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Emergency Physicians®

ADVANCING EMERGENCY CARE



POLICY STATEMENT

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Ultrasound Guidelines: Emergency, Point-of-care, and Clinical Ultrasound Guidelines in Medicine

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Section 1 – Introduction

Ultrasound (US) has become an integral modality in emergency care in the United States during the last two decades. Since the last update of these guidelines in 2008, US use has expanded throughout clinical medicine and established itself as a standard in the clinical evaluation of the emergency patient. There is a wide breadth of recognized emergency US applications offering advanced diagnostic and therapeutic capability benefit to patients across the globe. With its low capital, space, energy, and cost of training requirements, US can be brought to the bedside anywhere a clinician can go, directly or remotely. The use of US in emergency care has contributed to improvement in quality and value, specifically in regard to procedural safety, timeliness of care, diagnostic accuracy, and cost reduction. In a medical world full of technological options, US fulfills the concept of “staged imaging,” where the use of US first can answer important clinical questions accurately without the expense, time or side effects of advanced imaging or invasive procedures.

Emergency physicians have taken the leadership role for the establishment and education of bedside, clinical, point-of-care US use by clinicians in the United States and around the world. Ultrasonography has spread throughout all levels of medical education, integrated into medical school curricula through residency to postgraduate education of physicians, and extended to other providers such as nursing, advanced practice professionals, and prehospital providers. US curricula in undergraduate medical education is growing exponentially due to the leadership and advocacy of emergency physicians. US in emergency medicine (EM) residency training has now been codified in the Accreditation Council for Graduate Medical Education (ACGME) Next Accreditation System (NAS). Emergency US specialists have created the foundation of a subspecialty of ultrasonography that provides the expertise for establishing clinical practice, educating across the educational spectrum, and researching the wide range of applications of ultrasonography. Within healthcare institutions and healthcare systems, emergency physicians are now leading institutional clinical US programs that have used this guideline as a format for multidisciplinary programs.

US imaging and information systems have become more sophisticated and digital over the last decade allowing emergency US examinations to have versatility, mobility and integration. US hardware for emergency care has become more modular, smaller, and powerful, ranging from smartphone size to slim, cart-based systems dedicated to the emergency medicine market. US hardware has evolved to allow on-machine reporting, wireless connectivity and electronic medical record (EMR) and picture archiving and communication system (PACS) integration. A new software entity, US management systems, was created to provide administrative functionality and the integration of US images into electronic records. Emergency physician expertise was integral in the development of these hardware and software advances.

These guidelines reflect the evolution and changes in the evolving world of emergency medicine and the growth of US practice. Themes of universality of practice, educational innovation, core credentialing, quality improvement, and value highlight this new edition of the guidelines. The ultimate mission of providing excellent patient care will be enhanced by emergency physicians and other clinicians being empowered with the use of US.

Section 2 -- Scope of Practice

Emergency Ultrasound (EUS) is the medical use of US technology for the bedside evaluation of acute or critical medical conditions.¹ It is utilized for diagnosis of any emergency condition, resuscitation of the acutely ill, critically ill or injured, guidance of procedures, monitoring of certain pathologic states and as an adjunct to therapy. EUS examinations are typically performed, interpreted, and integrated into care by emergency physicians or those under the supervision of emergency physicians in the setting of the emergency department (ED) or a non-ED emergency setting such as hospital unit, out-of-hospital, battlefield, space, urgent care, clinic, or remote or other settings. It may be performed as a single

examination, repeated due to clinical need or deterioration, or used for monitoring of physiologic or pathologic changes.

Emergency US is synonymous with the terms clinical, bedside, point-of-care, focused, and physician performed, but is part of a larger field of clinical ultrasonography. In this document, EUS refers to US performed by emergency physicians or clinicians in the emergency setting, while clinical ultrasonography refers to a multidisciplinary field of US use by clinicians at the point-of-care.² Table 1 summarizes relevant US definitions in EUS.

Other medical specialties may wish to use this document if they perform EUS in the manner described above. However, guidelines which apply to US examinations or procedures performed by consultants, especially consultative imaging in US laboratories or departments, or in a different setting may not be applicable to emergency physicians.

Emergency US is an emergency medicine procedure, and should not be considered in conflict with exclusive “imaging” contracts that may be in place with consultative US practices. In addition, emergency US should be reimbursed as a separate billable procedure.³ (See Section 6- Value and Reimbursement)

EUS is a separate entity distinct from the physical examination that adds anatomic, functional, and physiologic information to the care of the acutely-ill patient.⁴ It provides clinically significant data not obtainable by inspection, palpation, auscultation, or other components of the physical examination.⁵ US used in this clinical context is also not equivalent to use in the training of medical students and other clinicians in training looking to improve their understanding of anatomic and physiologic relationships of organ systems.

EUS can be classified into the following functional clinical categories:

1. *Resuscitative*: US use as directly related to an acute resuscitation
2. *Diagnostic*: US utilized in an emergent diagnostic imaging capacity
3. *Symptom or sign-based*: US used in a clinical pathway based upon the patient’s symptom or sign (eg, shortness of breath)
4. *Procedure guidance*: US used as an aid to guide a procedure
5. *Therapeutic and Monitoring*: US use in therapeutics or in physiological monitoring

Within these broad functional categories of use, 12 core emergency US applications have been identified as Trauma, Pregnancy, Cardiac /Hemodynamic assessment, Abdominal aorta, Airway/Thoracic, Biliary, Urinary Tract, Deep Vein Thrombosis (DVT), Soft-tissue/Musculoskeletal (MSK), Ocular, Bowel, and Procedural Guidance. Evidence for these core applications may be found in Appendix 1. The criteria for inclusion for core are widespread use, significant evidence base, uniqueness in diagnosis or decision-making, importance in primary emergency diagnosis and patient care, or technological advance.

Alternatively, symptom and sign based US pathways, such as Shock or Dyspnea, may be considered an integrated application based on the skills required in the pathway. In such pathways, applications may be mixed and utilized in a format and order that maximizes medical decision-making, outcomes, efficiency and patient safety tailored to the setting, resources, and patient characteristics. See Figure 1.

Emergency physicians should have basic education in US physics, instrumentation procedural guidance, and Focused Assessment with Sonography in Trauma (FAST) as part of EM practice. It is not mandatory that every clinician performing emergency US examinations utilize or be expert in each core application, but it is understood that each core application is incorporated into common emergency US practice nationwide. The descriptions of these examinations may be found in the ACEP policy, Emergency Ultrasound Imaging Criteria Compendium.⁶ Many other US applications or advanced uses of these applications may be used by emergency physicians. Their non-inclusion as a core application does not

diminish their importance in practice nor imply that emergency physicians are unable to use them in daily patient care.

Each EUS application represents a clinical bedside skill that can be of great advantage in a variety of emergency patient care settings. In classifying an emergency US, a single application may appear in more than one category and clinical setting. For example, a focused cardiac US may be utilized to identify a pericardial effusion in the diagnosis of an enlarged heart on chest x-ray. The focused cardiac US may be utilized in a cardiac resuscitation setting to differentiate true pulseless electrical activity from profound hypovolemia. The focused cardiac US can be used to monitor the heart during resuscitation in response to fluids or medications. If the patient is in cardiac tamponade, the cardiac US can also be used to guide the procedure of pericardiocentesis. In addition, the same focused cardiac study can be combined with one or more additional emergency US types, such as the focused abdominal, the focused aortic or the focused chest US, into a clinical algorithm and used to evaluate a presenting symptom complex. Examples of this would be the evaluation of patients with undifferentiated non-traumatic shock or the focused assessment with sonography in trauma (FAST), or extended FAST examination in the patient presenting with traumatic injury. See Figure 1.

Ultrasound guided procedures provide safety to a wide variety of procedures from vascular access (eg, central venous access) to drainage procedures (eg, thoracentesis pericardiocentesis, paracentesis, arthrocentesis) to localization procedures like US guided nerve blocks. These procedures may provide additional benefits by increasing patient safety and treating pain without the side-effects of systemic opiates.

Other US applications are performed by emergency physicians, and may be integrated depending on the setting, training, and needs of that particular ED or EM group. Table 2 lists other emergency US applications.

Other Settings or Populations

Pediatrics. US is a particularly advantageous diagnostic tool in the management of pediatric patients, in whom radiation exposure is a significant concern. EUS applications such as musculoskeletal evaluation for certain fractures (rib, forearm, skull), and lung for pneumonia may be more advantageous in children than in adults due to patient size and density.⁷ US can be associated with increased procedural success and patient safety, and decreased length of stay.^{8,9} While most US modalities in the pediatric arena are the same as in adult patients (the EFAST exam for trauma, procedural guidance), other modalities are unique to the pediatric population such as in suspected pyloric stenosis and intussusception, or in the child with hip pain or a limp).¹⁰⁻¹² Mostly recently, EUS has been formally incorporated into Pediatric EM fellowship training.¹³⁻¹⁴

Critical Care. EUS core applications are being integrated into cardiopulmonary and non-invasive hemodynamic monitoring into critical care scenarios.¹⁵⁻¹⁶ Dual-trained physicians in emergency medicine and critical care are leading the application, education, and research of US for critically ill patients, and have significant leadership in advancing US concepts in multidisciplinary critical care practice. Advanced cardiopulmonary US application are being integrated into critical care practice.

Prehospital. There is increasing evidence that US has an increasing role in out-of-hospital emergency care.¹⁷⁻¹⁸ Challenges to the widespread implementation of out-of-hospital US include significant training and equipment requirements, and the need for careful physician oversight and quality assurance. Studies focusing on patient outcomes need to be conducted to further define the role of out-of-hospital US and to identify settings where the benefit to the patient justifies the investment of resources necessary to implement such a program.¹⁹

International arena including field, remote, rural, global public health and disaster situations. US has become the primary initial imaging modality in disaster care.²⁰⁻²⁴ US can direct and optimize patient care in domestic and international natural disasters such as tsunami, hurricane, famine or man-made disasters such as battlefield or refugee camps. US provides effective advanced diagnostic technology in remote geographies such as rural areas, developing countries, or small villages which share the common characteristics of limited technology (ie, x-ray, CT, MRI), unreliable electrical supplies, and minimally trained health care providers. US use in outer space is unique as the main imaging modality for space exploration and missions.²⁵⁻²⁶ Ultrasound has also been used in remote settings such as international exploration, mountain base camps, and cruise ships.²⁷ The increasing portability of US machines with increasing image resolution has expanded the use of emergent imaging in such settings. See ACEP linked resources at www.globalsono.org

Military and Tactical. The military has embraced the utilization of US technology in austere battlefield environments.²⁸⁻²⁹ It is now routine for combat support hospitals as well as forward surgical teams to deploy with next generation portable ultrasonography equipment. Clinical ultrasonography is often used to inform decisions on mobilization of casualties to higher echelons of care and justify use of limited resources. Within the last decade, emergency physicians at academic military medical centers have expanded ultrasonography training to clinical personnel who practice in close proximity to the point of injury, such as combat medics, special operations forces, and advanced practice professionals.³⁰ The overarching goal of these training programs is to create a generation of competent clinical sonologists capable of practicing “good medicine in bad places.” The military is pursuing telemedicine-enabled US applications, automated US interpretation capabilities, and extension of clinical ultrasonography in additional areas of operation, such as critical care air evacuation platforms.³¹

Section 3 – Training and Proficiency

There is an evolving spectrum of training in clinical US from undergraduate medical education through post-graduate training, where skills are introduced, applications are learned, core concepts are reinforced and new applications and ideas evolve in the life-long practice of US in emergency medicine.³²⁻³³

Competency and Curriculum Recommendations

Competency in EUS requires the progressive development and application of increasingly sophisticated knowledge and psychomotor skills for an expanding number of EUS applications. This development parallels the performance of any EUS exam.

The ACEP definition of US competency includes the following components. First, the clinician needs to recognize the indications and contraindications for the EUS exam. Next, the clinician must be able to acquire adequate images. This begins with an understanding of basic US physics, translated into the skills needed to operate the US system correctly (knobology), while performing exam protocols on patients presenting with different conditions and body habitus. Simultaneous with image acquisition, the clinician needs to interpret the imaging by distinguishing between normal anatomy, common variants, as well as a range of pathology from obvious to subtle. Finally, the clinician must be able to integrate EUS exam findings into individual patient care plans and management. Ultimately, effective integration includes knowledge of each particular exam accuracy, as well as proper documentation, quality assurance, and EUS reimbursement. See ACEP linked resources at www.acep.org/sonoguide.

