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Echocardiography curriculum development for physician assistants using entrustable professional activities

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Thesis

ECHOCARDIOGRAPHY CURRICULUM DEVELOPMENT FOR PHYSICIAN ASSISTANTS USING ENTRUSTABLE PROFESSIONAL ACTIVITIES

by

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ABSTRACT

Background

With the projected increase of cardiovascular disease in the aging population, a higher demand for echocardiography use is predicted. However, there is a shortage in the supply of cardiologists, to the point that a 2009 American College of Cardiology survey report called it a "cardiology workforce crisis". The report also recommends a more aggressive use of PAs and NPs as one of the solutions to fill the shortage. Currently, echocardiography is not routinely included in the scope of practice for PAs in cardiology. While PAs attain strong basic science knowledge and clinical training experience in PA school, they typically do not receive additional formal postgraduate training. PAs have limited training opportunities to train in echocardiography and receive certification of recognition, but a formally standardized training program and certifying examination geared specifically for PAs are yet to be developed. This study seeks to develop a pilot curriculum in training echocardiography which can be standardized for utilization across various regions and medical subspecialties. The curriculum draws on the concept of Entrustable Professional Activities (EPA), which is being actively used in graduate medical education

Hypothesis

After participating in the proposed pilot curriculum which involves online didactic learning and supervised hands-on clinical training, trained PAs will be able to reach proficiency in echocardiography operation and interpretation at level 4 supervision according to the EPA guidelines.

Methods

This study proposes a pilot curriculum with framework based on the EPA titled "performing and interpreting echocardiography" by PAs. The curriculum involves didactic and clinical training in echocardiography, with the goal to achieve mastery of level 4 supervision (minimal supervision). 2 subjects will be recruited from a teaching medical institution in the Greater Boston area with an IAC accredited echocardiography laboratory. After the 12-month training, participants will take ASCeXAM/ReASCE Online Practice Exam Simulation offered by the ASE. Upon 1) achievement of individualized EPAs as assessed by supervisor, and 2) simulation exam score of >80%, participants will earn a STAR in echocardiography.

Conclusion

The study is the first step to establishing an effective training curriculum that will eventually be a basis for creating a certifying exam in echocardiography, designed specifically for PAs. As this study merely suggests a new curriculum, future studies should focus on identifying strengths and weaknesses of the curriculum after implementation and expansion to multiple sites, and gather data to use for continual improvement of the training curriculum.

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LIST OF ABBREVIATIONS

AAMC..... Association of American Medical Colleges

ACC .....American College of Cardiology

ACCF .....American College of Cardiology Foundation

ACGME ..... Accreditation Council for Graduate Medical Education

ACS..... Advanced Cardiac Sonographer

AHA.....American Heart Association

APP .....Advanced Practice Provider

ARC-PA..... Accreditation Review Commission on Education for the Physician Assistant

ASE.....American Society of Echocardiography

CCI.....Cardiovascular Credentialing International

CHD .....Congenital Heart Disease

COCATS.....Core Cardiovascular Training Statement

EPA.....Entrustable Professional Activities

IAC.....Intersocietal Accreditation Commission

NCCPA ..... National Commission on Certification of Physician Assistants

NP .....Nurse Practictioner

PA ..... Physician Assistant

PAEA ..... Physician Assistant Education Association

ROC ..... Receive Operating Characteristic

TEE ..... Transesophageal Echocardiography

TTE ..... Transthoracic Echocardiography

INTRODUCTION

Background

Echocardiography uses ultrasound to assess cardiovascular anatomy and function, and is the most widely used and readily available cardiac imaging technique[3]. Combined with cardiac Doppler testing, echocardiography gives a measurement of ejection fraction, determines direction and velocity of bloodflow, and identifies structural and/or valvular diseases of the heart. With the projected increase of cardiovascular disease in the aging population, and lifestyle factors such as obesity, diabetes, inactivity, and smoking contributing to the growth, a higher demand for echocardiography use is predicted[33]. Echocardiography is a highly operator-dependent technique, and requires a thorough knowledge of cardiovascular anatomy and pathophysiology together with appropriate technical skills for a comprehensive and clinically useful study to be performed[32]. In today's practice, echocardiography is performed by ultrasound technicians if available, or performed and interpreted by specially trained physicians. However, compared to the increasing incidence of heart diseases and the subsequent demand for diagnostic echocardiography, there is a shortage in the supply of cardiologists, to the point that a 2009 American College of Cardiology survey report called it a "cardiology workforce crisis"[7]. The report also recommends a more aggressive use of PAs and NPs as one of the solutions to fill the shortage. Currently, echocardiography is not routinely included in the scope of practice for PAs in cardiology.

Statement of the Problem

PAs receive a broad generalist education adapted from the medical model perspective to develop core competencies in medical practice. In 2005, the 4 PA professional organizations—AAPA, ARC-PA, NCCPA, and PAEA—adopted the 6-domain professional competency structure, which ACGME designed for resident physician training, to guide PA education[55]. While PAs attain strong basic science knowledge and clinical training experience in PA school, they typically do not receive additional formal postgraduate training. Little is known about PA learning once they become employed[45]. The expectation is that PAs will learn more about their specialty through on-the-job experience over time.

With the expansion of PAs in specialty practice, there is an increasing need to understand how PAs develop and achieve competencies[45]. This includes identifying the most effective instructional and learning strategies and methods that supervising physicians can utilize to best train their PAs. Until now, expansion of scope of practice for PAs was often initiated in a small setting by a supervising physician's decision to experimentally train PAs in a new clinical skill set[14]. Data of proficiency gathered from such experiments would result in subsequent but slow acceptance by the medical community and regulating legislation. With each medical institution and supervising physician training their employed PAs according to their own preferences, there is no standardized formula to train PAs at the workplace[45]. No such guidelines have been published by PA professional organizations either. Similar problems are faced by PAs working in cardiology who desire to train in performing and interpreting

echocardiography. PAs have limited training opportunities to receive certification of recognition in echocardiography, but a formally standardized training program and certifying examination geared specifically for PAs are yet to be developed.

This study seeks to develop a pilot curriculum in training echocardiography which can be standardized for utilization across various regions and medical subspecialties. The curriculum draws on the concept of Entrustable Professional Activities (EPA), which is being actively used in graduate medical education. EPA is built on the idea that in teaching settings at the workplace, supervisors decide when and which clinical tasks they entrust the trainees to perform at level 4 supervision (minimal supervision). EPA-based curriculums are composed of observable and measureable process and outcomes, which can be used to determine entrustment decisions[52]. For the purpose of this study, the curriculum will focus on echocardiography training for PAs, so that after completing the curriculum, trained PAs can be entrusted to perform and interpret echocardiography.

Hypothesis

After participating in the proposed pilot curriculum which involves online didactic learning and supervised hands-on clinical training, trained PAs will be able to reach proficiency in echocardiography operation and interpretation at level 4 supervision according to the EPA guidelines.

Objectives and specific aims

This paper proposes an EPA-based pilot curriculum to train PAs in performing and interpreting echocardiography. Specific aims of this study are:

1. To design an EPA curriculum that can be standardized to train PAs in echocardiography operation and interpretation
2. To determine ability of trained PAs to reach proficiency in echocardiography at level 4 supervision (perform and interpret echocardiograms with minimal supervision).
3. To assess the effectiveness of the EPA-based curriculum in training PAs in echocardiography

REVIEW OF THE LITERATURE

Overview

Cardiovascular disease is responsible for 1 in 4 deaths in the United States[29]. Age is a significant factor in the risk for cardiovascular disease. Between 2010 and 2020, the U.S. population growth of adults with ages 55 and older is projected to increase from 31.4 percent to 36.6 percent[26]. Results from the 2009 survey performed by the American College of Cardiology anticipate that the demand for cardiovascular specialist supply will double between 2000 and 2050[7]. However, the number of cardiovascular physician training programs has been decreasing since 1994. Between 1994 and 1999, the number of adult cardiology training positions decreased by 10%[8]. The American College of Cardiology also predicts that practicing cardiologists may retire early, for reasons such as the increasing cost of malpractice insurance, reimbursement and financial considerations, and work-life balance[7]. Due to the increase in the elderly population and a decrease in the supply of cardiologists, it is predicted that by 2020, a population adjusted supply of cardiologist will be a mere 5.0 per 100,000[28]. This trend is expected to continue through 2040 as the baby boom generation continues to age[28].

Table 1. Shortage of Cardiologists by Subspecialty, 2008[7]

Cardiology Subspecialty	**Current Shortage**
General Cardiology	1685
Cardiac Electrophysiology	660
Interventional (coronary + peripheral)	1941
Pediatric	127

It is important to note, however, that long-term workforce predictions are notoriously inaccurate[8]. In 2014, only 5 years after the 2009 ACC survey of the cardiovascular workforce, the president of the ACC released an editorial and refuted the physician shortage, which the 2009 survey called a cardiology workforce "crisis." He argues that due to the enactment of the Affordable Care Act and the ensuing cost-saving strategies employed by hospitals, a total of 278,000 hospital jobs are projected to be lost by 2021. He states that for cardiology fellows, there is a decline in the number of "open jobs in desirable locations" and that there is an "oversupply of trainees." He fails, however, to address the factors which determine certain locations to be "desirable" by the physicians, and whether there is a surplus of open jobs in locations other than "desirable." Also, the editorial does not address whether there has been a change in the uprising demand for cardiologists. The author concludes by suggesting that a better modeling algorithm is necessary to appreciate the future supply and demand in cardiology workforce.

Recently in 2016, a study by Narang et al. examined the current cardiovascular workforce and identified an excess demand and undersupply of the cardiovascular workforce. The study confirmed the findings of the 2009 ACC survey and found similar factors, such as aging population and the growing cardiovascular disease burden, cardiologist burnout, and lengthy cardiovascular training, to be impacting the cardiovascular workforce (Figure 1).

