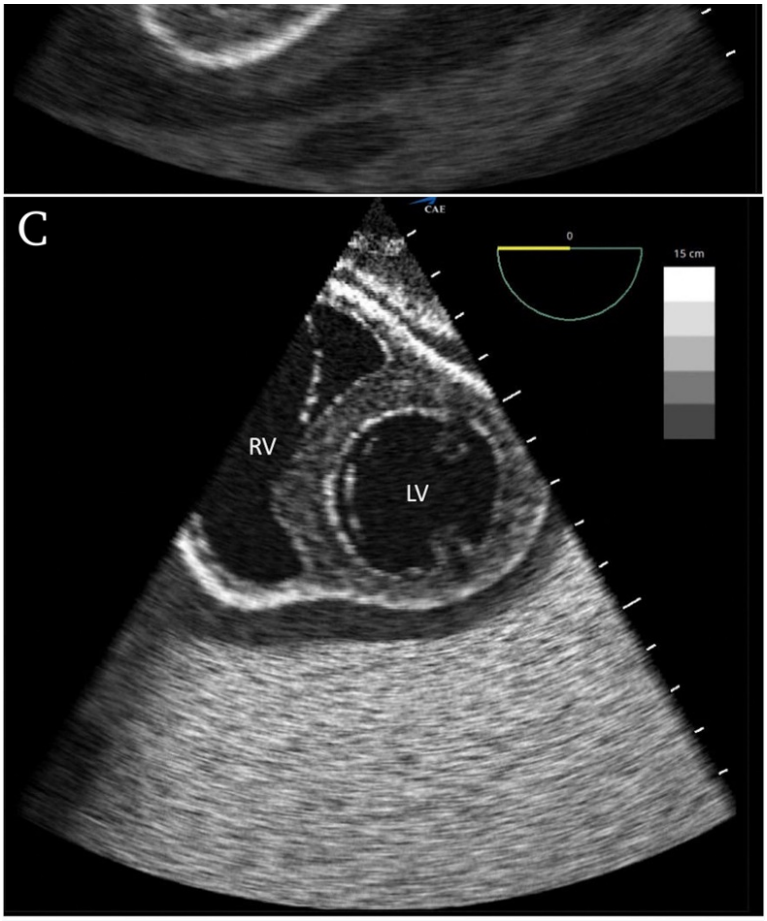


Figure 1. Simulator screenshots of the three transesophageal echocardiography views in the American College of Emergency Physicians guidelines: A: mid-esophageal four chamber; B: midesophageal long axis; and C. transgastric midpapillary short axisviews. Abbreviations: LA, left atrium; LV, left ventricle; RA, right atrium; RV, right ventricle.

Goals and Objectives

Choosing goals and objectives for this curriculum are of *a priori* importance and define the purpose and direction of this educational system. The learner objectives associated with teaching TEE to EPs relate directly to the rationale for such education i.e., the process and outcome objectives are to optimize cardiac arrest management in the ED. These goals involve both the cognitive (knowledge) and psychomotor (skill) aspects of learning domains.

This overall objective (“optimization of OHCA management”), however, is difficult to measure, and defining a limited number of measurable goals is a helpful part of this Kern step.

While it is likely that the educational experience involved with implementation of this curriculum will encompass more than these preconceived quantifiable objectives, their listing provides a general direction for the program. Examples of goals consistent with ACEP guidelines include use of TEE to:

- Identify correct CPR performances and to appropriately modify incorrect CPR technique;

- Recognize the presence or absence of cardiac standstill;
- Differentiate causes of hypotension due to low preload, vasodilation, and ventricular dysfunction; and
- Discern modifiable causes of OHCA including myocardial ischemia, ascending aortic dissection, pulmonary embolism, and cardiac tamponade.[6][7]

The process and outcome objectives for this curriculum, however, relate not only to learning how to manage OHCAs using TEE but also to retaining this skill set after such learning so it can be employed for subsequent management of these events. Ultimately, such skill retention implies that this TEE use has been integrated into a learner's clinical armamentarium and can be performed as needed without extensive repeat education. This learner transformation, moving from an emergency provider familiar with TTE to one who both learns to use TEE effectively for cardiac arrests and retains this skill set, represents the achievement of a quantum of competency. Such competency is the immediate goal of this curriculum design.

The last addition to the intended goals and objectives of this curriculum involves creating a self-perpetuating system wherein EPs trained in TEE for OHCA management teach other EPs in a comparable manner ("train-the-trainer" model). This construct allows for efficient dissemination of the skill set and an orderly achievement of the outcome objective of optimal management of cardiac arrest in the ED. The relative simplicity of the "focused" curricular TEE advocated by the ACEP involving only three views should facilitate this process and make this latter objective easier to achieve. (Table 1)