An EUS curriculum requires considerable faculty expertise, dedicated faculty time and resources, and departmental support. These updated guidelines continue to provide the learning objectives (See Appendix 2), educational methods, and assessment measures for any EUS residency or practice-based curriculum. As part of today’s effort to reinvent medical education, all educators are now faced with the challenge of

creating curricula that provide for individualized learning yet result in the standardized outcomes such as those outlined in current residency milestones.³⁴

Innovative Educational Methods and Assessment Measures

As a supplement to traditional EUS education already described in previous guidelines, recent online and technological innovation is providing additional individualized educational methods and standardized assessment measures to meet this challenge.^{32, 35-36} Free open access medical (FOAM) education podcasts and narrated lectures provide the opportunity to create the flipped EUS classroom.³⁷⁻⁴⁰ For the trainee, asynchronous learning provides the opportunity to repeatedly review required knowledge on demand and at their own pace. For educators, less time may be spent providing recurring EUS didactics, and more time dedicated to higher level tasks such as teaching psychomotor skills and integration of exam findings into patient and ED management. Both EUS faculty and trainees together may identify potential FOAM resources. However, EUS faculty must now take the new role of FOAM curator. New online resources must be carefully reviewed to ensure that each effectively teaches the objectives in these guidelines before being introduced into an EUS curriculum.

Similar to knowledge learning, there are new educational methods to teach the required psychomotor skills of EUS. The primary educational method continues to be small group hands-on training in the ED with EUS faculty, followed by supervised examination performance with timely quality assurance review. Simulation is currently playing an increasingly important role as both an EUS educational method and assessment measure.³⁶ Numerous investigators have demonstrated that simulation results in equivalent image acquisition, interpretation, and operator confidence in comparison to traditional hands-on training.⁴¹⁻⁴² US simulators provide the opportunity for deliberate practice of a new skill in a safe environment prior to actual clinical performance. The use of simulation for deliberate practice improves the success rate of invasive procedures and reduces patient complications.⁴³⁻⁴⁴ Additionally, simulation has the potential to expose trainees to a wider spectrum of pathology and common variants than typically encountered during an EUS rotation. Blended learning created by the flipped classroom, live instructor training, and simulation provide the opportunity for self-directed learning, deliberate practice and mastery learning.⁴⁵⁻⁴⁷

Simulation also provides a valid assessment measure of each component of EUS competency. Appropriately designed cases assess a trainee's ability to recognize indications, demonstrate image acquisition and interpretation, as well as apply EUS findings to patient and ED management.⁴² These proven benefits and the reduction in direct faculty time justify the cost of a high-fidelity US simulator. Furthermore, costs may be shared across departments.

Documenting Experience and Demonstrating Proficiency

Traditional number benchmarks for procedural training in medical education provide a convenient method for documenting the performance of a reasonable number of exams needed for a trainee to develop competency.⁴⁸⁻⁴⁹ However, learning curves vary by trainee and application.⁴⁹ Individuals learn required knowledge and psychomotor skills at their own pace. Supervision, opportunities to practice different applications and encounter pathology also differ across departments.

Therefore, in addition to set number benchmarks individualized assessment methods need to be utilized. Recommended methods include the following: real time supervision during clinical EUS, weekly QA teaching sessions and image review, ongoing QA exam feedback, standardized knowledge assessments, small group Observed Structured Clinical Examinations (OSCEs), one-on-one standardized direct observation tools (SDOTs), simulation assessments and other focused educational tools.³⁶ Ideally these assessment measures are completed both at the beginning and the end of a training period. Initial assessment measures identify each trainee's unique needs, providing the opportunity to modify a local curriculum as needed to create more individualized learning plans. Final assessment measures demonstrate current trainee

competency and future learning needs, as well as identify opportunities for improvement in local EUS education.

Trainees should complete a benchmark of 25-50 quality-reviewed exams in a particular application. It is acknowledged that the training curve may level out below or above this recommended threshold, and that learning is a lifelong process with improvements beyond initial training. Previously learned psychomotor skills are often applicable to new applications. For example, experience with FAST provides a springboard to learning resuscitation, genitourinary, and transabdominal pelvic EUS.

Overall EUS trainees should complete a benchmark of 150-300 total EUS exams depending on the number of applications being utilized. For example, an academic department regularly performing greater than six applications may require residents to complete more than 150 exams, while a community ED with practicing physicians just beginning to incorporate EUS with FAST and vascular access should require less.

If different modalities such as endovaginal technique are being used for an application, the minimum may need to include a substantial experience in that technique. We would recommend a minimum of 10 examinations in the other technique (eg, endocavitary for early pregnancy) with the assumption that educational goals of anatomic, pathophysiology, and abnormal states are identified with all techniques taught.

Procedural US applications require fewer exams given prior knowledge, psychomotor skills, and clinical experience with traditional blind technique. Trainees should complete five quality reviewed US-guided procedure examinations or a learning module on an US-guided procedures task trainer.

Training exams need to include patients with different conditions and body types. Exams may be completed in different settings including clinical and educational patients in the ED, live models at EUS courses, utilizing US simulators, and in other clinical environments. Abnormal or positive scans should be included in a significant number of training exams used to meet credentialing requirements. Image review or simulation may be utilized for training examinations in addition to patient encounters when adequate pathology is not available for the specific application. In-person supervision is optimal during introductory education but is not required for residency or credentialing examinations after initial didactic training.

During benchmark completion, all EUS exams should be quality reviewed for technique and accuracy by EUS faculty. Alternatively, an EUS training portfolio of exam images and results may be compared to other diagnostic studies and clinical outcomes in departments where EUS faculty are not yet available. After initial training, continued quality assurance of EUS exams is recommended for a proportion (5-10%) of ongoing exams to document continued competency.

Recently, several secure online quality assurance workflow systems have become commercially available (See Section 5- Quality and US Management). Current systems greatly enhance trainee feedback by providing for more timely review of still images and video loops, customized application and feedback forms, typed and voice feedback, as well as storage and export of data within a relational database.

Training Pathways

There are two recommended pathways for clinicians to become proficient in EUS. See Figure 2. The majority of emergency physicians today receive EUS training as part of an ACGME-approved EM residency. A second practice-based pathway is provided for practicing EM physicians and other EM clinicians who did not receive EUS training through completion of an EM residency program.

These updated EUS guidelines continue to provide the learning objectives, educational methods and assessment measures for either pathway. Learning objectives for each application are described in Appendix 2.

Residency Based Pathway

EUS has been considered a fundamental component of emergency medicine training for over two decades.⁵⁰⁻⁵² The ACGME mandates procedural competency in EUS for all EM residents as it is a “skill integral to the practice of Emergency Medicine” as defined by the 2013 Model of the Clinical Practice of EM.⁵³ The ACGME and the American Board of Emergency Medicine (ABEM) recently defined twenty-three sub competency milestones for emergency medicine residency training.³⁴ Patient Care Milestone twelve (12) describes the sequential learning process for EUS and should be considered a guideline in addition to other assessment methods mentioned in this guideline. Appendix 3 provides recommendations for EM residency EUS education.

Upon completion of residency training, emergency medicine residents should be provided with a standardized EM Resident EUS credentialing letter. For the EUS faculty, ED Director or Chairperson at the graduate’s new institution, this letter provides a detailed description of the EUS training curriculum completed, including the number of quality reviewed training exams completed by application and overall, and performance on SDOTs and simulation assessments.

Practice Based Pathway

For practicing emergency medicine (EM) attendings who completed residency without specific EUS training, a comprehensive course, series of short courses, or preceptorship is recommended. Shorter courses covering single or a combination of applications may provide initial or supplementary training. As part of pre-course preparation, EUS faculty must consider the unique learning needs of the participating trainees. The course curriculum should include trainee-appropriate learning objectives, educational methods and assessment measures as outlined by these guidelines. If not completed previously, then introductory training on US physics and knobology is required prior to training in individual applications. Pre-course and post-course online learning may be utilized to reduce the course time spent on traditional didactics and facilitate later review. Small group hands-on instruction with EUS faculty on models, simulators, and task trainers provides experience in image acquisition, interpretation, and integration of EUS exam findings into patient care. See Appendix 4.

Preceptorships typically lasting 1-2 weeks at an institution with an active EUS education program have also been utilized successfully to train practicing physicians. Each preceptorship needs to begin with a discussion of the trainees’ unique educational needs, hospital credentialing goals as well as financial support for faculty teaching time. Then the practicing physician participates in an appropriately tailored curriculum typically in parallel with ongoing student, resident, fellow and other educational programming.

Similar to an EM Resident EUS credentialing letter, course and preceptorship certificates should include a description of the specific topics and applications reviewed, total number of training exams completed with expert supervision, performance on other course assessment measures such as SDOTs or simulation cases, as well as the number of CME hours earned. These certificates are then given to local EUS faculty or ED Director/Chairperson to document training.

Advanced Practice Providers, Nursing, Paramedics, and other EM clinicians

In many practice environments, EUS faculty often provide clinical US training to other to non-physician staff including Advanced Practice Professionals, Nurses, Paramedics, Military Medics and Disaster Response Team members. The recommendations in these guidelines should be utilized by EUS faculty when providing such training programs. Pre-course preparation needs to include discussions with staff leadership to define role-specific learning needs and applications to be utilized. Introductory US physics, knobology, and relevant anatomy and pathophysiology are required prior to training in targeted applications.

For Advanced Practice Providers and other clinicians practicing in rural and austere environments where direct EUS trained EM physician oversight is not available, EUS training needs to adhere to the recommendations in these guidelines. Specifically, comprehensive didactics and skills training, as well as minimum benchmarks need to be completed prior to independent EUS utilization. Beyond this initial training, EUS faculty are needed to provide ongoing quality assurance review. Telemedicine may provide the opportunity for real time patient assessment, assistance with image acquisition, and immediate review of patient images.

Ongoing Education

As with all aspects of emergency medicine ongoing education is required regardless of training pathway. The amount of education needed depends on the number of applications being performed, frequency of utilization, the local practice of the individual clinician and other developments in EUS and EM. Individual EUS credentialed physicians should continue their education with a focus on US activities as part of their overall educational activities. Educational sessions that integrate US into the practice of EM are encouraged, and do not have to be didactic in nature, but may be participatory or online. Recommended EUS educational activities include conference attendance, online educational activities, preceptorships, teaching, research, hands-on training, program administration, quality assurance, image review, in-service examinations, textbook and journal readings, as well as morbidity and mortality conferences inclusive of US cases. US quality improvement is an example of an activity that may be used for completion of the required ABEM Assessment of Practice Performance activities.

Fellowship Training

Fellowships provide the advanced training needed to create future leaders in evolving areas of medicine such as clinical US. This advanced training produces experts in clinical US and is not required for the routine utilization of EUS.

An EUS fellowship provides a unique, focused, and mentored opportunity to develop and apply a deeper comprehension of advanced principles, techniques, applications, and interpretative findings. Knowledge and skills are continually reinforced as the fellow learns to effectively educate new trainees in EUS, as well as clinicians in other specialties, and practice environments. A methodical review of landmark and current literature, as well as participation in ongoing research, creates the ability to critically appraise and ultimately generate the evidence needed for continued improvements in patient care through clinical US. Furthermore, fellowship provides practical experience in EUS program management including quality assurance review, medical legal documentation, image archiving, reimbursement, equipment maintenance, and other administrative duties of an EUS program director.

Recommendations for fellowship content, site qualifications, criteria for fellowship directors, and minimum graduation criteria for fellows have been published by national EUS leadership and ACEP Emergency Ultrasound Fellowship Guidelines.⁵⁴⁻⁵⁵ Each fellowship program's structure and curriculum will vary slightly based on local institution and department resources. At all fellowship programs, mentorship and

networking are fundamental to a fellow's and program's ultimate success. Both require significant EUS faculty time for regular individual instruction as well as participation in the clinical US community locally and nationally. Hence, institution and department leadership support is essential to ensuring an appropriate number of EUS faculty, each provided with adequate non-clinical time.