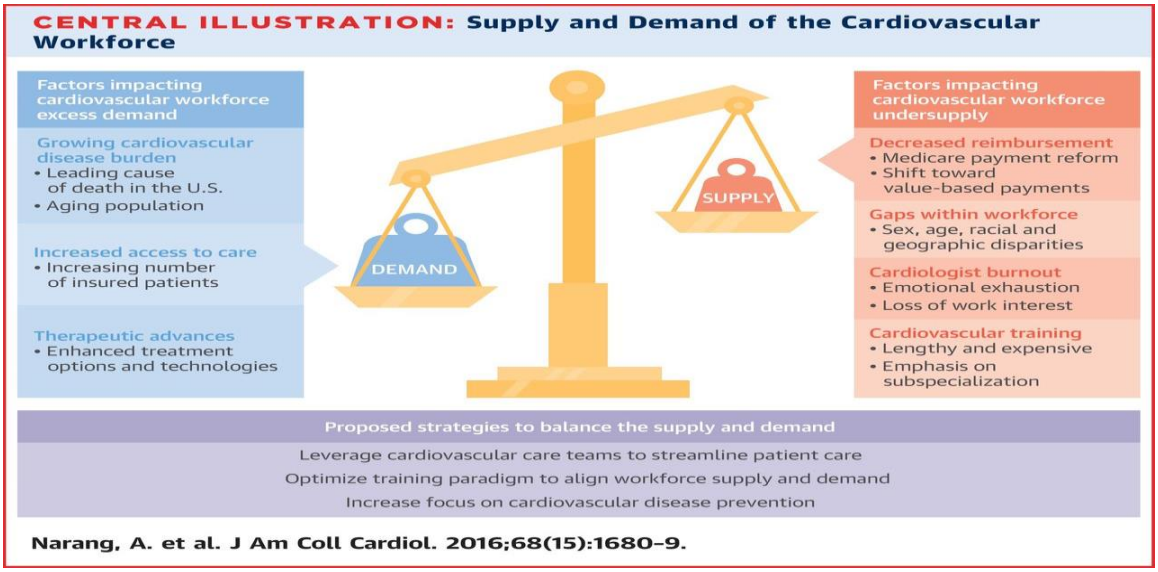

Figure 1. "Supply and Demand of the Cardiovascular Force"

Different geographical regions see varying extents of the undersupply and excess demand of cardiologists. Even Massachusetts, with several academic medical centers that train thousands of specialists annually, is "experiencing a critical physician shortage" in five specialties, including cardiology[27]. Geographic maldistribution is more marked in the Midwest and Western states[30]. These states include significant portions of Hospital Referral regions, which represent regional health care markets for tertiary medical care that generally requires the services of a major referral center. In 2007, 10 percent of these regions had 11 or fewer cardiovascular specialists per 100,000 elderly people, as compared to 193 or fewer for Metropolitan regions[30].

PAs in cardiology

As one of the means for increasing the cardiovascular workforce supply, the American College of Cardiology recommends supporting the expansion of general and cardiology-specific training programs for PAs and NPs[7].

Cardiology is the largest internal medicine subspecialty to employ PAs, making up 20% of all PAs in the field of internal medicine[12]. The American College of Cardiology Physician Assistant Work Group drafted and approved in 2011 the following definition of the PA in cardiology: "A PA is a highly skilled health care professional who practices medicine in a team-based setting with physicians…In the cardiology practice setting the Physician-PA team is able to expand access and provide high quality, cost-effective care to patients with cardiovascular disease[9]." Current roles of PAs in cardiology are listed in Table 2, with scope of practice varying widely by institution and geography.

Table 2. Current roles of PAs in Cardiology[1,15]

Perform patient history and physical exam	Perform admissions, consults, discharges
Make daily inpatient rounds	Interpret laboratory and diagnostic tests
Prescribe medications	Develop treatment plans
Supervise and interpret stress tests	Perform cardioversions
Perform device implantation	Perform cardiac catheterization
Take call	Provide patient education and lifestyle counseling

Existing Research

Expansion of roles of PAs in cardiology

Over the years, PA scope of practice in cardiology has continually expanded. Invasive procedures, such as Swan-Ganz catheterization, first-assist in cardiothoracic surgeries, and placement of central lines, that were once limited only to the hands of physicians are now routinely included in the scope of practice for PAs[31]. Since the 2002 study by Krasuski in assessing PAs' ability to perform cardiac catheterization after adequate training, cardiac catheterization came to be included among the scope of practice for PAs at some institutions[2]. The study measured outcomes of cardiac catheterization procedures performed by supervised PAs and compared them with those performed by supervised cardiology fellows-in-training. Outcome measures included "procedural length, fluoroscopy use, volume of contrast media, and complications including myocardial infarction, stroke, arrhythmia requiring defibrillation or pacemaker placement, pulmonary edema requiring intubation, and vascular complications." PA cases tended to be slightly faster ($P = 0.05$) with less fluoroscopic time ($P < 0.001$). The study notes that this finding can be attributed to the fact that more medically complicated patients, such as those with NYHA class 3 and 4 congestive heart failure, were assigned to the physicians (Table 3). However, patients assigned to the PAs did not differ from those assigned to the fellows in terms of angina class, number of diseased vessels (n=1.4 vs. 1.4 respectively, p=0.620), and left ventricular ejection fraction (54.3% vs. 54.1%, p=0.653). The technical aspects of injecting and imaging the coronary arteries would not have been affected by the classes of congestive heart failure.

Table 3. "Baseline Clinical Characteristics of Patients Undergoing Cardiac Catheterization"

	PA cases (n = 929) mean ± SD	**Fellow cases (n = 4,521) mean ± SD**	***P***
Age (years)	60.5 ± 12.2	60.6 ± 12.9	0.872
Male (%)	63.60%	59.70%	0.025
Diabetes (%)	29.00%	28.30%	0.682
Body mass index	28.8 ± 6.4	28.9 ± 7.0	0.713
Serum creatinine >1.3 mg/dl	5.50%	7.40%	0.04
NYHA class 3 and 4 angina (%)	33.80%	32.50%	0.424
NYHA class 3 and 4 congestive heart failure (%)	13.20%	19.50%	0.001

No difference in the volume of contrast media used was demonstrated between the PAs and the cardiology fellows. The incidence of major complications within 24 hour of the procedure was similar in both groups (p=0.892), with 0.54% in PA cases and 0.58% in fellow cases. No deaths occurred in either group. The authors stressed that the most important finding from the study was that both groups reported similarly low complication rates, and concluded that trained and supervised PAs can safely perform diagnostic cardiac catheterization with coronary angiography. However, it is important to note that the study only examined whether the trained PAs are able to perform cardiac

catheterization, and did not go further to explore whether they can be trained to accurately interpret the results of the procedure.

Expansion of roles in other fields

PAs have expanded their roles in other fields as well. A 2015 study by Duszak[13] found that PAs and NPs perform between 1% to 11% of nonvascular invasive procedures commonly performed by radiologists. Between 1994 and 2012, Medicare claims by "advanced practice providers," which include PAs and NPs, showed the following dramatic increases: paracentesis from 0 to 17967, thoracentesis from 119 to 4141, fine needle aspiration from 0 to 251, superficial lymph node biopsy from 0 to 251, abdominal biopsy from 1 to 1819, thoracic biopsy from 0 to 552, and abdominal drainage from 37 to 410 (Fig 2).

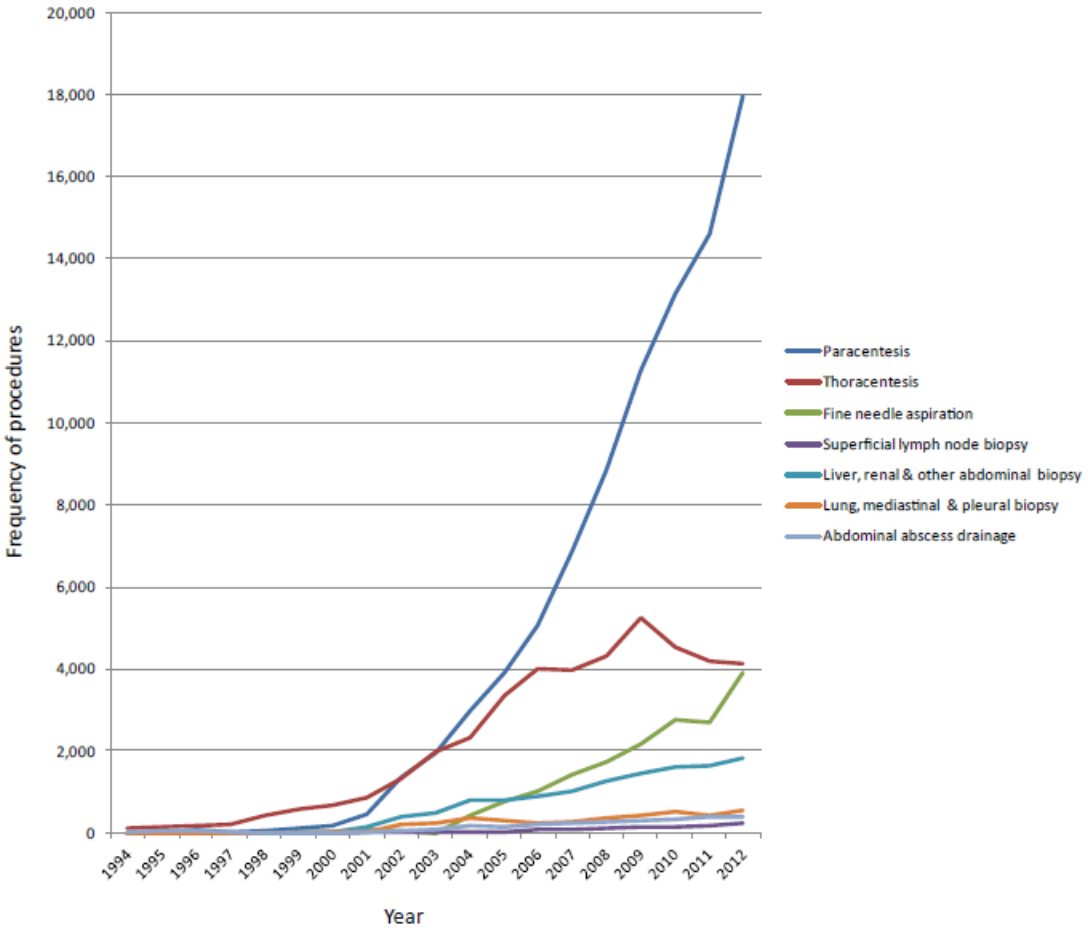

Figure 2. "Annual number of services rendered by APPs, by procedure category, to Medicare Part B beneficiaries, from 1994 to 2002"[13]

Arizona Joint Board of Medical Examiners authorized PAs to interpret mammograms as early as 1987 as a result of the study by Hillman et al[14], which trained PAs in mammographic interpretation and evaluated sensitivity and specificity of breast cancer detection by the trainee in comparison to that of radiologists. The PA trainee individually interpreted 727 mammograms and achieved a mean sensitivity of 0.78 in detecting breast cancer, as opposed to 0.61 by radiologists ($U=2.0$, $W=32.0$; $p<0.04$). Specificity of

interpretation showed no significant difference between the two groups (0.91 for PAs and 0.92 for radiologists, CI for differences: -0.06 to 0.04, Table 4).