Educational Strategies

Step 4 in this model of curriculum development involves defining the strategies to be employed to allow the above educational objectives to be achieved and will result in transformative learning i.e., EPs become providers who employ TEE in OHCA situations as part of their professional identity in the same way that they currently employ other POCUS techniques, airway management skills, etc. These educational techniques are best selected depending on the goals and objectives they are designed to achieve. For example, cognitive objectives are best accomplished with either didactic education (where they are isolated and taught *in vacuo*) or simulation training (where they are taught in conjunction with haptic learning) or sequentially by both methods.[23] Furthermore, the ideal method (perhaps because it allows for different learning styles or facilitates integration of learning objectives) for retention of both TEE knowledge and skills may be to employ simulation prior to didactic learning.[23] Proper TEE performance requires knowledge of three-dimensional cardiac anatomy,[23] however, and for this reason the opposite sequence (theory before practice) is sometimes utilized in ultrasound education.[24]

The strategies that have been previously effective in teaching TEE include pre-didactic asynchronous learning, didactic education, and simulation-based education, and ACEP guidelines indicate that evaluation of TEE competency for use in OHCA should involve either patients (clinical learning) or simulation.[15] Different techniques may be used sequentially. For example, initial asynchronous viewing of online TEE educational videos allows a "flipped classroom" style of teaching that promotes efficiency and collaboration and facilitates use of joint learning time to promote critical thinking and to

address more complex, clinically relevant problems.[25][26] Thereafter, additional cognitive educational objectives in this curriculum can be achieved by synchronous didactic instruction in order to communicate core content consistent with ACEP guidelines.

In contrast, psychomotor objectives are best taught by simulation-based education (or patient experiences), and this methodology also reinforces cognitive learning.[27] Because successful TEE performance is dependent on hand-eye coordination, standardized direct observational tools (SDOTs) that are designed to obtain quantifiable data through observation of EP trainees in conjunction with high-fidelity simulation systems (or clinical situations) provide an ideal modality for teaching image acquisition and interpretation.[15] Validated SDOTs in emergency medicine are relatively common and have been employed successfully in the instruction of TEE to EPs.[16]

These didactic and psychomotor educational strategies can promote learner centeredness of this curriculum insofar as they remain tailored to meet the specific needs of EPs desiring to master TEE skills for OHCA situations. An additional method to promote such focus that is consistent with ACEP guidelines is formal assessment. For this reason, a formative (as well as summative) evaluation of the ACEP TEE skill set should be performed by a "credentialed TEE provider"[15] that will assist in identifying the needs of *individual* EP learners. This evaluation might involve TEE simulations associated with hypothetical OHCA scenarios that necessitate appropriate probe manipulation to acquire views and to identify pathology and allow learners to corroborate that identification using at least two views. (Table 1)

One additional educational strategy designed to encourage self-directed learning involves making the TEE simulator available for EP learner use outside the standardized curricular time frame. In this manner, learners can practice acquisition of additional TEE views beyond those set forth in the ACEP guidelines that provide additional utility for specific OHCA situations. For example, while pulmonary embolism may be suspected by viewing the RV in both the ME 4C and TG SAX views, central emboli often can be visualized in the Ascending Aorta SAX view (not part of the ACEP protocol).[28] Likewise, this same TEE view may be used to corroborate a type A aortic dissection seen in the ME LAX view, and the Ascending Aorta SAX view has been recently suggested as an addition to the existing ACEP protocol for this reason.[29] Furthermore, most modern high-fidelity simulators include imagery of multiple pathologies beyond those evaluated in the basic curriculum that can be useful in assessing an OHCA patient.[30]

Implementation

This is the step in the Kern model where the proverbial "rubber meets the road." It provides solutions to some of the major real-world hurdles in the initiation and maintenance of the curriculum for the purpose of achieving its stated goals and objectives. An early part of this process involves the creation of curricular content (pre-didactic, didactic, and simulation-based) and a timeline that lists dates for selection and notification of EP applicants. Sample content for a curriculum designed to teach EPs to use focused TEE for OHCA management is set forth in Figure 2.

In addition to creation of content, another early event in implementation concerns identification of resources. These resources include specific personnel, including curriculum directors, curriculum faculty (instructors), and support staff,

protected time for these individuals, space and equipment that specifically includes one or more high fidelity TEE simulators (each currently costing approximately $50K), and funding to acquire and support the former resources. The successful acquisition of these resources likely will require both internal support (starting with the major stakeholders – patients, EPs, EDs, and hospitals) and external support.

Prior to full implementation of this curriculum to teach focused TEE to EPs, consideration should be given to a small-scale piloting of the more complex parts of the program (e.g., identification of OHCA TEE pathologies with TEE novices) in order to receive useful learner feedback and make appropriate revisions. Alternatively, or in addition, such a curriculum can be phased into an ED, starting with small groups (e.g., faculty with previous TEE training) and then expanding to larger, less-experienced cohorts. Depending on multiple factors including available resources and existing pressures to initiate the curriculum, it may be wiser to start small and then gradually increase production rather than starting large and failing for lack of resources or lack of adequate early evaluative feedback. (Table 1)