For the department, a fellowship speeds the development of an EUS program. Fellowships improve EM resident training resulting in increased performance of EUS examinations.⁵⁶ Furthermore, a fellowship training program may have a significant positive impact on overall EUS utilization, timely quality assurance review, faculty credentialing, billing revenue, and compliance with documentation.⁵⁷ For an institution, an EUS fellowship provides a valuable resource for other specialties just beginning clinical US programs. Collaborating with EUS faculty and fellows, clinicians from other departments are often able to more rapidly educate staff and create effective clinical US programs.

US in Undergraduate Medical Education

Emergency Medicine has again taken a lead role in efforts to improve Undergraduate Medical Education (UME) through the early integration of clinical US.⁵⁸⁻⁶² During the preclinical years, US has been demonstrated to be an effective educational method to reinforce student understanding of anatomy, physical examination skills, pathology and bedside diagnostic skills.⁶³⁻⁶⁸ During the clinical years, students are then better able to utilize US for clinical diagnosis and on specific rotations. US exposure in UME can provide a solid knowledge base for individuals to build upon and later utilize as US is integrated into their clinical training.

Integrating US into UME

Integration of US into pre-clinical UME often begins with medical student and faculty interest. By working closely with a medical school's curriculum committee, US may then be incorporated as a novel educational method to enhance learning within existing preclinical courses. Although dedicated US specific curriculum time is not often available in UME, considerable clinical US faculty time and expertise is still required for effective integration of US into existing medical school courses. Widespread clinical US utilization by different specialties within a medical school's teaching hospitals, and education within Graduate Medical Education programs, provides initial faculty expertise, teaching space, and US equipment. Ongoing education then requires local departmental and medical school leadership support, as well as continued organized collaboration between faculty from participating specialties.

Innovative educational methods again provide the opportunity for clinical US faculty to focus on small group hands-on instruction as described in the innovative education section.^{60,64,69-70}

Many academic departments that currently offer clinical rotations within Emergency Medicine already include an introduction to EUS as a workshop, or a set number of EUS shifts. Dedicated EUS elective rotations provide an additional opportunity for medical students interested in Emergency Medicine and other specialties utilizing clinical US to participate in an EUS rotation adapted to their level of training and unique career interests. See Appendix 5 for recommendations for EUS and Clinical US medical school rotations.

US in UME continuing into Clinical US in GME

UME US experience should prepare new physicians to more rapidly utilize clinical US to improve patient care during graduate medical education (GME) training. Medical students today therefore should graduate with a basic understanding of US physics, machine operation, and common exam protocols such as US guided vascular access. Medical students matriculating from a school with an integrated US curriculum, as well as those completing an elective clinical US rotation, should be provided with a supporting letter similar

in regard to didactics, hands-on training, and performed examinations. Although all trainees need to complete the EUS residency milestones, trainees with basic proficiency in clinical US from UME training may progress more rapidly and ultimately achieve higher levels of EUS expertise during GME. Additionally, these residents may provide considerable EUS program support as peer-to-peer instructors, residency college leaders, investigators and potentially future fellows.

Section 4 – Credentialing and Privileging

Implementing a transparent, high quality, verifiable and efficient credentialing system is an integral component of an emergency US program. An emergency US director, along with the department leadership, should oversee policies and guidelines pertaining to emergency US. The department should follow the specialty-specific guidelines set forth within this document for their credentialing and privileging process.

Pertaining to clinician performed US, the American Medical Association (AMA) House of Delegates in 1999 passed a resolution (AMA HR. 802) recommending hospitals' credentialing committees follow specialty-specific guidelines for hospital credentialing decisions related to US use by clinicians.⁷¹ This resolution affirms that US imaging is within the scope of practice of appropriately trained physician specialists and provides clear support for hospital credentialing committees to grant emergency US (EUS) privileging based on the specialty-specific guidelines contained within this document without the need to seek approval from other departments. Furthermore, HR 802 states that opposition that is clearly based on financial motivation meets criteria to file an ethical complaint to the AMA.

The provision of clinical privileges in EM is governed by the rules and regulations of the department and institution for which privileges are sought. The EM Chairperson or Medical Director or his/her designate (eg, emergency US director) is responsible for the assessment of clinical US privileges of emergency physicians. When a physician applies for appointment or reappointment to the medical staff and for clinical privileges, including renewal, addition, or rescission of privileges, the reappraisal process must include assessment of current competence. The EM leadership will, with the input of department members, determine the means by which each emergency physician will maintain competence and skills and the mechanism by which each physician is monitored.

EM departments should list emergency US within their core emergency medicine privileges as a single separate privilege for "Emergency US" or US applications can be bundled into an "US core" and added directly to the core privileges. EM should take responsibility to designate which core applications it will use, and then track its emergency physicians in each of those core applications. To help integrate physicians of different levels of sonographic competency (graduating residents, practicing physicians, fellows and others), it is recommended that the department of emergency medicine create a credentialing system that gathers data on individual physicians, which is then communicated in an organized fashion at predetermined thresholds with the institution-wide credentialing committee. This system focuses supervision and approval at the department level where education, training, and practice performance is centered prior to institutional final review. As new core applications are adopted, they should be granted by an internal credentialing system within the department of emergency medicine.

Eligible providers to be considered for privileging in emergency ultrasonography include emergency physicians or other providers who complete the necessary training as specified in this document via residency training or practice based training (see Section 3 - Training and Proficiency). After completing either pathway, these skills should be considered a core privilege with no requirement except consistent utilization. At institutions that have not made EUS a core privilege, submission of 5-10% of the initial requirement for any EUS application is sufficient to demonstrate continued proficiency.

Sonographer certification or emergency US certification by external entities is not an expected, obligatory or encouraged requirement for emergency US credentialing.⁷² Physicians with advanced US training or responsibilities may be acknowledged with a separate hospital credential if desired.

Regarding re-credentialing or credentialing at a new health institution or system, ACEP recommends that once initial training in residency or by practice pathway is completed, credentialing committees recognize that training as a core privilege, and ask for proof of recent updates or a short period of supervision prior to granting full privileges.

In addition to meeting the requirements for ongoing clinical practice set forth in this document, physicians should also be assessed for competence through the CQI program at their institution. (See Section 5-Quality and US Management) The Joint Commission (TJC) in 2008 implemented a new standard mandating detailed evaluation of practitioners' professional performance as part of the process of granting and maintaining practice privileges within a healthcare organization.⁷³ This standard includes processes including the Ongoing Professional Practice Evaluation (OPPE) and the Focused Professional Practice Evaluation (FPPE). Specific to FPPE and US credentialing, for infrequently performed US examinations, FPPE monitoring can be performed on a pre-determined number of examinations (ie, review of the diagnoses made on the first 10 or 20 of a particular US examination). The FPPE process should: 1. Be clearly defined and documented with specific criteria and a monitoring plan; 2. Be of fixed duration; and 3. Have predetermined measures or conditions for acceptable performance. OPPE can incorporate EUS quality improvement processes. US directors should follow these guidelines when setting up their credentialing and privileging processes.

Section 5 – Quality and US Management

In order to ensure quality, facilitate education, and satisfy credentialing pathways, a plan for an emergency US quality assurance (QA) and improvement program should be in place. This plan should be integrated into the overall ED operations. The facets of such a program are listed below. Programs should strive for meeting these criteria, and may seek accreditation through the Clinical Ultrasound Accreditation Program (CUAP).⁷⁴

Emergency US Director

The emergency US director is a board-eligible or certified emergency physician who has been given administrative oversight over the emergency US program from the EM Chairperson, director or group. This may be a single or group of physicians, depending on size, locations, and coverage of the group. Specific responsibilities of an US director and associates may include:

- Developing and ensuring compliance to overall program goals: educational, clinical, financial, and academic.
- Selecting appropriate US machines for clinical care setting and developing and monitoring maintenance care plan to ensure quality and cleanliness.
- Designing and managing an appropriate credentialing and privileging program for physicians, residents, or advanced practice providers (APP) or other type of providers within the group and/or academic facility.
- Designing and implementing in-house and/or out-sourced educational programs for all providers involved in the credentialing program.
- Monitoring and documenting individual physician privileges, educational experiences, and US scans.
- Developing, maintaining, and improving an adequate QA process in which physician scans are reviewed for quality in a timely manner and from which feedback is generated.

The emergency US director must be credentialed as an emergency physician and maintain privileges for emergency US applications. If less than two years in the position of US director, it is recommended that the

director have either: 1) graduated from an emergency US fellowship, 2) participated in an emergency US management course, or 3) completed an emergency US preceptorship or mini-fellowship. If part of a multihospital group, there must be consideration of local US directors with support from overall system US director. Institutional and departmental support should be provided for the administrative components listed above.

Supervision of US Training and Examinations

Ultrasound programs in clinical specialties have a continuing and exponential educational component encompassing traditionally graduate and post-graduate medical training, but now undergraduate, APP, prehospital, remote, and other trainees are seeking training. Policies regarding the supervision and responsibility of these US examinations should be clear. (See Sections 2, 3, and 4)

US Documentation

Emergency US is different from consultative US in other specialties as the emergency physician not only performs but also interprets the US examination. In a typical hospital ED practice, US findings are immediately interpreted, and should be communicated to other physicians and services by written reports in the ED medical record. Emergency US documentation reflects the nature of the exam, which is focused, goal-directed, and performed at the bedside contemporaneously with clinical care. This documentation may be preliminary and brief in a manner reflecting the presence or absence of the relevant findings. Documentation as dictated by regulatory and payor entities may require more extensive reporting including indication, technique, findings, and impression. Although EMRs are quickly becoming the norm, documentation may be handwritten, transcribed, templated, or computerized. Regardless of the documentation system, US reports should be available to providers to ensure timely availability of interpretations for consultant and health care team review.⁷⁵ Ideally, EMR systems should utilize effective documentation tools to make reporting efficient and accurate.

During out-of-hospital, remote, disaster, and other scenarios, US findings may be communicated by other methods within the setting constraints. Incidental findings should be communicated to the patient or follow-up provider. Discharge instructions should reflect any specific issues regarding US findings in the context of the ED diagnosis. Hard copy (paper, film, video) or digital US images are typically saved within the ED or hospital archival systems. Digital archival with corresponding documentation is optimal and recommended.⁷⁶ Finally, documentation of emergency US procedures should result in appropriate reimbursement for services provided.⁷⁷⁻⁷⁸ (See Section 6 – Value and Reimbursement)

Quality Improvement Process

Quality improvement (QI) systems are an essential part of any US program. The objective of the QI process is to evaluate the images for technical competence, the interpretations for clinical accuracy, and to provide feedback to improve physician performance.

Parameters to be evaluated might include image resolution, anatomic definition, and other image quality acquisition aspects such as gain, depth, orientation, and focus. In addition, the QI system should compare the impression from the emergency US interpretation to patient outcome measures such as consultative US, other imaging modalities, surgical procedures, or patient clinical outcome.

The QI system design should strive to provide timely feedback to physicians. Balancing quality of review with provision of timely feedback is a key part of QA process design. Any system design should have a data storage component that enables data and image recall.

A process for patient callback should be in place and may be incorporated into the ED's process for calling patients back. Callbacks should occur when the initial image interpretation, upon QA review, may have been questionable, inappropriate and of clinical significance. In all cases, the imaging physician is informed of the callback and appropriate counseling/training is provided.

Images obtained prior to a provider attaining levels sufficient for credentialing should be reviewed.

Once providers are credentialed, programs should strive to sample a significant number of images from each provider that ensures continued competency. Due to the varieties of practice settings the percentage of scans undergoing quality assurance should be determined by the US director and should strive to protect patient safety and maintain competency. While this number can vary, a goal of 10% may be reasonable, adjusted for the experience of the providers and newness of the US application in that department.

The general data flow in the QA system is as follows:

1. Images obtained by the imaging provider should be archived, ideally on a digital system. These images may be still images or video clips, and should be representative of the US findings.
2. Clinical indications and US interpretations are documented on an electronic or paper record by the imaging provider.
3. These images and data are then reviewed by the US director or his/her designee.
4. Reviewers evaluate images for accuracy and technical quality and submit the reviews back to the imaging provider.
5. Emergency US studies are archived and available for future review should they be needed.

QA systems currently in place range from thermal images and log books to complete digital solutions. Finding the system that works best for each institution will depend on multiple factors, such as machine type, administrative and financial support, and physician compliance. Current digital management systems offer significant advantages to QA workflow and are recommended.