Table 4. "Sensitivity, Specificity, and ROC Areas of Readers' Interpretations"

Reader Number	Radiologists			PAs Without Consultation			PAs With Consultation		
	Sens.	Spec.	ROC Area	Sens.	Spec.	ROC Area	Sens.	Spec.	ROC Area
1	0.74	0.89	0.871						
2	0.52	0.95	0.841						
3	0.71	0.92	0.861						
4	0.75	0.85	0.880						
5	0.56	0.93	0.822						
6	0.36	0.96	0.757						
7				0.79	0.87	0.896	0.78	0.89	0.895
8				0.73	0.93	0.903	0.75	0.92	0.891
9				0.78	0.92	0.902	0.79	0.93	0.907
10				0.81	0.93	0.891	0.76	0.95	0.877
Mean	0.61	0.92	0.835	0.78	0.91	0.896	0.77	0.92	0.891
SE	0.06	0.02	0.018	0.02	0.01	0.003	0.02	0.01	0.003

Note.—ROC = receiver operating characteristic; PA = physician assistant; Sens. = sensitivity; Spec. = specificity; SE = standard error.

The study went on further to evaluate the time-salary cost difference between the two groups; mean time-salary cost per case for the PA working alone is 0.62, which is approximately one-fourth of the cost of radiologists ($U = 0.0$, $W = 10.0$; $p < 0.01$). The authors concluded that "properly trained, evaluated and supervised" PAs can interpret mammograms. In the same year that the study was published, the Arizona Joint Board of Medical Examiners authorized the PAs cited in the study to interpret mammograms, given the following conditions: "1) PAs must work under the supervision of the HMOs radiology department; 2) all cases that are interpreted as positive, or about which the PA is uncertain, must be referred to a radiologist for interpretation before further evaluation;

3) no less than 5% of each month's cases must be randomly selected for overreading by radiologists as a continuing quality control[14]."

Echocardiography and telecardiology

Echocardiography is the most widely used and readily available imaging technique for assessing cardiovascular anatomy and function[3]. With the projected increase of cardiovascular disease in the aging population, and lifestyle factors such as obesity, diabetes, inactivity, and smoking contributing to the growth, a higher demand for echocardiography use is predicted[33]. However, the persistent shortage of cardiologists in rural areas, along with the statistics that rural patients report higher levels of heart disease, hypertension, and stroke than their urban counterparts[34], access by the rural population to services such as echocardiography is limited.

Telecardiology utilizing remote echocardiography, which refers to remote interpretation of scanned echocardiographic images, serves as a partial solution to meet the increased demand of echocardiography. Technological advancements that created portable and affordable cardiac ultrasound systems called hand-carried cardiac ultrasound (HCU)[36], as well as web-based transmission solutions of echocardiogram imaging have led to the birth of telecardiology[35].

ASE-REWARD study by Singh et al[35] examined the feasibility of remote echocardiography. 9 sonographers performed 1023 focused echocardiographic studies using handheld devices and uploaded the scans on a web-based viewing system for interpretation by 75 physicians with level 2 or 3 equivalent training in echocardiogram.

1021 scans were interpreted via web and compared with the interpretation given by cardiologists on-site of the ultrasound examination. The results showed excellent agreement in assessing valvular lesions ($k=0.85$, $p<0.001$), but not in other abnormal findings such as left ventricular systolic dysfunction and left ventricular hypertrophy. Left ventricular systolic dysfunction made up 45.9% of the major abnormalities found in the study subjects. Time from scanning to final interpretation ranged from approximately 7 to 25 hours, which would not be adequate for emergent cases. According to the American Heart Association, acute wall motion abnormalities in ischemia must be assessed and PCI performed within the goal door-to-balloon time for of 90 minutes[51]. Other studies in the past have studied the concordant accuracy in detecting structural cardiac abnormalities between traditional echocardiography and portable imaging devices, and found varying results. These studies also involved a small number of subjects (appendix 1). Also, remote studies may make follow-up examination difficult if the initial study is deemed inappropriate. Nonetheless, eventual implementation of such practices will provide increased access to echocardiography, creating increased demand for trained professionals to perform and interpret the imaging.

In fact, American Society of Echocardiography report in 2002 compared HCU with current state of the art echocardiographic examinations and concluded that although HCU does not fulfill the criteria for a comprehensive echocardiographic examination, HCU can provide accurate preliminary examination and increased accessibility for a wide variety of users that may see patients before referring them to level III cardiovascular specialist.

ASE believes that with the availability of inexpensive HCU technology, "a further progression of cardiovascular ultrasonography beyond the cardiovascular specialist likely will occur," and employ an increasingly large and diverse group of users, including advanced cardiac sonographers and PAs[36]. In today's practice, echocardiography is performed by ultrasound technicians if available, or performed and interpreted by specially trained physicians.

Training for physicians - COCATS

COCATS 4 Task Force 5: Training in Echocardiography, endorsed by the American Society of Echocardiography and the American College of Cardiology, serves as the most current standards for training adult cardiovascular fellows in echocardiography. The guidelines categorize training in echocardiography into 3 levels. Level I training is defined as an "introductory or early level of competency in performing and interpreting TTE that is achieved during fellowship training but not sufficient to provide independent interpretation of results[3]." Level II training requires additional training and a qualifying examination to "measure specific knowledge, skills, or competence," and is necessary for the physician to "provide independent interpretation of echocardiograms[3]." Level III training requires additional experience beyond the standard 3-year cardiology fellowship for the physician to have the ability to perform, interpret and train others in advanced aspects of echocardiography, as well as engage in research and direct an academic echocardiography laboratory[3]. Each level of training requires a specific sum of didactic, clinical, and hands-on experience. These requirements are listed in table 5.

Table 5. "Summary of training requirements in echocardiography for cardiology fellows"

Level	Duration of Training(Months)	Cumulative Duration of Training(Months)	Minimal No. of TTE Examinations Performed	Minimal No. of TTE Examinations Interpreted
I	3	3	75	150
II	3	6	150	300
III	3	9	300	750

Throughout the training, competency is evaluated through" direct observation by instructors, in-training examinations, case logbooks, conference and case presentations, multisource evaluations, trainee portfolios, simulation, and reflection and self-assessment." Competency assessments follow guidelines set by the ACGME, the "Core competency components and training curricular milestone" (appendix 2). Several online self-assessment programs are available, including ACCF's Maintenance of Certification Collection Module 1: Echocardiography[16] and the ASCeXAM simulation exam offered by ASE[53]**.** Upon achieving Level II requirements, trainees are strongly advised to take the ASCeXAM, offered by the National Board of Echocardiography, in order to receive a certification of competency. Certifications of competency are offered in the following areas: Transthoracic 2-D and Doppler Echocardiography interpretation alone (t), Transesophageal Echocardiography (e), Transthoracic plus Transesophageal Echocardiography (te), Transthoracic plus Stress Echocardiography (ts), Comprehensive (c) which includes all three procedures. Currently, the ASCeXAM applications are open

specifically to licensed physicians with fellowship training in cardiovascular disease at an ACGME accredited training program[17], who meet the training criteria in echocardiography, as listed in Table 5.

Training for cardiac sonographers

A cardiac sonographer is an allied health practitioner who performs echocardiographic examinations, primarily diagnostic recordings of cardiac ultrasonography images and Doppler hemodynamic data. Protocol and technique guidelines are provided in the Essentials and Standards by the Intersocietal Commission for the Accreditation of Echocardiographic Laboratories. As the technique is extremely operator-dependent, the cardiac sonographer must possess cognitive skills and proficiency to use appropriate sonographic techniques in order to produce accurate anatomic and physiologic information for the physician to review for diagnostic interpretation[19]. A cardiac sonographer specializing in adult TTE are required to have a broad understanding of cardiovascular diseases and adapt the examination to optimize imaging according to the possible pathology findings. Although it is the responsibility of the physician to provide diagnostic clinical interpretations, the cardiac sonographer must be skilled in selecting relevant echocardiographic data, making quantitative calculations from these data, and communicating his or her impressions to the physician interpreting the study.

Training for cardiac sonography consists of several pathways. According to the Cardiovascular Credentialing International, an ANSI (American National Standards Institute) accredited organization which offers the Registered Cardiac Sonographer

certification, one must hold a high school diploma at a minimum and fulfill the experience and/or education criteria listed in Appendix 3 in order to be eligible to sit for the certification examination.

Educational programs are advised to follow the ASE recommended educational curriculum, which is described in the *Educational Outline- Echocardiography and Doppler Echocardiography*[20]. Topics in the recommended didactic curriculum include: cardiac anatomy and physiology, cardiac pathology and pathophysiology, medical ethics and legal issues, professionalism, health care delivery, pharmacology, basic history-taking and cardiac physical examination[19]. It is notable that these topics are also a part of the PA school curriculum[21]. PAs, however, undergo more intensive clinical training in various medical subspecialties. Whereas sonographers use clinical correlation skills with the goal limited to assessing whether they had accurately scanned the patients for physician's read, PAs can utilize echocardiography much like the physicians do by using their clinical knowledge for diagnostic purposes.

Current roles of sonographers and the birth of advanced cardiac sonographers

Even with adequate training and certification, many sonographers may not have sufficient practical or clinical knowledge to accurately obtain echocardiographic study that accords with an individual patient's clinical presentation[22]. This is especially true in that echocardiograms are mostly read after the patient has left the laboratory and thus, a one-technique-fits-all type of echocardiogram study would not suffice to subsequently provide an accurate interpretation. The American Society of Echocardiography's

Sonographer Training and education committee urges that the cardiac sonographer not only perform the ultrasonography, but that they also "participate with the supervising physician in the interpretive review of the examination to provide input in the evaluation of data and contribute relevant technical information[19].