I. Asynchronous Learning
II. Didactic Synchronous Learning
    A. TEE Fundamentals
        1. Utility, Contraindications, Complications
        2. Probe Components, Manipulations, Insertion
        3. Step-by-step TEE Exam with Knobology
        4. TEE Views (ME 4C, ME LAX, TG MP SAX)
    B. Focused TEE
        1. Identification of Cardiac Activity
        2. Optimization of CPR
        3. Assessment of Intravascular Volume (Preload, Afterload)
        4. Evaluation of Systolic Left and Right Ventricular Function
        5. Pulmonary Embolism
        6. Cardiac Tamponade
        7. Type A Aortic Dissection
III. Simulation Learning
    A. Image Acquisition with Normal Physiology and Selected Pathologies
    B. Evaluation of Hypothetical OHCA Scenarios

Figure 2. Outline of sample content of a curriculum designed to teach focused TEE for OHCA management consistent with American College of Emergency Physicians guidelines. Abbreviations: TEE, transesophageal echocardiography; ME 4C, midesophageal four chamber; ME LAX, midesophageal long axis; TG MP SAX, transgastric midpapillary short axis; CPR, cardiopulmonary resuscitation; OHCA, out of hospital cardiac arrest.

Program Evaluation

This evaluation step can either be summative (to rate performance) or formative (to improve performance). Some evaluations can serve both functions. Furthermore, such summative and formative evaluations can relate to learners or to

the program, so a total of four broad types of evaluations are possible.[31]

Both formative and summative learner assessment can occur via didactic and simulation-based evaluations: the former (formative) can be implemented at intervals during the curriculum with specific feedback designed to improve learner TEE skills and the latter (summative) can happen as a standardized direct observational benchmark in the form of a checklist.[16] (see “Educational Strategies”) Ideally, other summative learner assessments should occur following curriculum completion. For example, graduates of the TEE curriculum can be assessed at intervals regarding their frequency of use of TEE for ED OHCAs to ensure that they are applying this skill set regularly. In addition, their relative success with such use should be determined as judged by outcome data (successful image acquisition and interpretation, and alteration of resuscitation management strategy based on TEE findings). Furthermore, since this curriculum is designed as part of a “train-the-trainer” model, summative evaluation of the EP graduates should include an assessment of their track record in TEE instruction of other EPs.

Formative program evaluation is critical to identify those areas in the curriculum that are effective and those areas that need improvement. Such evaluation can occur via surveys from learners that provide constructive feedback and suggestions for program modification. (Figure 3) Both quantitative ratings and qualitative data from open-ended questions can be employed for such formative purposes. Summative program evaluation allows determination of whether program objectives have been met and should consider such parameters as EP graduation rates and rates of EP graduate initiation of new ED TEE programs i.e., whether “train-the-trainer’ goals have been met. In addition to such quantitative data, summative evaluation of this curriculum may include qualitative descriptions of unintended barriers to teaching this skill set in this manner, unanticipated implementation issues, or unforeseen outcomes of the curriculum development. (Table 1)

1. The TEE didactic exercise was a valuable educational experience.
2. The TEE simulation exercise was a valuable educational experience.
3. As a result of my TEE didactic experience, I gained knowledge concerning how TEE can be utilized to better manage cardiac arrests.
4. As a result of my TEE educational experience, I learned how to acquire specific “rescue TEE” images during cardiac arrest situations.
5. As a result of my TEE educational experience, I learned to interpret “rescue TEE” images associated with common cardiac arrest conditions.
6. The TEE views selected for focused instruction (ME 4C, ME LAX, and TG MP SAX views) were sufficient for this initial educational experience.
7. The didactic component associated with this educational experience should be shortened.
8. The TEE educational experience (didactic and simulation) prepared me to begin to utilize TEE during cardiac arrests.
9. If given the opportunity in the future, I am likely to employ TEE in Emergency Department cardiac arrests.
10. If given the opportunity in the future, I am likely to teach focused TEE for cardiac arrests to colleagues.

Figure 3. An example of a survey for TEE program evaluation. Likert scale responses are requested in response to statements. Abbreviations: TEE, transesophageal echocardiography; ME 4C, midesophageal four chamber; ME LAX, midesophageal long axis; TG MP SAX, transgastric midpapillary short axis.

Conclusion

There is a well-defined need to develop a curriculum to teach EPs use of TEE to optimally manage OHCAs. The ACEP recognized this state of affairs roughly half a decade ago and proposed guidelines that incorporated acquisition of a limited number of TEE views as an educational standard. It is likely that teaching correct interpretation of these acquired views to EPs is also necessary. The design of a curriculum for these purposes is readily modelled by a Kern six-step process that also can serve to shepherd its execution and its academic success. As such, similar to its use with educational endeavors for other such medical exigencies, this model can provide a template to facilitate the development, implementation, and evaluation of a successful ED TEE curriculum. In order to promote its widest dissemination, this curriculum should be pursued in a “train-the-trainer” fashion, and the ultimate success of such curricular development will be measured in the speed of ED adoption of TEE as a standard diagnostic technique during OHCA.

Statements and Declarations

Ethical Approval

Not applicable because this article does not contain any studies with human or animal subjects.

Informed Consent

Not applicable because this article does not contain any studies with human or animal subjects.

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