US QA may also contribute to the ED's local and national QI processes. US QA activities may be included in professional practice evaluation, practice performance, and other quality improvement activities. Measures such as performance of a FAST exam in high acuity trauma, detection of pregnancy location, use of US for internal jugular vein central line cannulation may be the initial logical elements to an overall quality plan. In addition, US QA databases may contribute to a registry regarding patient care and clinical outcomes.

US programs that include multiple educational levels and various types of providers should implement processes to integrate QA into the education process as well as the departmental or institutional quality framework. Technology allowing remote guidance and review may be integrated into the US QA system.

US Machines, Safety, and Maintenance

Dedicated US machines located in the ED for use at all times by emergency physicians are essential. Machines should be chosen to handle the rigors of the multi-user, multi-location practice environment of the ED.⁷⁹ Other issues that should be addressed regarding emergency US equipment include: regular in-service of personnel using the equipment and appropriate transducer care, stocking and storage of supplies, adequate cleaning of external and internal transducers with respect to infection control, maintenance of US machines by clinical engineering or a designated maintenance team, and efficient communication of equipment issues. Ultrasound providers should follow common ED US safety practices including ALARA, probe decontamination, and machine maintenance.

Risk Management

US can be an excellent risk reduction tool through 1) increasing diagnostic certainty, 2) shortening time to definitive therapy, and 3) decreasing complications from procedures that carry an inherent risk for complications.⁸⁰ An important step to managing risk is ensuring that physicians are properly trained and credentialed according to national guidelines such as those set by ACEP. Proper quality assurance and improvement programs should be in place to identify and correct substandard practice. The greatest risk in regard to emergency US is lack of its use in appropriate cases.

The standard of care for emergency US is the performance and interpretation of US by a credentialed emergency physician within the limits of the clinical scenario. Physicians performing US imaging in other specialties or in different settings have different goals, scopes of practice, and documentation requirements, and consequently should not be compared to emergency US. As emergency US is a standard emergency medicine procedure, it is included in any definition of the practice of emergency medicine with regards to insurance and risk management.

Section 6 – Value and Reimbursement

Value in health care has been defined as outcomes that matter to patients relative to cost.⁸¹ The value of clinical US is maximized when time spent by the clinician prevents costly imaging, invasive therapeutics, unnecessary consultations and produces accessible real-time results for the patient and the health care system.

Value is added to the medical system when US imaging increases patient health or decreases the cost to achieve that same level of patient health. Clinical US contributes to patient health in several ways:

1. Improving patient safety by reducing medical errors during procedures
2. Increasing patient satisfaction
3. Improving departmental resource utilization
4. Eliminating costly or invasive procedures
5. Improved clinical decision making

Reimbursement for US derives from Current Procedural Terminology (CPT) codes and their respective relative value units (RVUs). The reimbursements for US are calculated on work performed by entities within the healthcare system, with some going to physicians and some going to hospital entities.³ The current system assumes a similar workflow for all US. The evolution of clinician-performed or clinical US has changed the workflow for many clinicians.

The current workflow for clinical US differs widely from the historical workflow. While consultative US centers on providing a work product for the interpreting physician, clinical US centers on the patient. The clinician evaluating the patient utilizes US at the patient's bedside to answer a focused question or guide an invasive procedure. The bedside physician takes over tasks that are attributed to the hospital's practice expense such as bringing the unit to the bedside, obtaining US images, and archiving images for the medical record. Figure 3 shows the workflow in the model of clinical US.

In addition to workflow differences, clinical bedside US has low expenses related to capital equipment, physical plant and supplies. The US machine is a less expensive mobile unit located in the ED and moved to the patient's bedside. Hospitals are turning to lower cost archiving alternatives to PACS, US management systems (also known as middleware or workflow solutions) or cloud based software solutions which allow readily accessible digitally archived images.

CPT values physician work (wRVU) required for common emergency US at approximately 40% of the global RVU (total professional plus total technical). Active emergency US programs allow the hospital to bill technical fees which support the cost of the machine, supplies, and arriving/quality assurance software.

Efficiencies gained by incorporating bedside US imaging in the care of emergency medicine patients can produce an overall cost savings to the health care system. Clinical point-of-care ultrasound may provide significant benefits by reducing the needs for hospitalization, improved diagnosis and improved outcomes. With these benefits, shared savings should be attributed appropriately to the entity which affected the change.

A more detailed calculation of work depends on the specific clinical system organization and division of labor/resources. Future alternative payment structures such as value based purchasing, bundled payments, or accountable care organizations (ACOs) should appropriately factor the resources, efficiency and value of clinical based US into the value and reimbursement of emergency medical care.

Section 7- Clinical US Leadership in Healthcare Systems

Increasingly, many specialties have an interest in utilizing US in their clinical practice across diverse patient care settings. Consequently, there is a need for direction, leadership, and administrative oversight for hospital systems to efficiently deliver this technology in an organized and coordinated manner. Emergency physicians by nature have a broad scope of practice and interact with essentially all specialties and are thus uniquely positioned to take this role. Specifically, healthcare and hospital systems should:

- 1) consider clinical, point-of-care ultrasonography separate from consultative imaging and
- 2) use these guidelines for design of institutional clinical US programs, and
- 3) strongly consider experienced emergency physician US leaders for system leadership in clinical, point-of-care ultrasonography.

There are many approaches to institutional oversight of multidisciplinary US programs including consensus from major utilizers, the formation of a governing body such as a clinical US steering committee or the creation of the position of an institutional clinical US director, who has a broad understanding of all the uses of clinical US. Specific items to consider which require leadership and coordination include policy development, equipment purchase, training and education, competency assessment and credentialing, quality assurance, and value/reimbursement.

Inherently, there will be a large number of requests for point-of-care US equipment. There may be significant advantages to standardizing or coordinating hardware and software when possible so that providers may share equipment across departments. This standardization may allow purchasing and cost saving advantages due to bulk deals and offers advantages in training and machine familiarity (eg, resuscitation areas). Standardization may have some negative effects with vendor exclusivity in regards to advancement in technologies and feature availability which may benefit individual settings.

In academic and community centers there will be a need for educating all levels of trainees. Ideally, education for each individual specialty should come from within that specialty. In the situation where education is needed, but there are no leaders within a specific specialty, then the training may fall to the director or committee as described above. In these cases, the director should work with the leadership within each specific specialty to make sure the training meets the specific need of that department. “Train the trainer” programs should be encouraged. It is crucial to develop multiple leaders within the hospital to meet the ever-increasing educational needs. Once these leaders are established it will be useful to have the committee or director to oversee and coordinate to make sure the education is consistent across specialties, and that resources and work effort are shared and not duplicated.

Credentialing for each specialty should follow national guidelines and be specialty specific.⁷¹ However if national training guidelines for specialties do not exist, the director or committee should work to create general credentialing guidelines based on the ACEP structure, that are flexible enough to work with each specialty to meet their needs for specific applications.

Quality assurance should be organized and run within a department; however, frequently, there are not leaders with the time, qualifications, and/or interest in providing this service and need. In these cases, the director or committee should develop a plan to meet this need. Institutions must provide appropriate resources to system-wide Clinical US programs to allow efficient operations including hardware (US machines) and software such as US management programs. (See Section 5 –Quality and US Management)

Clinical US in hospital and health care systems can be coordinated with successful initiation, maturation, and continual operation of a well-developed plan led by knowledgeable physicians with point-of-care experience. Coordination of specialties, equipment, software, education, quality review, and reimbursement are essential elements of such programs.

Section 8- Future Issues

Recent technological advances have improved access and overall US imaging. Wireless transducers, handheld systems and app based imaging connected via smart device are all reality.⁸²⁻⁸⁵ These enhancements represent novel and exciting forms of US technology that expand the availability of US to new clinical settings due to increased portability and relative affordability. These new devices are currently being evaluated in a variety of clinical settings and more diverse situations that had not previously been possible.

Telesonography is a rapidly developing model which allows transfer of US images and video from remote locations to obtain consultation and treatment recommendations.^{80,86} Recent advances in US and informatics allow remote experts to direct on-site less experienced ultrasonographers to obtain and interpret images that can impact patient care in real-time. An expert US mentor could potentially guide distant untrained health care providers geographically dispersed over multiple locations around the world. This paradigm may be utilized across all applications including procedural assistance. The practice of remote telesonography has the potential to improve quality of care in underserved communities in both domestic and international settings.

The automation of clinical US is yet another developing arena. Several companies have announced plans to build automated diagnostic protocols such as B-line detection in lung US and echocardiographic parameter assessment. These automated protocols may become the great equalizers by allowing a relative novice access to the same diagnostic information others have spent years training to attain. Finally, transducer technology will continue to change, including high resolution transducers that optimize sonographic windows, integrated probe/machine devices, and devices that use existing and new computer connections. Continuous advancements will allow clinicians to utilize US technology more and more and to limit inherent limitations and obstacles to use.

Other health care providers are also now realizing the utility of clinical US in their daily practice. Advanced practice professionals, nurses, emergency medical service personnel and others recognize the potential in their practice settings and desire to learn appropriate applications. Emergency physicians will continue to work with our colleagues at local, regional and national levels to help educate and establish appropriate training and practice standards for the safety of our patients. Leadership, supervision, and collaboration with other point-of-care specialists will continue to be critical to assure the safe, effective use of clinical US.

Advanced users of US in emergency, clinical, and point-of-care US have been creating a subspecialty of expert ultrasonographers who provide education, research, and advanced clinical practice with US. In addition, quality programs such as the Clinical Ultrasound Accreditation Program will provide leadership to EDs who can meet the criteria in this document.

As emergency US moves forward, continued high quality research in the field needs to occur. Future methodological improvements focused on patient outcomes are crucial for the advancement of point-of-care US within medicine. Multi-center studies producing higher level of evidence will allow the continued growth and appropriate use of US in emergency care. The future, while undeniably bright still requires much effort on the part of us all.

Section 9 – Conclusion

ACEP endorses the following statements on the use of emergency, clinical, point -of -care US:

1. Emergency, clinical point-of-care ultrasound performed, interpreted, and integrated into clinical care by emergency physicians is a fundamental skill in the practice of emergency medicine.
2. The scope of practice of emergency US can be classified into categories of resuscitation, diagnostic, symptom or sign-based, procedural guidance, and monitoring/therapeutics in which a variety of emergency US applications exists, including the core applications of trauma, pregnancy, abdominal aorta, cardiac/HD assessment, biliary, urinary tract, deep venous thrombosis, thoracic-airway, soft-tissue/musculoskeletal, ocular, bowel and procedural guidance.
3. Training and proficiency requirements should include didactic, experiential and integrative components as described within this document.
4. Emergency US training in emergency medicine residency programs should be fully integrated into the curriculum and patient care experience.
5. Emergency US should be considered a core credential for emergency physicians undergoing privileging in modern healthcare systems without need for external certification.
6. US QA and management require appropriate resources including physician direction, dedicated US machines, digital US management systems, and resources for QA.
7. Healthcare clinical point-of-care ultrasound programs optimally led by emergency physicians should be supported with resources for leadership, quality improvement, training, hardware and software acquisition and maintenance.
8. Emergency US is an independent procedure that should be reimbursed and valued, independent of the ED history, physical examination, and medical decision-making.
9. Emergency physicians with advanced US expertise should contribute leadership in clinical ultrasonography at the departmental, institutional, system, national, and international level.
10. Evolving technological, educational, and practice advancements may provide new approaches, efficiencies, and modalities in the care of the emergent patient.

Table 1. Relevant Ultrasound Definitions

Resuscitative	US use directly related to a resuscitation
Diagnostic	US utilized a diagnostic imaging capacity
Symptom or Sign-Based	US used in a clinical pathway based upon the patient's symptoms or sign (eg, shortness of breath)
Therapeutic and Monitoring	US use in therapeutics or physiological monitoring
Procedural Guidance	US used as an aid to guide a procedure
Consultative Ultrasound	A written or electronic request for an US examination & interpretation for which the patient is transported to a laboratory or imaging department outside of the clinical setting.
Emergency Ultrasound	Performed and interpreted by the provider as an emergency procedure and directly integrated into the care of the patient
Clinical Ultrasound	US used in the clinical setting, distinct from the physical examination, that adds anatomic, functional and physiologic information to the care of the acutely ill patient.
Educational Ultrasound	US performed in a non-clinical setting by medical students or other clinician trainees to enhance physical examination skills. Exams usually performed on cadavers or live models.