In hopes that echocardiographic examinations of improved quality would be performed on every patient before he or she leaves the laboratory, a new position of Advanced Cardiovascular Sonographer (ACS) has been created. Proposed and supported by the American Society of Echocardiography Advanced Practice Task Force, an ACS would fulfill the following responsibilities: 1) “teach staff sonographers with current technology how to assess cases that require the use of specific echocardiographic methods; 2) review studies that have been performed by staff sonographers; 3) provide in-service education for staff sonographers concerning new methods that are to be incorporated into the echocardiographic examinations; and 4) ensure that the necessary echocardiographic data are obtained for the patient on the basis of the clinical history and presentation[22].” The CCI-published task list for an ACS includes reviewing echo image quality and completeness, identifying cardiovascular abnormalities, creating preliminary echo report, and ensuring report completeness and accuracy. Table 6 lists the proposed educational curriculum by ASE. It should be noted that the curriculum in Table 6 is also covered in the PA training program curriculum, as suggested by NCCPA[22]. Prerequisites to sit in examination for ACS certification by CCI are listed in appendix 3.

Table 6. Proposed curriculum for Advanced Cardiovascular Sonographer certificate

Advanced Cardiovascular hemodynamics/physiology & pathophysiology	Acquired heart disease in the adult
Research methods and biostatistics	New ultrasound technologies, including contrast agents
Surgical and medical options	Comparative imaging analysis
Pharmacology	Curriculum and instruction for the adult learner
Clinical internship	

Although the first batch of CCI-certified ACS was birthed in 2015, a number of studies in the past have examined the benefits that additionally trained sonographers would bring to the echocardiographic laboratory. A study by Bude et al trained two sonographers with 10 and 30 years of experience to independently triage and dictate echocardiograms to be reviewed in batch by cardiologists at the end of the day, essentially providing a preliminary interpretation report. The sonographers were titled "ultrasound practitioners" and trained in echocardiogram interpretation by 1 week of direct observation as well as 4 weeks of on-the-job training. Their competencies were determined by the end of the 4-week training through a case-based oral examination, given by the radiologist who was an examiner in sonography for the American Board of Radiology (ABR). After 1 year of such practice, the reports created by the ultrasound practitioners were compared with the interpretation provided by physicians. The reports by the practitioners were graded

subjectively on a 4-point scale, according to the modification required at formal readout by physicians. (A, no change; B, minor change not affecting patient care; C, moderate change not affecting care in a dramatic way; and D, major change markedly affecting care). A total of 5683 echocardiographic studies were monitored by the 2 practitioners and the graded report results were averaged as follows: A, 96.1%; B, 3.6%; C, 0.3%; and D, 0.00%[23].

Current echocardiography training available for PAs

Currently, training opportunities in echocardiogram interpretation are almost non-existent for PAs. PAs who wish to receive further training in a specialty may pursue postgraduate residency or Specialty Certificates of Added Qualifications (CAQ). "CAQ is a "kind of portfolio, a way to organize one's experience, CME, physician attestation, and medical knowledge[11]. Currently, there is no CAQ available for echocardiography. There 41 operational postgraduate training programs recognized by the Association of Postgraduate Physician Assistant Programs in 17 medical and surgical specialties such as emergency medicine, surgery, hematology/oncology, and orthopedics[54]. These programs follow ACGME guidelines for physician residency programs[54]. There are 2 postgraduate residency programs devoted to cardiology, offered under the names of the Piedmont Heart Cardiology fellowship and the Carolinas Healthcare System Specialty Care Fellowship. The curriculum offered at Piedmont Heart institute includes only a "limited bedside echocardiography" training.

In order to obtain a CAQ in a specialty, a minimum of 150 credits of Category 1 CME focused on the specialty, as well as 2000-4000 hours of experience working as a PA in the specialty are required. Physician attestation is also required and competency must be shown by a qualifying exam. CAQ is currently offered in cardiovascular/thoracic surgery, but not in general cardiology. Limited training in echocardiogram interpretation is available for allied health professionals, through educational seminars offered by organizations such as the ASE University and the Gulf Coast Ultrasound Institute. PAs can also obtain on-the-job training if the echocardiography laboratories house supervising physicians who are willing to afford the time and effort to teach the subject. The American Society of Echocardiography also offers a title named "Fellow of the American of Echocardiography (FASE)," that also acts as a certificate of recognition for healthcare professionals who have achieved some training in echocardiography. See appendix 5 for requirements.

Although some certificates of recognition are available, a standardized exam to assess and recognize the competency of PAs with such specialized training is yet to be created. Until 1999, physicians who successfully passed the ASCeXAM but do not fulfill the necessary criteria for certification were awarded the title of "Testamur." However, the title of testamur does not establish competency, and is not even available for PAs. ASCeXAM now requires that all exam-takers submit a "certificate of good standing" as a licensed physician from the Medical Council[36]. Without a standardized training curriculum or a competency examination available to recognize these educational

achievements, the extra training a PA receives in echocardiogram interpretation becomes unpractical in clinical settings.

Entrustable professional activities

Training of PAs to assume new clinical responsibilities, which subsequently resulted in expansion in their scope of practice, has occurred in various pathways over the years. It often started from physician delegation and/or institution granted privilege, and some clinical duties eventually became incorporated in state legislation[14]. Each medical institution has its own set of defined roles and competency evaluation for its employed PAs, but there is a lack of a standardized set of skills expected of a PA. According to Englander et al, similar issues have been reported for medical students entering residency, as "no standard defines the clinical skills that medical students must demonstrate upon graduation… and as a result, there is disagreement about the specific clinical abilities and acumen that should be expected of a medical degree (MD) graduate[41]." In an attempt to narrow the gap between the residency program directors' expectations and the actual clinical abilities of a resident, the AAMC, in 2014, published 13 "Core Entrustable Professional Activities for Entering Residency."[42]

EPA, a concept introduced in 2005, is "a unit of professional practice that can be fully entrusted to a trainee, as soon as he or she has demonstrated the necessary competence to execute this activity unsupervised[40]." Current medical education and workplace proficiency are evaluated based on a set of established competencies, which are often described with words such as "knowledge, skills, attitudes, values" and can be

abstract[41]. Ten Cate defined competencies to be "general attributes of a doctor… confined to a limited set of qualities." Table 7 lists the 6 general competencies utilized by ACGME to assess a resident physician's clinical abilities.

Table 7. "ACGME General Competencies"

1. Patient Care
2. Medical Knowledge
3. Interpersonal and Communication Skills
4. Professionalism
5. Practice-based Learning and Improvement
6. Systems-based Practice

EPAs are different in that they are "observable and measurable units of work…and, as such, align the assessment process with what learners actually do and what faculty observe in the workplace. Table 8 lists major differences between competency and EPA. EPAs, however, were not designed to replace competencies. Rather, the two interconnect and successful completion of an EPA requires fulfillment of multiple competency domains[4].

Table 8. "Key distinctions between competencies and EPAs"[39]

Competency	**EPA**
Person descriptors	Work descriptors
Unit of assessment is the ability of the individual	Unit of assessment is the outcome of the activity

Context-independent, making assessment difficult	Embedded in a clinical context, making assessment meaningful
Addresses the knowledge, skills, and attitudes of a specific task	Addresses the knowledge, skills, and attitudes of competencies that need to be integrated for care delivery

In a curriculum based on EPAs, increasing levels of "trust" in trainee autonomy are established by 5 levels of supervision, as shown in Table 9. Mastery beyond Level 3 represents a threshold to allow for entrustment of the particular activity to the trainee.

Table 9. "Five levels of supervision and the equivalent entrustment scale"[44]

Graded supervision allows for…	**Entrustment Scale**
1. Observing the activity	Not ready for entrustment
2. Acting with direct supervision present in the room	Ready for direct supervision
3. Acting with supervision available within minutes	Ready for indirect supervision
4. Acting unsupervised (i.e., under clinical oversight)	Ready for "unsupervised" practice
5. Providing supervision to juniors	Ready to supervise

The concept of EPA was initially developed to remodel the competency-based postgraduate medical education, but is now more widely applied in health professions education, including PA education[43], as well as in the workplace[40]. Mulder et al developed and implemented an EPA based training curriculum for PAs at University Medical Center Utrecht. The study developed an individualized EPA for each PA trainee, based on a standard design (Table 10).

Table 10. EPA design

a. Title
b. Description
c. Link with the competency framework
d. Required knowledge, skills and attitudes
e. Information sources to assess progress
f. Conditions for level 4 supervision
g. Method to arrive at a justified entrustment decision for this EPA

Throughout the training period, trainees maintained a progress portfolio in which they documented their progress by collecting observation and feedback forms, test results and reflections. Once a supervisor and 2 other physicians conclude that these documents in the portfolio were adequate for mastery of level 4 of a specific EPA, the trainees were given a statement of awarded responsibility (STAR). Once the trainee obtains a STAR for an EPA, he/she is deemed qualified to perform the activity with "only background supervision"[43]. Figure 3 organizes the progression into 3 steps.