Table 2. Other emergency ultrasound applications (adjunct or emerging)

Advanced Echo
Transesophageal Echo
Adnexal Pathology
Testicular
Transcranial Doppler
Vascular
Contrast Studies
ENT
Infectious Disease

Figure 1. ACEP 2016 Emergency US Guidelines Scope of Practice

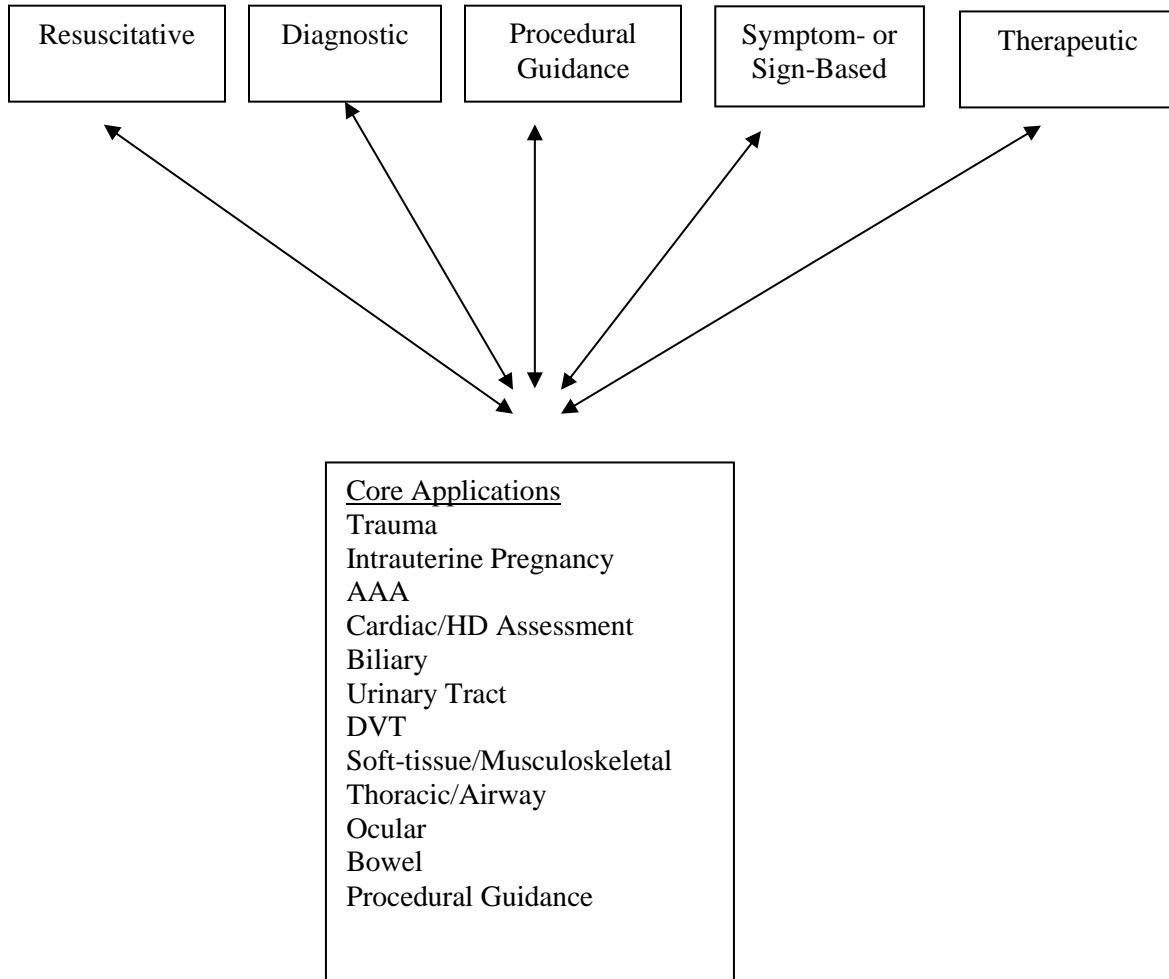


Figure 2. Pathways for emergency ultrasound training, credentialing, and incorporation of new applications

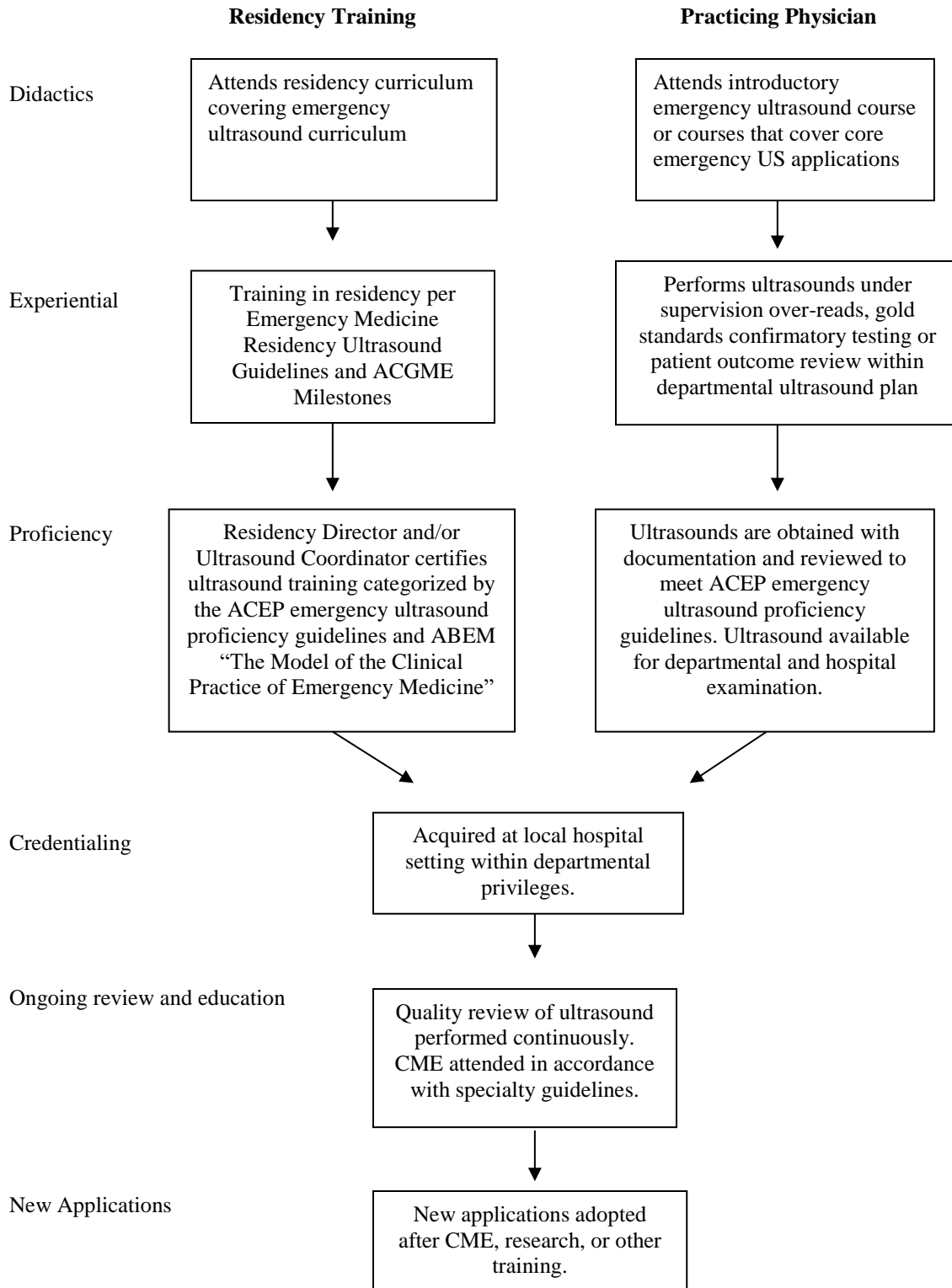
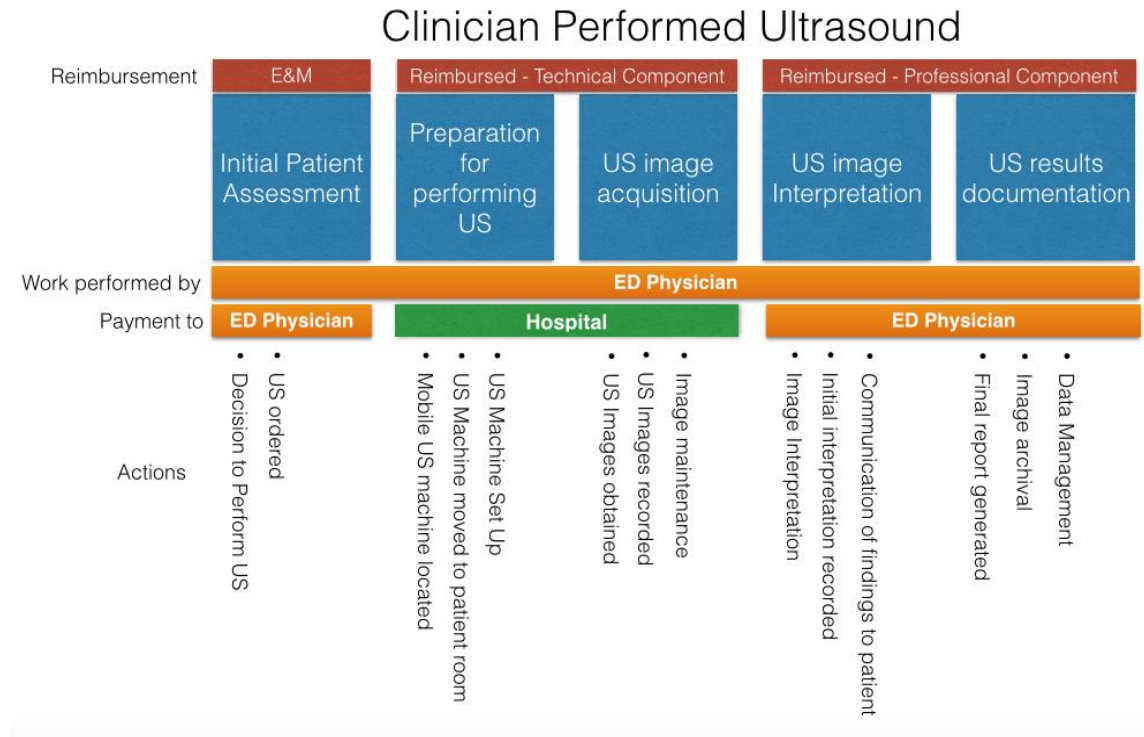


Figure 3 – Clinical Ultrasound Workflow



Appendix 1. Evidence for Core Emergency Ultrasound Applications

Trauma

The use of US in a trauma patient is typically for the detection of abnormal fluid or air collection in the torso. This application applies to both blunt and penetrating trauma in all ages. Perhaps the first bedside US technique studied in the hands of non-radiologists was the focused assessment with sonography in trauma (FAST) examination. First demonstrated in Europe and by surgeons, the technique was later adopted by emergency physicians.⁸⁷ In one early prospective study, FAST was 90% sensitive and 99% specific in detecting peritoneal bleeding in blunt trauma, and 91% sensitive and 100% specific in penetrating trauma.⁸⁸ A retrospective review of patients with penetrating thoracic trauma demonstrated 100% sensitivity for the detection of pericardial effusion and more rapid diagnosis and management when US was employed in their assessment.⁸⁹ Recently, a prospective randomized controlled study assessed 262 blunt trauma patients managed using the FAST exam as a diagnostic adjunct vs. no FAST exam. Patients randomized to the FAST exam group had more rapid disposition to the operating room, required fewer CT scans, and incurred shorter hospitalizations, fewer complications, and lower charges than those in whom the FAST was not performed.⁹⁰ During the last decade, pneumothorax has been added to the FAST exam as the EFAST examination.⁹¹ FAST examination also may have an effect on the utilization of ionizing radiation tests.⁹²

Pregnancy

Use of emergency US in pelvic disorders centers on the detection of intrauterine pregnancy (IUP), detection of ectopic pregnancy, detection of fetal heart rate in all stages of pregnancy, dating of the pregnancy, and detection of significant free fluid. Bedside pelvic US during the first trimester of pregnancy can be used to exclude ectopic pregnancy by demonstrating an intrauterine pregnancy. Studies of EP-performed US in this setting have demonstrated sensitivity of 76-90% and specificity of 88-92% for the detection of ectopic pregnancy.^{77-78,93-94} In one study, EPs were able to detect an intrauterine pregnancy in 70% of patients with suspected ectopic pregnancy (first trimester pregnancy with abdominal pain or vaginal bleeding).⁹³ When intrauterine fetal anatomy was visualized at the bedside, ectopic pregnancy was ruled out with a negative predictive value of essentially 100%. When bedside US evaluation was incorporated into a clinical algorithm for the evaluation of patients with suspected ectopic pregnancy, the incidence of discharged patients returning with ruptured ectopic pregnancy was significantly reduced.⁹⁵ Pelvic US by emergency physicians also save resources including length of stay and consultative imaging.⁹⁶

Abdominal Aortic Aneurysm (AAA)

The use of emergency US of the aorta is mainly for the detection of AAA, though aortic dissection may occasionally be detected. Although CT scan and MRI often serve as the criterion standard for AAA assessment, US is frequently used by radiology departments as a screening modality as well. In the ED, bedside US demonstrates excellent test characteristics when used by emergency physicians to evaluate patients with suspected AAA. One study of 68 ED patients with suspected AAA demonstrated sensitivity, specificity, positive and negative predictive values of 100%.⁹⁷ In another, 125 patients were assessed by EPs. Sensitivity was 100%, specificity 98%, positive predictive value 93% and negative predictive value 100% in this study.⁹⁸ In both studies, CT scan, radiology US, MRI, and operative findings served as a combined criterion standard.

Emergent Echocardiography and Hemodynamic Assessment

Emergent cardiac US can be used to assess for pericardial effusion and tamponade, cardiac activity, a global assessment of contractility, and the detection of central venous volume status. One early study of bedside echocardiography by EPs demonstrated 100% sensitivity for the detection of pericardial effusion in the setting of penetrating chest trauma. In this series, patients evaluated with US were diagnosed and treated more rapidly when US was employed in their assessment.^{89,99} Test characteristics of EP-performed echocardiography (when compared to expert over-read of images) for effusion include sensitivity of 96-100%, specificity 98-100%, positive predictive value 93-100% and negative predictive value 99-100%. The prognostic value of EP-performed bedside echocardiography has been well-established.¹⁰⁰ In one study of 173 patients in cardiac arrest, cardiac standstill on US was 100% predictive of mortality, regardless of electrical rhythm (positive predictive value of 100%).¹⁰¹ US has been incorporated into the resuscitation of the critically ill and arrest patient. In the assessment of patients with undifferentiated hypotension, EP assessment of cardiac contractility correlated well and has improved diagnostic accuracy (R=0.84).¹⁰²⁻¹⁰⁴ Emergent cardiac US has expanded to the use of heart failure and dyspnea.¹⁰⁵⁻¹⁰⁶ In addition hemodynamic assessment with US for preload, cardiac function, and afterload has become an accepted diagnostic and monitoring tool.¹⁰⁷⁻¹¹⁶

Hepatobiliary System

The use of emergency US for hepatobiliary disease has centered on biliary inflammation and biliary obstruction. Although many sonographic criteria for acute cholecystitis exist (including gallstones, thickened gallbladder wall, pericholecystic fluid, sonographic Murphy's sign, and common bile duct dilatation), gallstones are present in 95-99% of acute cholecystitis cases.¹¹⁷ This finding is quite accessible to the EP using bedside US, and may be placed into the context of an individual patient's clinical picture (presence of fever, tenderness, laboratory evaluation, etc.). The test characteristics for gallstone detection by bedside US are: sensitivity 90-96%, specificity 88-96%, positive predictive value 88-99% and negative predictive value 73-96%.¹¹⁸⁻¹²¹ A retrospective review of 1252 cases of suspected cholecystitis demonstrated that bedside emergency physician US vs radiology US evaluation decreased length of stay by 7% (22 minutes) overall, and up to 15% (52 minutes) when patients were evaluated during evening or nighttime hours.¹²²

Urinary Tract

The use of emergency US in the urinary tract is for detection of hydronephrosis and bladder status. The detection of hydronephrosis on bedside US, when combined with urinalysis and clinical assessment, may be helpful in differentiating patients with acute renal colic.¹²³⁻¹²⁴ Bedside renal US by experienced EPs has demonstrated sensitivity of 75-87% and specificity of 82-89% when compared with CT scan.¹²⁵⁻¹²⁶ Urinary tract US has also been shown similar to radiology US and CT imaging for imaging for patients with suspected renal colic.¹²⁷

Deep Vein Thrombosis

The use of emergency US for detection of DVT has centered on the use of multilevel compression US on proximal veins, especially in the lower extremity.¹²⁸⁻¹²⁹ A number of ED studies have examined the test characteristics of EP-performed limited venous compression sonography for the evaluation of DVT. A recent systematic review of six studies, (with a total of 132 DVTs in 936 patients) found a pooled sensitivity and specificity of 95% and 96%, respectively.^{41,130} One study demonstrated more rapid disposition for patients undergoing bedside US for DVT assessment compared with radiology department DVT assessment (95 vs. 225 minutes).¹³¹

Soft Tissue/Musculoskeletal

The use of emergency US in soft-tissue has focused on soft-tissue infection, foreign bodies, and cutaneous masses. Although a host of musculoskeletal applications of bedside US have been studied by EPs, among the most common and best described is the assessment of cellulitis and abscess at the bedside. Ultrasound has been shown to improve the clinical assessment of patients with cellulitis and possible abscess in several studies.¹³² In one study of 105 patients with suspected abscess, US demonstrated sensitivity of 98%, specificity 88%, positive predictive value 93% and negative predictive value 97% compared with needle aspiration.¹³²⁻¹³³ Another study demonstrated that bedside US altered the management of patients with cellulitis (and no clinically obvious abscess) in 56% of cases.¹³⁴ These patients were found to have abscesses or require surgical evaluations which were not evident on clinical examination alone. Fractures have been identified in series and prospective studies with good accuracy.¹³⁵⁻¹³⁶ Tendons injuries and joint effusions have been studied with excellent clarity.¹³⁷⁻¹³⁹

Thoracic-Airway

The use of emergency US in the thorax has been for the detection of pleural effusion and pneumothorax, interstitial and inflammatory disorders.¹⁴⁰⁻¹⁴⁴ Bedside US for the evaluation of thoracic disorders was described in the 1990s in European critical care settings. Since then, emergency physicians have utilized the technology for the detection of pneumothorax and other acute pathology. In the setting of blunt thoracic trauma, EP-performed US demonstrated sensitivity of 92-98%, specificity 99%, positive predictive value 96-98% and negative predictive value 99% compared with CT scan or air release during chest tube placement.¹⁴⁵ In the last decade, tracheal and airway assessment and endotracheal guidance has been studied with US. Recent cardiac resuscitation guidelines have included tracheal US as a alternative confirmatory test in cardiac arrest.¹⁴⁶⁻¹⁵²

Ocular

The use of emergency US in the eye has described for the detection of posterior chamber and orbital pathology. Specifically, US has been described to detect retinal detachment, vitreous hemorrhage, and dislocations or disruptions of structures.¹⁵³⁻¹⁵⁶ In addition the structures posterior to the globe such as the optic nerve sheath diameter may be a reflection of other disease in the central nervous system.

Bowel

Abdominal US can aid in the diagnosis a wide array of bowel pathology. Appendicitis is the most common surgical emergency of the abdomen and has traditionally been diagnosed by CT; however trained emergency physicians have been capable of diagnosing appendicitis with point-of-care US with 60-96% sensitivity and 68-98% specificity.¹⁵⁷⁻¹⁷¹ Emergency US has been shown to decrease radiation exposure and length of stay.⁹ Ultrasound for ileus and small bowel obstruction has been performed for decades. It has been shown to be more sensitive and specific for obstruction than x-ray, and can be performed accurately by emergency providers.¹⁷²⁻¹⁷⁴ Pneumoperitoneum can be also diagnosed by US with high sensitivity and specificity, and due to its availability and speed, has been proposed as a screening tool in the acute abdomen. In some countries, US is the first line imaging modality for the diagnosis of diverticulitis.¹⁷⁵⁻¹⁷⁶ With proper training and experience, emergency providers can use this tool to facilitate diagnosis of diverticulitis.¹⁷⁷ Ultrasound can give quick information about abdominal wall masses and suspected hernias, even aiding in the classification of hernias. In addition, it can be performed dynamically and facilitate the reduction of hernias in real-time.¹⁷⁸⁻¹⁸¹ Ultrasound plays a particularly important role in the pediatric population, and is

the initial diagnostic method of choice for both intussusception and pyloric stenosis. Studies have shown that emergency providers with limited training can effectively diagnose these conditions.¹⁸²⁻¹⁸³

Procedural Guidance

Ultrasound guidance has been studied as a useful adjunct to many common ED procedures, including venous access, thoracentesis, paracentesis, joint aspiration, and others.^{137,184-185} Studies since the early 1990s have demonstrated the efficacy of US guidance for central venous cannulation, and the use of this technology has been advocated by the United States Agency for Healthcare Research and Quality as one of the top 11 means of increasing patient safety in the United States.¹⁸⁶ Recently, a randomized controlled study of 201 patients undergoing central venous cannulation demonstrated higher success rates with dynamic US guidance (98% success) when compared with static US guidance (82%) or landmark-based methods (64%).¹³⁶

Appendix 2. Emergency Ultrasound Learning Objectives

Listed below are recommended learning objectives for a comprehensive EUS clinician curriculum, rotation, or series of training courses. For detailed indications, limitations, protocols, documentation requirements, and other important details for each application, please refer to the ACEP Emergency Ultrasound Imaging Criteria Compendium.⁵

Introduction

- Distinguish between consultative, clinical, point of care, and emergency ultrasound (EUS).
- Recognize primary EUS applications.
- Discuss support for EUS from key organizations including ACEP, AMA, ABEM, SAEM, and AIUM.
- Describe ACEP recommendations on training and credentialing in EUS.

Physics & Instrumentation

- Explain ultrasound physics relevant to EUS:
 - Piezoelectric effect
 - Frequency
 - Resolution
 - Attenuation
 - Echogenicity
 - Doppler including pulse wave, color and power
- Operate the EUS system as needed to obtain and interpret images adequate for clinical decision making including:
 - Image mode
 - Gain
 - Time gain compensation
 - Focus
 - Probe types
- Recognize common ultrasound artifacts including:
 - Reverberation
 - Side lobe
 - Mirror
 - Shadowing
 - Enhancement
 - Ring-down

Trauma

- Describe the indications, clinical algorithm, and limitations of EUS in blunt and penetrating thoracoabdominal trauma.
- Perform the EUS protocol for Trauma.
- Identify relevant US anatomy including the pleura, diaphragm, inferior vena cava, pericardium, liver, spleen, kidneys, bladder, prostate and uterus.
- Recognize pathologic findings and pitfalls in the evaluation of pneumothorax, hemothorax, hemopericardium, cardiac activity, volume status, and hemoperitoneum.
- Integrate Trauma EUS findings into individual patient, departmental, and disaster management.

First-Trimester Pregnancy

- Describe the indications, clinical algorithm, and limitations of EUS in first-trimester pregnancy pain and bleeding.
- Understand the utility of quantitative B-HCG in the evaluation of first-trimester pregnancy pain and bleeding.

- Perform EUS protocols for transabdominal and transvaginal views as needed, including fetal heart rate and gestational age measurement techniques.
- Identify relevant US anatomy including the cervix, uterus, adnexa, bladder and cul-de-sac.
- Recognize the relevant findings and pitfalls when evaluating for intrauterine and ectopic pregnancy:
 - Early embryonic structures including the gestational sac, yolk sac, fetal pole, and heart
 - Location of embryonic structures in pelvis
 - Embryonic demise
 - Molar pregnancy
 - Findings of ectopic pregnancy including pseudogestational sac, free fluid, and adnexal masses
- Integrate First Trimester Pregnancy EUS findings into individual patient and departmental management.