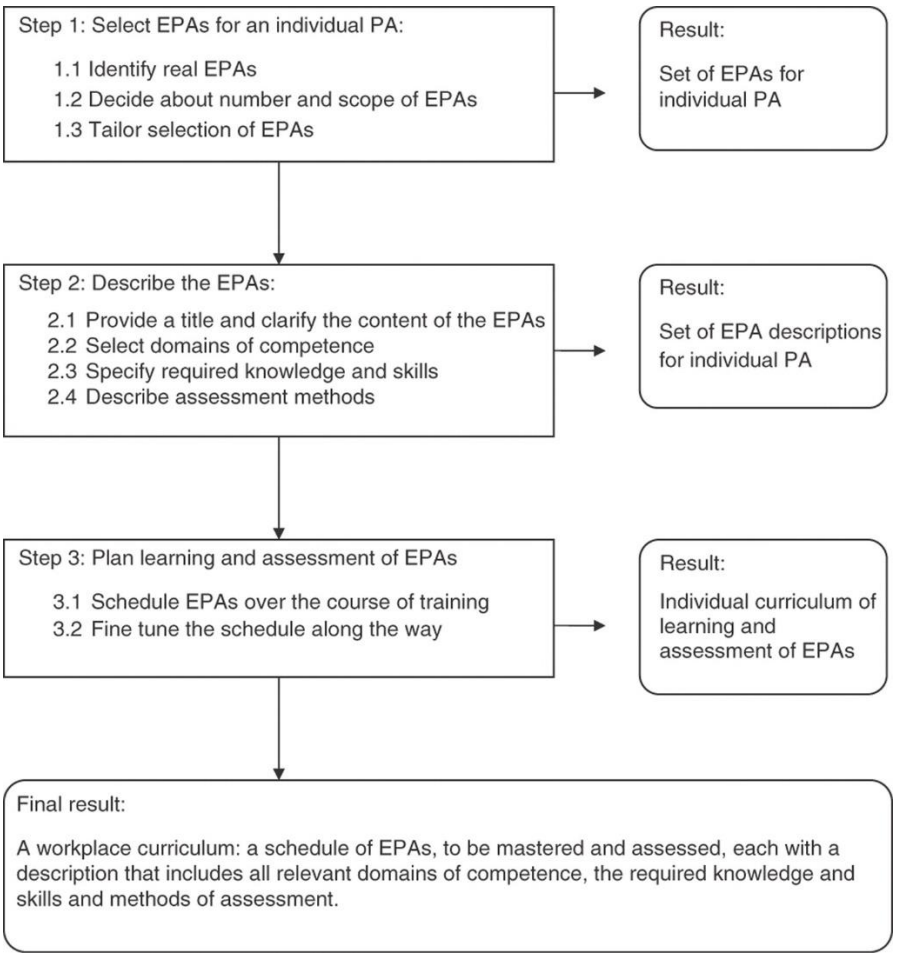

Figure 3. "Building an individual workplace curriculum around EPAs"[43].

A collection of these STARs formed an attainments portfolio, which would reflect the medical capabilities of the PA. This would be especially helpful for a new employer, as it can serve to align the expectations of both the PA and the employer. It could also serve as a model structure in developing new curricula for expansion of PA roles in medicine beyond its current scope of practice.

Currently, there is no established curriculum to train PA's in echocardiography. This study seeks to develop an EPA-based pilot curriculum for training cardiology PAs in performing and interpreting echocardiography.

METHODS

Study design

This study proposes a pilot curriculum with framework based on the EPA of "performing and interpreting echocardiography" by PAs. The curriculum involves didactic and clinical training in echocardiography, with the goal to achieve mastery of level 4 supervision (perform and interpret echocardiograms with minimal supervision).

The following EPA was created for this study, based on the format developed by ten Cate[44] (Table 11).

Table 11. Proposed EPA for PA training in echocardiography

a. Title	Performing and interpreting echocardiography
b. Description	Subject: This EPA applies to PAs working in cardiology. Skills: PAs will perform and interpret echocardiography, report results to the health care team and patients in oral and written forms. Context: ambulatory and inpatient setting. Limitations: to be determined by supervisor.
c. Link with competency framework:	x Patient Care x Medical Knowledge x Interpersonal and Communication Skills x Practice-based Learning
d. Required knowledge, skills and attitudes:	Knowledge: see Table 13 Skills: see Table 14 Attitudes and Behavior: effective translation of clinical information, convey understanding of the clinical condition and prognosis; and deliver this information in a respectful, empathetic, and caring manner to patients, referring physicians and other providers
e. Information sources to assess progress:	Supervisor assessment, online modules, case and participation logs, exam scores
f. Conditions for level 4 supervision:	1) Perform minimum number of echocardiography as listed in table 15 *and* 2) Achieve score $\geq$80% on ASCeXAM simulation exam offered by ASE

g. Method to arrive at a justified entrustment decision for this EPA	1) Didactics: online self-learning modules, conferences, journal clubs, clinical case conferences, and lectures developed/prepared by level III physicians 2) Hands-on clinical training with level II/III physicians and sonographers

Study population and sampling

2 subjects will be recruited from a teaching medical institution in the Greater Boston area with an IAC accredited echocardiography laboratory, with at least 1 medical staff with COCATS level III willing to devote time to training the PA subjects. Subjects must have current PA license issued by the state of Massachusetts and have experience of working in cardiology for 2 years or more (Table 12).

Table 12. Inclusion Criteria of study subjects and participating laboratory

Study Subject	**Participating Laboratory**
PA-C, licensed to work in MA	IAC accredited
2 years of experience working in cardiology/cardiovascular medicine	Affiliated with a teaching hospital

Education Curriculum

The pilot curriculum will consist of didactic lessons and hands-on training in transthoracic echocardiography. Participants will devote a minimum of 8 working hours per week to the training. The goal is to achieve mastery of level 4 in performance and interpretation of echocardiogram.

Didactic sessions

Didactics will consist of online self-learning modules, conferences, journal clubs, clinical case conferences, and lectures developed/prepared by level III physicians at the echocardiography laboratory. Online modules include ACC online learning modules, 2016 ASCeXAM Review course by ASE.

Topics listed in tables 13 and 14 are based on competency guidelines by ACC/AHA clinical competence statement on echocardiography[38]. Didactic sessions must include the listed topics.

Table 13. "Basic Cognitive Skills Required for Competence in echocardiography"

Knowledge of physical principles of echocardiographic image
Knowledge of instrument settings required to obtain an optimal image
Knowledge of normal cardiac anatomy
Knowledge of pathologic changes sin cardiac anatomy due to acquired and CHD
Knowledge of fluid dynamics of normal blood flow
Knowledge of pathological changes in blood flow due to acquired heart disease and CHD
Knowledge of appropriate indications for echocardiography
Knowledge of the differential diagnostic problem in each case and the echocardiographic techniques required to investigate these possibilities
Knowledge of appropriate transducer manipulation
Knowledge of cardiac auscultation and electrocardiography for correlation with results of the echocardiogram
Ability to distinguish an adequate from an inadequate echocardiographic examination
Knowledge of appropriate semi-quantitative and quantitative measurement techniques and ability to distinguish adequate form inadequate quantitation
Ability to communicate results of the examination to the patient, medical record, and other physicians
Knowledge of alternatives to echocardiography

Table 14. "Patient care and procedural skills in echocardiography"

Skill to perform and interpret a basic transthoracic echocardiographic examination.

Skill to perform and interpret a comprehensive transthoracic echocardiographic examination.
Skill to perform and interpret a comprehensive transesophageal echocardiographic examination.
Skill to recognize pathophysiology, quantify severity of disease, identify associated findings, and recognize artifacts in echocardiography.
Skill to integrate echocardiographic findings with clinical and other testing results in the evaluation and management of patients.
Skill to interpret stress echocardiography.
Skill to incorporate stress hemodynamic information in the management of complex valve disease or hypertrophic cardiomyopathy.
Skill to utilize echocardiographic techniques during cardiac interventions, including intraoperative transesophageal echocardiography.
Skill to perform and interpret basic 3-dimensional echocardiography.
Skill to utilize advanced 3-dimensional echocardiography during guidance of procedures and/or surgery.
Skill to perform and interpret contrast echocardiographic studies.

Hands-on clinical training

Participants will work with sonographers and level II/III physicians at the echocardiography laboratory to learn echocardiographic image acquisition, image interpretation, and clinical Integration. Minimum number of cases to be completed during the training are listed in table 15.

Table 15. Trainig requirements for performance and interpretation of adult TTE

Cumulative duration of training	Minimum total number of examinations performed	Minimum number of examinations interpreted
12 months	150	300

Documentation

Participants will maintain a log of completion of lectures, online modules, and echocardiograms performed and interpreted, training observation and feedback forms,

and reflections. The documents will be used by trainers and supervisor to assess progress and mastery of EPA.

Assessment of competency

At the culmination of the 12-month training, participants will take ASCeXAM/ReASCE Online Practice Exam Simulation offered by the ASE and submit score to the supervisor. Upon 1) achievement of individualized EPAs as assessed by supervisor, and 2) a simulation exam score of >80% (pass rates are from the 2016 examinations administrations published by NBE), participants will earn a STAR in echocardiography. STAR is to be signed by the supervisor and 2 other committed physicians who can attests to the competency of the PA participants in echocardiography.

Recruitment

A flyer with description of the study will be distributed to IAC accredited echocardiography laboratories at teaching hospitals in the Greater Boston area. Participants who meet the inclusion criteria in table 12 and have the written support of laboratory director and a minimum of 2 committed teaching/medical staff at the laboratory will be selected for the study.

Timeline and resources

Timeline

Recruitment of participants will take place over a period of 6 months. Training duration will be set at 12 months. Minimum of 8 hours of work schedule per week will be devoted to the training, but individual progress will differ according to each participant's established EPA and periodical assessments. At the culmination of the 12-month training, participants will take ASCeXAM/ReASCE Online Practice Exam Simulation offered by the ASE and submit score to the supervisor.

Key personnel

The proposed training curriculum requires collaboration of an entire echocardiography laboratory team, including not only the PA participants, but also the laboratory director, teaching physicians, as well as sonographers, who will be involved in teaching and training.

Facilities/Equipment

Training will take place at an echocardiography laboratory at a teaching hospital and will require access to the following equipment: hand-held echocardiography device, multimodality echocardiography device with M-mode, 2-D, and Doppler imaging capabilities, computer. Additional equipment and/or technologies may be used for training, as the teaching physician deems necessary.

Budget

ACC membership to access learning and self-assessment modules - $135

2016 ASCeXAM Review course by ASE - $525

ASCeXAM/ReASCE Online Practice Exam Simulation - $250

Institutional Review Board

The study will be submitted for review to the Boston University Medical Campus IRB for exemption for educational studies under 45 CFR 46.101 (b) criteria.

CONCLUSION

Discussion

Education and training guidelines for resident physicians and fellows learning specific tasks in medical specialties have long been well-established[48]. An example is the COCATS 4 Task Force 5 guidelines and the ACC/AHA Clinical Competency Statement on Echocardiography.