Abdominal Aorta

- Describe indications, clinical algorithm, and limitations of EUS in the evaluation of aortic pathology.
- Perform EUS protocols to evaluate the abdominal aorta including measurement techniques.
- Identify relevant US anatomy including the aorta with major branches, inferior vena cava, and vertebral bodies.
- Recognize pathologic findings and pitfalls when evaluating for aortic aneurysm and dissection.
- Integrate Aorta EUS findings into individual patient and departmental management.

Echocardiography and HD Assessment

- Describe the indications and limitations of emergency echocardiography.
- Perform standard echocardiography windows (subcostal, parasternal, and apical) and planes (four chamber, long and short axis).
- Identify relevant US anatomy including pericardium, cardiac chambers, valves, aorta and inferior vena cava.
- Estimate qualitative left ventricular function and central venous pressure to guide HD assessment of patient.
- Recognize cardiac arrest, pericardial effusions with or without tamponade, and dilation of the aortic root or the descending aorta.
- Integrate Emergency echocardiography findings into individual patient and departmental management.

Biliary Tract

- Describe the indications and limitations of EUS of the biliary tract.
- Perform EUS protocols to evaluate the biliary tract.
- Identify relevant US anatomy including the gallbladder, portal triad, inferior vena cava, and liver.
- Recognize the relevant findings and pitfalls when evaluating for cholelithiasis and cholecystitis.
- Integrate EUS of the biliary tract into individual patient and departmental management.

Urinary Tract

- Describe the indications and limitations of EUS of the urinary tract.
- Perform EUS protocols to evaluate the urinary tract.
Identify relevant US anatomy including the renal cortex, renal pelvis, ureter, bladder, liver, and spleen.
- Recognize the relevant findings and pitfalls when evaluating for hydronephrosis, renal calculi, renal masses, and bladder volume.
- Integrate EUS of the urinary tract into individual patient and departmental management.

Deep Vein Thrombosis

- Describe the indications and limitations of EUS for the detection of deep venous thrombosis.

- Perform EUS protocols for the detection of deep venous thrombosis of the upper and lower extremities including:
 - Vessel identification
 - Compression
 - Doppler imaging of respiratory variation and augmentation.
- Identify relevant US anatomy of the upper and lower extremities including the deep venous and arterial systems, major nerves, and lymph nodes.
- Recognize the relevant findings and pitfalls when evaluating for deep venous thrombosis.
- Integrate EUS for deep venous thrombosis into individual patient and departmental management.

Soft Tissue & Musculoskeletal

- Describe the indications and limitations of soft tissue and musculoskeletal EUS.
- Perform EUS protocols for the evaluation of soft tissue and musculoskeletal pathology.
- Identify relevant US anatomy including:
 - Skin
 - Adipose
 - Fascia
 - Muscle
 - Tendons and Ligaments
 - Muscles
 - Lymph Nodes
 - Bones and Joints
- Recognize the relevant findings and pitfalls when evaluating the following:
 - Soft tissue infections: Abscess versus cellulitis
 - Subcutaneous fluid collection identification
 - Foreign body location and removal
 - Tendon injury (laceration, rupture)
 - Fractures
 - Joint identification
- Integrate soft tissue and musculoskeletal EUS findings into individual patient and departmental management.

Thoracic -Airway

- Describe the indications and limitations Thoracic EUS
- Perform EUS protocols for the detection of:
 - Pneumothorax
 - Pleural Effusion
 - Alveolar Interstitial Syndromes
- Identify relevant US anatomy of thoracic structures.
- Recognize the relevant findings and pitfalls when evaluating for thoracic pathology
- Recognize the sonographic findings of tracheal and esophageal anatomy, especially in regard to EM procedures
- Integrate thoracic EUS findings into individual patient and departmental management.

Ocular

- Describe the indications and limitations of ocular EUS.
- Perform EUS protocols for the detection of vitreous hemorrhage, retinal detachment, and other pathology.
- Identify relevant US anatomy of the globe and orbital structures.
- Recognize the relevant findings and pitfalls when evaluating for ocular pathology.
- Integrate ocular EUS into individual patient and departmental management.

Procedural Guidance

- Describe the indications and limitations when using US guidance for bedside procedures.
- Perform EUS protocols for procedural guidance including both transverse and longitudinal approaches when appropriate. These procedures may include:
 - Vascular access: Central and peripheral
 - Confirmation of endotracheal intubation
 - Pericardiocentesis
 - Paracentesis
 - Thoracentesis
 - Foreign body detection removal
 - Bladder aspiration
 - Arthrocentesis
 - Pacemaker placement and capture
 - Abscess identification and drainage
- Identify relevant US anatomy for each particular procedure.
- Recognize the relevant findings and pitfalls when performing EUS for procedural guidance.
- Integrate EUS for procedural guidance into individual patient and departmental management.

Bowel

- Describe the indications and limitations of Bowel EUS
- Perform EUS protocols for the detection of:
 - Appendicitis
 - Bowel Obstruction
 - Pneumoperitoneum
 - Diverticulitis
 - Hernia
 - Pediatric Intussusception and Pyloric Stenosis
- Identify relevant US anatomy of bowel structures.
- Recognize the relevant findings and pitfalls when evaluating for bowel pathology
- Integrate bowel EUS findings into individual patient and departmental management.

Appendix 3. Recommendations for an EM Residency EUS Education Program

Successful EUS Residency Education in accordance with these guidelines requires significant departmental and institutional support. The purpose of these additional recommendations is to delineate the scope of resources required to facilitate the rapid development and maintenance of EUS Residency Education programs. Application of these recommendations is dependent on EM Residency size, current and planned EUS utilization, and institutional capabilities.

EUS Faculty:

1. **EUS Director:** At least one full time EM attending faculty with sufficient EUS program coordination expertise. Sufficient non-clinical time for planning and conducting all EUS program activities is essential to ensuring adequate resident training.
2. **EUS Faculty:** At least one additional full time EM attending faculty member committed to actively developing EUS program expertise. Sufficient non-clinical time for conducting EUS program activities is essential to ensuring adequate resident training. The number of dedicated EUS faculty needed is dependent on the size of the residency and quality of the training program provided.
3. **Credentialed EUS Faculty:** To adequately supervise and educate residents in EUS, a minimum of fifty percent of Core Faculty members at all EM residency programs need to be credentialed in EUS. For example, if a program has 12 core faculty, then 6 need to be credentialed in EUS. May be inclusive of the EUS Director and Faculty.

Equipment and Materials:

1. EUS systems with appropriate transducers and imaging capabilities readily available for immediate resident clinical use 24/7.
2. EUS online or print text reference resources readily available in the ED.
3. Recent and landmark EUS literature as well as opportunities to participate in local quality improvement and research projects need to be provided to residents and core US faculty.

Educational Program Activities:

1. **Initial EUS Training:** Didactic and hands on instruction in EUS physics, machine use, and at least one springboard application such as the Trauma exam need to be provided early in residency as a half or full day course.
2. **Annual EUS Rotations:** Two week rotation in the first year to learn basic EUS knowledge and skills, followed by at least one week in each subsequent year to reinforce learning and acquire more advanced skills. One rotation without continued learning within the EM residency curriculum is inadequate. For each trainee, a minimum of 80 hours of dedicated EUS rotation time is recommended during an EM residency.
3. **Suggested rotation educational methods and assessment measures:**
 - a. **Orientation:** Begin rotation with a baseline EUS skills assessment to identify trainee's unique learning needs. Follow with hands on small group instruction in the ED focusing on machine operation, exam protocols, image optimization and interpretation, documentation, as well as integration of EUS findings into daily clinical practice.
 - b. **Daily supervised scanning shifts with EUS faculty in the ED** to provide opportunities for both proctored and semi-independent image acquisition and interpretation. All training exams are submitted for timely quality assurance review.
 - c. **Weekly Academic Day:**
 - i. **Quality Assurance Review** session during which a portion of current trainee's EUS exams are discussed, focusing on challenging cases, pathology, and integration into daily patient and ED management.
 - ii. **Simulation cases and review of image libraries** for additional exposure to less common pathology.

- iii. Journal club including a discussion of a recent or landmark EUS literature, an online narrated didactic or live lecture, or chapter review.
 - iv. Hands on small group instruction in the ED focusing on current trainees learning needs identified during QA Review or scanning shifts.
 - d. End the rotation with a final assessment of EUS knowledge utilizing a standardized exam such as the ACEP US Online Exams, as well as an additional EUS skill assessment.
 - e. Provide a timely end of EUS rotation assessment of knowledge and skills to each resident. Additionally, provide trainees with continued opportunities to evaluate the EUS program itself.
4. Achieving EUS exam requirements: Completion of set number procedural benchmarks documents adequate experience to develop proficiency. Additional assessment measures described in these guidelines are needed to ensure EUS competency such as participation in QA sessions, SDOT's, OSCE's, and simulation assessments.
5. Ongoing Quality Assurance System: Digital archiving system for EUS exam images and interpretations for timely quality assurance review and trainee feedback on individual exams.
- a. All trainee exams need to be reviewed by EUS faculty until minimum benchmarks are achieved. After this, a proportion of trainee exams need to be reviewed on an ongoing basis throughout residency.
 - b. Timely exam feedback must be provided to trainees during and between EUS rotations. Trainees need ready access to individual exam feedback and total exams completed by application and overall.
6. Integrated EUS training in the residency curriculum: Learning needs to be reinforced during quarterly or biannual EUS workshops comprised of EUS didactics and hands on instruction. An additional 20 hours of dedicated EUS learning between rotations is recommended during a 3 or 4 year residency.

Appendix 4. Recommendations for an EUS Course

Successful training courses in EUS require significant advance planning and resource commitment. Each course requires a curriculum designed by the course director that includes a local trainee needs assessment, learning objectives, educational methods, and assessment measures. The learning objectives for any EUS Course or rotation are listed in Appendix 2. Important considerations are discussed below

1. **Faculty:** Course director must be an emergency ultrasound faculty physician. The course director will recruit other clinicians already credentialed in EUS to assist with knowledge learning, skills training, and trainee assessment. A faculty planning meeting is needed during curriculum development. Additionally, a meeting immediately prior to the course provides all faculty with an understanding of the setup and curriculum.
2. **Site and Set Up:** The ideal course site includes a large didactic room as well as separate rooms or areas for scanning stations. Private areas for endovaginal US are required.
 - a. **Ultrasound Stations:** Appropriate machines and transducers are necessary. The student to instructor ratio should be no higher than 5 to 1 to ensure appropriate skills training.
 - b. **Ultrasound Models:** Image acquisition protocols may be learned on normal live models. Image interpretation requires the incorporation of patients with known pathologic findings, simulators, or incorporation of image libraries.
 - i. Pathology models may include otherwise healthy paid or volunteer persons with pericardial effusions, cholelithiasis, aortic aneurysms and chronic ambulatory peritoneal dialysis patients.
 - ii. Full informed consent should be obtained from all models and a signed waiver of responsibility is recommended. If an undiagnosed finding is discovered in a model, then the Course Director must appropriately notify the model and ensure appropriate follow up.
3. **Knowledge Learning:**
 - a. An introductory course for trainees must include instruction in basic US physics, machine operation, and a small number of initial EUS applications to be clinically utilized. Suggested initial applications include Trauma Ultrasound, Central and Peripheral Venous Access, and Abdominal Aortic Aneurysm Ultrasound. However, the initial applications will vary by local site as determined by a pre-course needs assessment completed by the course director and local trainee leadership.
 - i. A half day introductory course is appropriate for a single application. Longer courses are required for additional applications. Shorter, repeated courses, supplemented by routine, quality assured, EUS performance during clinical work, are more likely to improve learning and utilization.
 - b. Pre and post course educational materials must be provided to reinforce course learning. Suggested sources of information include course director approved online narrated lectures, podcasts, websites, traditional textbooks, didactic syllabi, and journal articles.
 - i. Utilization of the flipped classroom provides the opportunity for more focused didactics reviewing key concepts and answering trainee questions at the course. Focused didactics provide the opportunity for increased skill training.
 - ii. Frequent rotations between didactics and skills training sessions improve trainee and faculty engagement.
4. **Skills Training:**
 - a. The technical laboratory is an integral component of any ultrasound course.