However, no such guidelines exist for PAs in the workforce. According to a study by Polansky, PAs are "expected to use a model of lifelong learning to expand and enhance their generalist competencies, but there has been no prior investigation to determine the means by which PAs learn in the workplace"[45]. Also, no standards for postgraduate education and training have been established. Without clear guidelines on training PAs in the workplace, PA scope of practice and training methods can vary dramatically depending on the learning environment that the supervising physician or the medical institution promotes. This would be especially true for PAs working in medical specialties, and "opportunities to develop competencies related to specialty practice are limited[45]."

The goal of this study is to develop and implement an innovative curriculum that can be the basis of standard training for PAs in echocardiography and ultimately become part of a portfolio of EPAs of a cardiology PA. With successful implementation, the format of this curriculum may be expanded in training PAs for various skill sets in other medical specialties.

It is notable that this study comes shortly after AAMC has published new guidelines in May 2014 to provide expectations for both learners and teachers that include 13 activities that all medical students should be able to perform upon entering residency. Currently, 10 pilot institutions have implemented the new guidelines. If the curriculum from this study is deemed applicable to a wider market of PAs, PA postgraduate education can also benefit during this time of great change in medical education.

In this study, only PAs with work experience of 2 or more years in cardiology/cardiovascular medicine were recruited. According to a study by Polansky, it typically takes 1 to 2 years to feel "ready to practice" after graduating from PA school[45]. It was deemed important for the study participants to have a well-established grasp of medical knowledge and clinical experience in cardiology before moving onto training in a new and more advanced skill set like echocardiography.

There are some limitations to this study. Since the curriculum was designed for 12 consecutive months of training PAs during their working schedule and the training collaboration of the entire echocardiography laboratory, it may be difficult to recruit willing participants who have the support of their peers, supervisors and training staff. Thus, the sample size was limited to 2 PAs. Although the sample size is too small for significant data analysis, implementation of a pilot program at one site certainly can give rise to expanded adoptions at other institutions. It is also notable that the Arizona Joint Board of Medical Examiners authorized selected PAs to interpret mammograms after reviewing Hillman's study, which involved training of only 4 PAs[14].

It is unclear whether echocardiography laboratories and their medical staff would be willing to devote time and effort to this long-term project. Thus, one of the inclusion criteria for the study is that it recruits a teaching institution, where a fellow training program in echocardiography has likely been established, so that there is some structure and experience with training new learners. Physicians and sonographers may be opposed to the idea of allowing PAs to perform and interpret echocardiography, as they may see it as a competition to their field of expertise. However, PA involvement in echocardiography may actually increase income, much as technologists reading Pap smears has for pathologists[14].

Another limitation of the study is that the PA trainees are to devote a minimum of 8 hours per week to the curriculum, rather than training full-time solely focused on echocardiography. Finding 8 hours to devote to a new curriculum in the midst of performing other clinical duties may be difficult, depending on the patient volume and workload. Also, the time gap between successive trainings each week may deter effective flow in learning. However, it would be nearly impossible to find employers who would excuse their PAs out of clinical duties to devote full-time to training in a new concept. Since the study sets only a minimum number of training hours each week, participants can allot as much time to training echocardiography during slow seasons or downtimes.

The strength of this study is the flexibility of the curriculum. The study provides a general structure of a pilot curriculum, and its details can be modified to fit the needs of each trainee, institution, and medical specialty. Also, EPA based curricula for training PAs in workplace has already been tested in the study by the Dutch medical community,

which concluded that building a competency-based clinical workplace curriculum on EPAs is a "feasible, inspiring and promising process[43]."

This study is generalizable, as it can serve as model after which different EPAs and corresponding curricula can be designed to train PAs in the workplace. But first, the curriculum must be implemented at different sites and data gathered on the strengths and weaknesses of the program. Collected data must be analyzed and exchanged between pilot institutions, so that the curriculum can undergo continual improvement before it is applied to a wider array of institutions and medical specialties. This process follows the Learning Collaborative Model, developed by AAMC for the pilot institutions implementing the 13 core EPAS for entering residency (Fig 4).

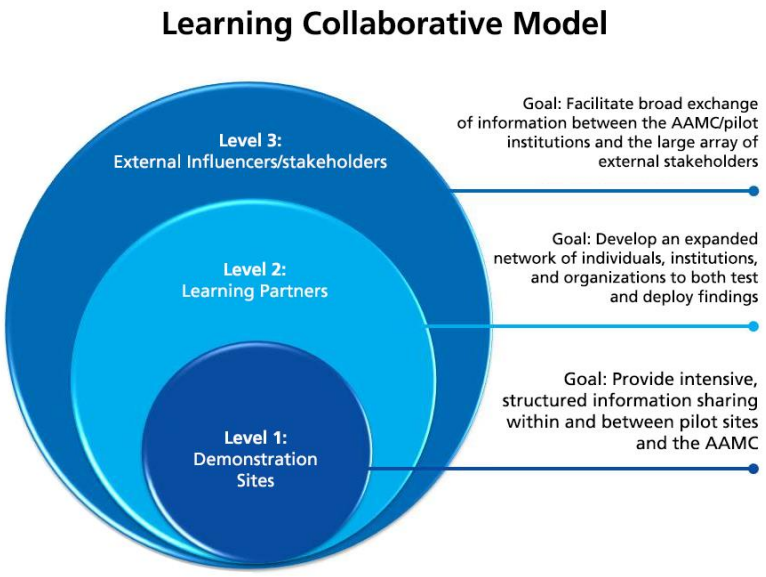

Figure 4. "Learning collaborative model for core EPAs for entering residency"

Summary

According to the workforce analysis report, released in December 2016 by the US Department of Health and Human Services, greatest physician shortage among internal medicine subspecialties is projected to be in cardiology by year 2025 (7080 FTEs)[46]. Interestingly, one of the greatest surpluses of PAs working in internal medicine subspecialties is expected to be in cardiology (2000 FTEs)[46]. Expansion of opportunities for PAs to learn echocardiography and other skill sets could lead to more balanced distribution of clinical responsibilities among cardiologists and PAs.

It would also be cost effective, as PA salary is substantially lower than that of a physician[49]. "Shared work" between physician and PA is reimbursed 100% by Medicare. In performing and interpreting echocardiography, a PA would always work with a level II/III physician and not release reports independently. The Arizona Joint Board of Medical Examiners authorized the PAs cited in Hillman's study to interpret mammograms with the following provisos: (1) the PAs must work under the supervision of the HMO's radiology department; (2) all cases that are interpreted as positive, or about which the PA is uncertain, must be referred to a radiologist for interpretation before further evaluation; (3) no less than 5% of each month's cases must be randomly selected for overreading by radiologists as a continuing quality control[14]. Similar conditions may be applied to legislature allowing PAs to interpret echocardiograms. For example, PAs can release preliminary reports to be overread by physicians, who would then release the final report.

As this study merely suggests a new curriculum, future studies should focus on identifying strengths and weaknesses of the curriculum after implementation and expansion to multiple sites, and gather data to use for continual improvement of the training curriculum.

Clinical and/or public health significance

The study is the first step to establishing an effective training curriculum that will eventually be a basis for creating a certifying exam in echocardiography, designed specifically for PAs. Furthermore, regulatory laws would allow for inclusion of echocardiography within PA scope of practice. This pilot curriculum, if implemented and expanded, would accomplish the AAPA 2016-2020 strategic plan to "advance the recognition of PA skills… and develop and pursue legal strategies to expand and protect PA practice."[47]

The general structure of this curriculum can be applied to other areas of clinical training and used to create a portfolio of EPAs in which a PA has achieved mastery. This will apply to training new PAs who have just graduated from PA school, as well as PAs moving into a different field of medicine. Attainment portfolios, containing documentation that PAs are able to achieve mastery of new EPAs, can be used as evidence for expansion of scope of practice for PAs, in developing new certifying exams, and modifying legislation to expand and protect PA practice. The hope is that a pathway to recognizing PAs for their demonstrated abilities and potentials for advancement will be laid.

APPENDIX 1

Major studies evaluating the diagnostic accuracy and utility of echocardiography performed using pocket-sized imaging devices[35]

Study	**n**	**Study population/ setting**	**POC setup** (device; personnel)	**Reference standard**	**Salient findings**
Prinz et al.30	349	Consecutive patients referred for echocardiography at a tertiary hospital	Vscan; experienced cardiologist	Complete study performed on high-end echocardiography equipment	Excellent concordance for majority of the abnormalities<comma> including LV dimensions<comma> LV systolic function<comma> valve lesions<comma> etc.
Choi et al.35	89	A humanitarian mission in a remote community	Vscan; nonexpert cardiology fellow	Same images reviewed by the expert echocardiographers on a workstation and on a smart phone	The on-site diagnosis was altered by the expert interpreter in 38% cases; excellent concordance between workstation-based and smart phone–based interpretation by the same expert
Galderisi et al.31	304	Endocrinology and oncology patients referred for cardiac consultations; patients with known cardiac illnesses were excluded	Vscan; 102 scans by experts and 202 by trainees	Complete study performed on high-end echocardiographic equipment	Overall κ value between pocket-sized device and standard examination = 0.67 (0.84 for experts<comma> 0.58 for trainees)
Testuz et al.38	104	Patients requiring urgent echocardiogram at a tertiary hospital	Vscan; experienced cardiologist	Complete study performed on high-end echocardiographic equipment	Excellent agreement (κ > 0.8) for LV systolic function and pericardial effusion<comma> good or modest agreement (κ > 0.55) for valve lesions (all lesions were semiquantitatively scored)
Cardim et al.28	189	Patients referred for cardiac outpatient consultations	Vscan; experienced cardiologists	None	Addition of POC imaging significantly improved diagnostic accuracy and reduced unnecessary echocardiographic referrals
Andersen et al.32	108	Patients admitted to medical department at a tertiary care hospital	Vscan; experienced cardiologists	Complete study performed on high-end echocardiography equipment	Excellent concordance for majority of the abnormalities including LV systolic function<comma> right ventricular function<comma> pericardial effusion<comma> valve lesions<comma> etc.
Skjetne et al.29	119	Patients admitted to a cardiac unit at a tertiary care hospital	Vscan; experienced cardiologists	Complete study performed on high-end echocardiography equipment	Excellent concordance for majority of the abnormalities; addition of POC imaging to bedside clinical examination significantly improved diagnostic accuracy
Lafitte et al.33	100	Patients referred for echocardiography for conventional clinical indications	Vscan; experienced physician blinded to results of standard examination	Complete study performed on a high-end echocardiographic system	Excellent concordance for majority of the abnormalities
Liebo et al.36	97	Patients referred for echocardiography for	Vscan; images interpreted by two	Complete study performed on a high-	Accuracy varied according to the type of the abnormality

		conventional clinical indications	experienced echocardiographers and two cardiology fellows	end echocardiographic system	and the level of experience; overall<comma> accuracy was highest for LV systolic function
Michalski et al.37	220	Consecutive patients undergoing echocardiography (110 inpatient<comma> 110 outpatient)	Vscan; a cardiology resident (second year of training) and an experienced cardiologist	Complete study performed on a high-end echocardiographic system	Concordance for most abnormalities was moderate to very good for the resident and good to excellent for the experienced cardiologist
Biais et al.34	151	Patients admitted to the emergency department and requiring echocardiography	Vscan; experienced echocardiographer	Complete study performed on a high-end echocardiographic system	Excellent concordance ($\kappa >$ 0.8) for most parameters
Prinz et al.39	320	Consecutive patients referred for echocardiography at a tertiary hospital	Vscan; inexperienced echocardiographer	Complete study performed on a high-end echocardiographic system	Image quality and diagnostic accuracy showed significant improvement over the 8-week period over which patients were recruited
Fukuda et al.40	125	Patients undergoing echocardiography for various indications	Acuson P10; experienced echocardiographer	Complete study performed on a high-end echocardiographic system	Excellent correlation and agreement for cardiac chamber size and function
Mjolstad et al.27	196	Patients admitted to medical department at a tertiary care hospital	Vscan; experienced cardiologists	Complete study performed on a high-end echocardiographic equipment	Excellent concordance for majority of the abnormalities; addition of POC imaging to bedside clinical examination significantly improved diagnostic accuracy
Panoulas et al.41	122	Cardiology patients	Vscan; inexperienced echocardiographers	Complete study performed on high-end echocardiographic equipment	Addition of POC imaging significantly improved diagnostic accuracy

APPENDIX 2

Core Competency Components and Curricular Milestones for Training in Echocardiography[3]

Competency Component		Milestones (Months)			
MEDICAL KNOWLEDGE		**12**	**24**	**36**	**Add**
1	Know the physical principles of ultrasound and the instrumentation used to obtain images.	I			
2	Know the appropriate indications, including the appropriate use criteria, for: M-mode, 2-dimensional, and 3-dimensional transthoracic echocardiography; Doppler echocardiography and color-flow imaging; transesophageal echocardiography; tissue Doppler and strain imaging; and contrast echocardiography.		I		
3	Know the limitations and potential artifacts of the echocardiographic examination.	I			
4	Know the standard views included in a comprehensive transthoracic echocardiogram.	I			
5	Know the standard views included in a comprehensive transesophageal echocardiogram.		I		
6	Know the techniques to quantify cardiac chamber sizes and evaluate left and right ventricular systolic and diastolic function and hemodynamics.			II	
7	Know the characteristic findings of cardiomyopathies.		I		
8	Know the use of echocardiographic and Doppler data to evaluate native and prosthetic valve function and diseases.			II	
9	Know the echocardiographic and Doppler findings of cardiac ischemia and infarction, and the complications of myocardial infarction.		I		
10	Know the echocardiographic findings of pericardial disease, pericardial effusion, and pericardial constriction.		II		
11	Know the characteristic findings of basic adult congenital heart disease.			II	
12	Know the findings of complex/postoperative adult congenital heart disease.			III∗†	III∗
13	Know the techniques to evaluate cardiac masses and suspected endocarditis.		II		
14	Know the techniques to evaluate diseases of the aorta.		II		
15	Know the techniques to assess pulmonary artery pressure and diseases of the right heart.		II		
16	Know the use and characteristic findings in the evaluation of patients with systemic diseases involving the heart.		II		
17	Know the indications for, and the echocardiographic findings in, patients with known or suspected cardioembolic events.		II		
18	Know key aspects of contrast echocardiography including interpretation, administration techniques, and safety information.			II	
19	Understand the principles and applications of 3-dimensional echocardiography.		II		
20	Recognize and treat the potential complications of stress, contrast, and transesophageal echocardiography.		II		
	EVALUATION TOOLS: conference presentation, direct observation, and in-training examination.				
PATIENT CARE AND PROCEDURAL SKILLS		**12**	**24**	**36**	**Add**
1	Skill to perform and interpret a basic transthoracic echocardiographic examination.		I		
2	Skill to perform and interpret a comprehensive transthoracic echocardiographic examination.			II	
3	Skill to perform and interpret a comprehensive transesophageal echocardiographic examination.			II	
4	Skill to recognize pathophysiology, quantify severity of disease, identify associated findings, and recognize artifacts in echocardiography.			II	

5	Skill to integrate echocardiographic findings with clinical and other testing results in the evaluation and management of patients.		I		
6	Skill to interpret stress echocardiography.			II	
7	Skill to incorporate stress hemodynamic information in the management of complex valve disease or hypertrophic cardiomyopathy.			II	
8	Skill to utilize echocardiographic techniques during cardiac interventions, including intraoperative transesophageal echocardiography.			III†	III
9	Skill to perform and interpret basic 3-dimensional echocardiography.			II	
10	Skill to utilize advanced 3-dimensional echocardiography during guidance of procedures and/or surgery.			III†	III
11	Skill to perform and interpret contrast echocardiographic studies.			II	
	EVALUATION TOOLS: direct observation, logbook, and simulation.				
SYSTEMS-BASED PRACTICE		12	24	36	Add
1	Work effectively and efficiently with the echocardiography laboratory staff.	I			
2	Incorporate risk/benefit, safety, and cost considerations in the use of ultrasound techniques.			I	
3	Participate in echocardiographic quality monitoring and initiatives.			II	
	EVALUATION TOOLS: direct observation and multisource evaluation.				
PRACTICE-BASED LEARNING AND IMPROVEMENT		12	24	36	Add
1	Identify knowledge and performance gaps and engage in opportunities to achieve focused education and performance improvement.		I		
	EVALUATION TOOLS: conference presentation and direct observation.				
PROFESSIONALISM		12	24	36	Add
1	Know and promote adherence to guidelines and appropriate use criteria.		I		
2	Interact respectfully with patients, families, and all members of the healthcare team, including ancillary and support staff.	I			
	EVALUATION TOOLS: conference presentation, direct observation, multisource evaluation, and reflection and self-assessment.				
INTERPRESONAL AND COMMUNICATION SKILLS		12	24	36	Add
1	Communicate with and educate patients and families across a broad range of cultural, ethnic, and socioeconomic backgrounds.		II		
2	Communicate testing results to physicians and patients in an effective and timely manner.		II		
3	Communicate detailed information on cardiac anatomy for surgical planning or guidance of interventional procedures.			II	
	EVALUATION TOOLS: direct observation and multisource evaluation.				

APPENDIX 3

Requirements for Cardiac Sonographer examination by CCI

Qualification Prerequisite (All applicants must fulfill one of the following)	Supporting Documentation
RCS1-2013 Two years of full-time or full-time equivalent work experience in cardiac ultrasound. The applicant must have participated in a minimum of 600* cardiac ultrasound studies at the time of application. In the verification letter, the medical director(s) must confirm the number of studies performed during the applicant's employment.	**RCS1-2013** Employment Verification Letter (must confirm the number of studies performed during the applicant's employment).
RCS235-2013 A graduate of a diploma, associate, or baccalaureate academic program in health science (including, but not limited to, cardiovascular technology, ultrasound, radiologic technology, respiratory therapy, or nursing) **AND** One year full-time or full-time equivalent work experience in cardiac ultrasound (echocardiography) **AND** Performance of a minimum of 600* cardiac ultrasound studies in their career, which is defined as work experience and/or clinical experience gained during a formal educational program. In the verification letter(s) the medical director(s) and/or program director(s) must confirm the number of studies performed during the applicant's employment and/or during the academic program.	**RCS235-2013** Completion certificate and/or educational transcript **AND** Employment Verification Letter **AND** Clinical Experience Letter (only required for applicants submitting verification of the number of studies completed during a formal educational program)
RCS4 Applicant must be a graduate of a programmatically accredited program** in cardiac ultrasound (echocardiography).	**RCS4** Completion certificate and/or educational transcript **AND** Student Verification Letter
RCS5 A graduate of a NON-programmatically accredited program in cardiac ultrasound (echocardiography) which has a minimum of one year of specialty training and includes a minimum of 800 clinical hours in the specialty in which the examination is being requested.	**RCS5** Completion certificate and/or educational transcript **AND** Student Verification Letter **AND** Clinical Experience Letter
RCS6 Active ultrasound credential holder with six (6) months of full-time or full-time equivalent work experience in cardiac ultrasound. The applicant must have participated in a minimum of 100 cardiac ultrasound studies* at the time of application. In the verification letter, the medical director(s) and/or clinical supervisor must confirm the number of studies performed during the applicant's employment and/or during the academic program.	**RCS6** Copy of wallet card showing date earned and active through date of ultrasound registry credential **AND** Employment Verification Letter (must confirm the number of studies performed during the applicant's employment). **AND/OR** Clinical Experience Letter (only required for applicants submitting verification of the number of studies completed during a formal educational program)

Source: http://cci-online.org/sites/default/files/2015%20ACS%20App%20Book-FINAL_0.pdf

APPENDIX 4.

Qualification requirements for Advanced Cardiac Sonographer Examination by CCI

Qualification Requirements

All applicants must meet the following criteria:

1. Have a high school diploma or general education diploma at the time of application.
2. Fulfill one (1) of the qualifications of the exam for which you are applying. See qualifications listed in the table below.
3. Provide typed documentation to support the qualification under which you are applying. Required documentation for each qualification is listed below. CCI reserves the right to request additional information.

Qualification Prerequisite	Supporting Documentation *(See examples on page 6)*
ACS1 A graduate of an Advanced Cardiac Sonography educational program which has been accredited by the Committee on Accreditation for Advanced Cardiovascular Sonography (COA-ACS)*	**ACS1** A copy of a graduate certificate **AND** Student verification letter from the Advanced Cardiac Sonography educational program director.
ACS2 A graduate of a programmatically accredited program in cardiac ultrasound/ echocardiography.* **AND** Hold an active echocardiography registry credential (includes but not limited to RCS, RCCS, or RDCS) **AND** Seven (7) years of cardiac ultrasound clinical experience as a registered cardiac sonographer. It is anticipated, but not required, that the applicant have performed a minimum of 8000 echocardiograms in their career which is defined as work experience and/or formal clinical education program.	**ACS2** A copy of a graduate certificate from the programmatically accredited educational program. **AND** Copy of wallet card showing date earned and active through date of registry credential (RCS, RCCS or RDCS) **AND** Employment verification letter which indicates time period of employment and primary duties of applicant, and clinical competence related to the field of cardiac ultrasound.
ACS3 A graduate of a diploma, associate, or baccalaureate academic program in health science (including, but not limited to, cardiovascular technology, ultrasound, radiologic technology, respiratory therapy, or nursing) **AND** Hold an active echocardiography registry credential (includes but not limited to RCS, RCCS, or RDCS) **AND** Eight (8) years of cardiac ultrasound clinical experience as a registered cardiac sonographer. It is anticipated, but not required, that the applicant have performed a minimum of 8000 echocardiograms in their career which is defined as work experience and/or formal clinical education program.	**ACS3** A copy of a graduate certificate **AND** Copy of wallet card showing date earned and active through date of registry credential (RCS, RCCS or RDCS) **AND** Employment verification letter which indicates time period of employment and primary duties of applicant, and clinical competence related to the field of cardiac ultrasound.
ACS4 Hold an active echocardiography registry credential (includes but not limited to RCS, RCCS, or RDCS) **AND** Ten (10) years of cardiac ultrasound clinical experience as a registered cardiac sonographer. It is anticipated, but not required, that the applicant have performed a minimum of 8000 echocardiograms in their career which is defined as work experience and/or formal clinical education program.	**ACS4** Copy of wallet card showing date earned and active through date of registry credential (RCS, RCCS, or RDCS) **AND** Employment verification letter which indicates time period of employment and primary duties of applicant, and clinical competence related to the field of cardiac ultrasound.

Source: http://cci-online.org/sites/default/files/2015%20ACS%20App%20Book-FINAL_0.pdf

APPENDIX 5

Requirements for Fellow of the American Society of Echocardiography[17]

PHYSICIANS	SCIENTISTS	ALLIED HEALTH PROFESSIONALS
TARGET: 12 Total Points SECTION 1 Fulfilled and 6-10 points for board/subspecialty certification; plus 2-6 Points from at least two (2) professional activities categories (education, research, leadership/ volunteerism) To total a minimum of 12 points	**TARGET: 12 Total Points** SECTION 1 Fulfilled and 2 points from at least two (2) professional activities categories (education, research, leadership/ volunteerism) To total a minimum of 12 points	**TARGET: 12 Total Points** SECTION 1 Fulfilled and 2 points from at least two (2) professional activities categories (education, research, leadership/ volunteerism) To total a minimum of 12 points

SECTION 1. Standardized Requirements for all FASE applicants.

If you do not meet all of the criteria in Section 1, you are not eligible to apply for FASE at this time.

PHYSICIANS 0 Points	SCIENTISTS 10 Points	ALLIED HEALTH PROFESSIONALS 10 Points
☐ Medical License in good standing (active without limitations/ restrictions)	☐ Holds a PhD degree (cannot hold an active medical license)	☐ License in good standing (active without limitations/ restrictions) should your state or country require this for practice (OR, NM, etc.) Please leave blank if not applicable.
☐ ASE Early Career or Professional Physician/Scientist Membership for current and previous year (membership verified by ASE staff)	☐ ASE Professional Physician/ Scientist Membership for current and previous year (membership verified by ASE staff)	☐ ASE Allied Health Professional Membership for current and previous year (membership verified by ASE staff)
☐ Proof of Specialty Board certification		☐ Proof of current credentials maintained for the previous 5 years by a verifiable credentialing body.

PHYSICIANS 0 Points	SCIENTISTS 10 Points	ALLIED HEALTH PROFESSIONALS 10 Points
☐ Proof of subspecialty board certification in cardiovascular ultrasound (Diplomate or Testamur status [NBE]; verifiable international certification; RPVI credentialed in vascular ultrasound [ARDMS]) Refer to Section 2. Note: *If there are no current certification examinations directed towards your subspecialty (e.g. Pediatric Cardiologists) or the above do not fit within your subspecialty, proof of Board certification may suffice*		
☐ Verification (certificate/transcripts) of completion of 25 CME hours specific to cardiovascular ultrasound in the three (3) years preceding submission of the application.		☐ Verification (certificate/transcripts) of completion of 15 CME hours specific to cardiovascular ultrasound in the three (3) years preceding submission of the application.
☐ Three (3) supporting letters (see page 8 for list of acceptable sources) that reflect that TWO of the FASE categories are fulfilled (education, research, leadership/volunteerism). Supporting letters and curriculum will be assessed by verifiable participation in TWO or more of the three professional activities listed in Section 3. within the past five years.	☐ Three (3) supporting letters (see page 8 for list of acceptable sources) that reflect that TWO of the FASE categories are fulfilled (education, research, leadership/volunteerism). Supporting letters and curriculum will be assessed by verifiable participation in TWO or more of the three professional activities listed in Section 3. within the past five years.	☐ Three (3) supporting letters (see page 8 for list of acceptable sources) that reflect that TWO of the FASE categories are fulfilled (education, research, leadership/volunteerism). Supporting letters and curriculum will be assessed by verifiable participation in TWO or more of the three professional activities listed in Section 3. within the past five years.
☐ Up to date curriculum vitae (reflective of activities within one year of application)	☐ Up to date curriculum vitae (reflective of activities within one year of application)	☐ Up to date curriculum vitae or resume (reflective of activities within one year of application)
☐ Completed checklist that illustrates specific examples of how applicant meets the FASE criteria.	☐ Completed checklist that illustrates specific examples of how applicant meets the FASE criteria.	☐ Completed checklist that illustrates specific examples of how applicant meets the FASE criteria.
STANDARDIZED POINTS - 0	STANDARDIZED POINTS - 10	STANDARDIZED POINTS - 10
	SECTION 1. STANDARDIZED REQUIREMENTS POINT VALUE	

☐ EDUCATION - (points are not cumulative; the highest score in this category will be applied toward total points*) Commitment to education in cardiovascular ultrasound as demonstrated on a regular basis by teaching. In order to fulfill this category, active, ongoing participation in education of students, residents, fellows, other healthcare providers and/or allied health professions is required. (activities must be ongoing and have occurred within the past 5 years)	No. of Points
☐ Cardiovascular ultrasound education at own institution (regular training, internal lectures, curriculum development)	1
☐ Cardiovascular ultrasound education at local/regional meetings, serving as faculty (at least 3 times within the last 5 years)	2
☐ Cardiovascular ultrasound education at national/international meetings, serving as faculty (at least 3 times within the past 5 years)	3
SECTION 3. EDUCATION (RECORD HIGHEST SINGLE POINT VALUE)	

☐ RESEARCH - (points are not cumulative; the highest score in this category will be applied to total points*) Scientific publications in topics related to cardiovascular ultrasound. In order to fulfill this category, participation in the research must have occurred within the last 5 years. For physicians, authorship in at least one publication is required where you have served as an author on scientific publications in a peer-reviewed journal in topics related to cardiovascular ultrasound. Publication of abstracts or case reports alone do not fulfill this criteria. For allied health professionals, active participation in the research is required (authorship is not required but encouraged).	No. of Points
☐ Participant in cardiovascular ultrasound related research (including abstracts), but not necessarily the author, *(non-physicians only)*	1
☐ Middle author on peer reviewed scientific publication(s) in which topics are cardiovascular ultrasound related.	1
☐ Senior or first author of section of a text book on a topic specific to cardiovascular ultrasound	2
☐ Senior or first author on peer reviewed scientific publication(s) in which topics are cardiovascular ultrasound related.	3
SECTION 3. RESEARCH (RECORD HIGHEST SINGLE POINT VALUE)	

☐ LEADERSHIP/VOLUNTEERISM CRITERIA - (points are not cumulative; the highest score in this category will be used*) Active participation (outside of attendance) at ASE sponsored activities or other local/regional/international cardiovascular ultrasound societies. Active participation in other echo-related volunteer activities outside of the applicant's primary employment fulfill this criteria (unpaid, not part of regular employment) Activities must have occurred within the past 5 years.	No. of Points
☐ Volunteer for local/regional/national/international cardiovascular ultrasound society meeting (e.g., organizing, speaking, securing meeting space, securing industry support)	1
☐ Participant in cardiovascular ultrasound outreach or free screening aimed at the public or underserved populations.	2
☐ Volunteer for ASE activities (outreach, abstract review, JASE article reviewer, micro-volunteering, advocacy, etc.)	2
☐ Serving on an ASE committee(s), task force(s), council(s)	2
☐ Serving on an editorial board for a cardiovascular ultrasound journal	2
☐ Serving as an officer for a local/regional/national/international cardiovascular ultrasound organization	3
SECTION 3. LEADERSHIP/VOLUNTEERISM (RECORD HIGHEST SINGLE POINT VALUE)	

LIST OF JOURNAL ABBREVIATIONS

Am J Roentgenol	AJR. American Journal of Roentgenology
Catheter Cardiovasc Interv	Catheterization and Cardiovascular Interventions
Eur J Echocardiogr	European Journal of Echocardiography
J Am Coll Cardiol	Journal of the American College of Cardiology
J Am Heart Assoc	Journal of the American Heart Association
J Am Soc Echocardiogr	Journal of the American Society of Echocardiography
J Diagn Med Sonogr	Journal of Diagnostic Medical Sonography
J Physician Assist Educ	Journal of Physician Assistant Education
J Ultrasound Med	Journal of Ultrasound in Medicine
JAAPA	JAAPA: Official Journal of the American Academy of Physician Assistants
Med Teach	Medical Teacher

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