- a. Based on the needs assessment, appropriate and specific learning objectives need to be defined for each station.
 - i. Trainees should be deliberately assigned to small groups not necessarily including immediate peers to create more focused learning teams.
 - ii. For trainees with prior EUS experience, an initial skills assessment with an SDOT or simulator will help to ensure that trainee specific instruction is provided.
 - iii. Instructors should work to maximize the time that the transducer is the trainee's hands, avoid over teaching of advanced concepts beyond the trainees needs, encourage questions, and consistently engage each trainee.

Appendix 5. EUS and CUS Training for Medical Students

EUS Training during a one month EM Rotation:

General EM clerkships should include an introduction to EUS that may entail a single dedicated emergency US shift with direct faculty supervision, a one-day EUS course, or simply case-by-case incorporation of EUS into patient care in the ED. Students should strive to become familiar with a single emergency US application such as the FAST exam, and should be exposed to additional EUS exams over the course of the clerkship. EUS literature and selected textbook chapters should be made available for student review.

Dedicated EUS rotation recommendations:

1. Emergency US rotations begins with instruction in Physics/Instrumentation, followed by select applications such as FAST, Aorta, Renal, Biliary Cardiac, Procedures, Pelvic (including endovaginal US), Deep Venous Thrombosis, and Skin/Soft Tissue/Musculoskeletal.
2. Didactic education should be delivered in electronic, preferably online, format in an attempt to maximize hands-on education in the clinical area. Course directors may choose to utilize the emergency US didactic materials available on the ACEP Web site.
3. Assessment should include an online pre-test including still image/video interpretation and case-based applications of EUS. To assess their progress, students will complete the test again at the end of the rotation.
4. Each student should obtain approximately 100 scans over the course of a 4-week rotation, or approximately 75 scans over the course of a 2-week rotation. Dedicated shifts may include evenings or weekends to maximize exposure to pathology and interesting emergency US cases. Students should generate personal log of EUS exams on which to build during their postgraduate education.
5. All student-performed scans should be directly supervised by EUS credentialed faculty or recorded for subsequent quality assurance review with the rotation director.
6. Students should complete the reading of one EUS text or viewing of an online curriculum over the course of the rotation. In addition, students should identify a current publication relevant to EUS and discuss their findings with the rotation director.

Additional Opportunities for CUS Training in Undergraduate Medical Education:

Additionally, opportunities abound for EUS directors to get involved in medical student education at the various levels of medical school training. With the advent of more US in the various specialties, this preparation in medical school can benefit students with interests outside of emergency medicine.

EUS directors could consider incorporating US into.

1. Gross anatomy course highlighting common US anatomy (eg, FAST exam during study of the abdomen, heart)
2. Physiology course highlighting doppler, M mode, and basic waveform analysis.
3. Pathology course highlighting common pathologies such as fluid in potential spaces, depressed cardiac function, cellulitis, abscess, retinal detachment or other commonly seen pathologies in the ED.
4. Introduction to Clinical Medicine course highlighting US guided vascular access.
5. Ultrasound in the physical exam. Although US use in clinical practice is a diagnostic test that warrants a generated report, it can be used to teach components of the physical exam. For example, teaching the traditional cardiac auscultation can be augmented with cardiac images of the heart.
6. Ultrasound training before clinical rotations. Some schools have developed short clinical skills time before rotations where US can be implemented to help student learners see how US is used in that particular field.
7. Ultrasound electives in the 4th year can include a longitudinal program where US lectures, hands on, and journal club can be incorporated into a course.

The future of US in medical education is still being built. It seems like there are early adopters trying to implement US yet there is still a lack of consensus if or how US should be optimally applied in medical

education. The key component is finding an US champion to spearhead US into the undergraduate medical education framework. From there, getting students involved through an US interest group can improve the impact through direct feedback and student motivation. The two methods of a top down administrative implementation of US in medical education is the best method, yet warrants buy in from the dean and the curriculum committee. A bottom up approach through student interest, electives and extracurricular exposure takes longer but can still impact student competence in US. The next 5-10 years are sure to bring more clarity to this topic as US continues to expand.

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References

1. Heller MB, Mandavia D, Tayal VS, et al. Residency training in emergency ultrasound: fulfilling the mandate. *Acad Emerg Med.* 2002;9:835-9.
2. ACR-SPR-SRU Practice Parameter for Performing and Interpreting Diagnostic Ultrasound Examinations. 2017. Accessed June 20, 2018 at <https://www.acr.org/-/media/ACR/Files/Practice-Parameters/us-perf-interpret.pdf>
3. ACEP Emergency Ultrasound Section. Emergency Ultrasound Coding and Reimbursement Document. 2009. Accessed June 20, 2018 at <https://www.acep.org/how-we-serve/sections/emergency-ultrasound/subcommittees/reimbursement/>
4. Geria RN, Raio CC, Tayal V. Point-of-care ultrasound: not a stethoscope-a separate clinical entity. *J Ultrasound Med.* 2015;34:172-3.
5. American College of Emergency Physicians. Definition of Clinical Ultrasonography [policy statement]. Approved January 2014. Accessed June 20, 2018 at <https://www.acep.org/patient-care/policy-statements/definition-of-clinical-ultrasonography>
6. American College of Emergency Physicians. Emergency Ultrasound Imaging Criteria Compendium [policy statement]. Approved October 2014. Accessed June 20, 2018 at <https://www.acep.org/globalassets/uploads/uploaded-files/acep/by-medical-focus/ultrasound/emergency-ultrasound-imaging-criteria-compendium.pdf>
7. Shah VP, Tunik MG, Tsung JW. Prospective evaluation of point-of-care ultrasonography for the diagnosis of pneumonia in children and young adults. *JAMA Pediatr.* 2013;167:119-25.
8. Gallagher RA, Levy J, Vieira RL, et al. Ultrasound assistance for central venous catheter placement in a pediatric emergency department improves placement success rates. *Acad Emerg Med.* 2014;21:981-6.

9. Elikashvili I, Tay ET, Tsung JW. The effect of point-of-care ultrasonography on emergency department length of stay and computed tomography utilization in children with suspected appendicitis. *Acad Emerg Med.* 2014;21:163-70.
10. Bartocci M, Fabrizi G, Valente I, et al. Intussusception in childhood: role of sonography on diagnosis and treatment. *J Ultrasound.* 2015;18:205-11.
11. Plumb J, Mallin M, Bolte RG. The role of ultrasound in the emergency department evaluation of the acutely painful pediatric hip. *Pediatr Emerg Care.* 2015;31:54-8; quiz 9-61.
12. Deanehan J, Gallagher R, Vieira R, et al. Bedside hip ultrasonography in the pediatric emergency department: a tool to guide management in patients presenting with limp. *Pediatr Emerg Care.* 2014;30:285-7.
13. Marin JR, Lewiss RE, AAP, et al. Point-of-care ultrasonography by pediatric emergency medicine physicians. *Pediatrics.* 2015;135(4):e1113-22.
14. Vieira RL, Hsu D, Nagler J, et al. Pediatric emergency medicine fellow training in ultrasound: consensus educational guidelines. *Acad Emerg Med.* 2013;20:300-6.
15. Zieleskiewicz L, Muller L, Lakhali K, et al. Point-of-care ultrasound in intensive care units: assessment of 1073 procedures in a multicentric, prospective, observational study. *Intensive Care Med.* 2015;41:1638-47.
16. Gallard E, Redonnet JP, Bourcier JE, et al. Diagnostic performance of cardiopulmonary ultrasound performed by the emergency physician in the management of acute dyspnea. *Am J Emerg Med.* 2015;33:352-8.
17. Nelson BP, Sanghvi A. Out of hospital point of care ultrasound: current use models and future directions. *Eur J Trauma Emerg Surg.* 2015.
18. Press GM, Miller SK, Hassan IA, et al. Evaluation of a training curriculum for prehospital trauma ultrasound. *J Emerg Med.* 2013;45:856-64.
19. Taylor J, McLaughlin K, McRae A, et al. Use of prehospital ultrasound in North America: a survey of emergency medical services medical directors. *BMC Emerg Med.* 2014;14:6.
20. Shorter M, Macias DJ. Portable handheld ultrasound in austere environments: use in the Haiti disaster. *Prehosp Disaster Med.* 2012;27:172-7.
21. Zhou J, Huang J, Wu H, et al. Screening ultrasonography of 2,204 patients with blunt abdominal trauma in the Wenchuan earthquake. *J Trauma Acute Care Surg.* 2012;73:890-4.
22. Zhang S, Zhu D, Wan Z, et al. Utility of point-of-care ultrasound in acute management triage of earthquake injury. *Am J Emerg Med.* 2014;32:92-5.
23. Raja AS, Propper BW, Vandenberg SL, et al. Imaging utilization during explosive multiple casualty incidents. *J Trauma.* 2010;68:1421-4.
24. Shah S, Dalal A, Smith RM, et al. Impact of portable ultrasound in trauma care after the Haitian earthquake of 2010. *Am J Emerg Med.* 2010;28:970-1.
25. Kirkpatrick AW, Campbell MR, Novinkov OL, et al. Blunt trauma and operative care in microgravity: a review of microgravity physiology and surgical investigations with implications for critical care and operative treatment in space. *J Am Coll Surg.* 1997;184:441-53.
26. Campbell MR, Billica RD, Johnston SL, et al. Performance of advanced trauma life support procedures in microgravity. *Aviat Space Environ Med.* 2002;73:907-12.
27. Nelson BP, Sanghvi A. Out of hospital point of care ultrasound: current use models and future directions. *Eur J Trauma Emerg Surg.* 2016;42:139-50.
28. Russell TC, Crawford PF. Ultrasound in the austere environment: a review of the history, indications, and specifications. *Mil Med.* 2013;178:21-8.
29. Rozanski TA, Edmondson JM, Jones SB. Ultrasonography in a forward-deployed military hospital. *Mil Med.* 2005;170:99-102.
30. Morgan AR, Vasios WN, Hubler DA, et al. Special operator level clinical ultrasound: an experience in application and training. *J Spec Oper Med.* 2010;10:16-21.
31. Strode CA, Rubal BJ, Gerhardt RT, et al. Satellite and mobile wireless transmission of focused assessment with sonography in trauma. *Acad Emerg Med.* 2003;10:1411-4.

32. American College of Emergency Physicians. Emergency Ultrasound Guidelines [policy statement]. *Ann Emerg Med.* 2009;53:550-70.
33. American College of Emergency Physicians. Emergency Ultrasound Guidelines-2001. *Ann Emerg Med.* 2001;38:470-81.
34. Beeson MS, Carter WA, Christopher TA, et al. The development of the emergency medicine milestones. *Acad Emerg Med.* 2013;20:724-9.
35. American College of Emergency Physicians. Use of Ultrasound Imaging by Emergency Physicians. *Ann Emerg Med.* 2001;38:469-70.
36. Lewiss RE, Hoffmann B, Beaulieu Y, et al. Point-of-care ultrasound education: the increasing role of simulation and multimedia resources. *J Ultrasound Med.* 2014;33:27-32.
37. Thoma B, Joshi N, Trueger NS, et al. Five strategies to effectively use online resources in emergency medicine. *Ann Emerg Med.* 2014;64:392-5.
38. Scott KR, Hsu CH, Johnson NJ, et al. Integration of social media in emergency medicine residency curriculum. *Ann Emerg Med.* 2014;64:396-404.
39. American College of Emergency Physicians. Sonoguide. Accessed June 20, 2018 at <http://www.acep.org/sonoguide>
40. AEUS Narrated Lecture Series. SAEM, 2015. Accessed June 3, 2016 at: <http://community.saem.org/blogs/matt-fields/2014/09/07/aeus-narrated-lecture-series>
41. Knudson MM, Sisley AC. Training residents using simulation technology: experience with ultrasound for trauma. *J Trauma.* 2000;48:659-65.
42. Damewood S, Jeanmonod D, Cadigan B. Comparison of a multimedia simulator to a human model for teaching FAST exam image interpretation and image acquisition. *Acad Emerg Med.* 2011;18:413-9.
43. Barsuk JH, McGaghie WC, Cohen ER, et al. Simulation-based mastery learning reduces complications during central venous catheter insertion in a medical intensive care unit. *Crit Care Med.* 2009;37:2697-701.
44. Barsuk JH, Cohen ER, Vozenilek JA. Simulation-based education with mastery learning improves paracentesis skills. *J Grad Med Educ.* 2012;4:23-7.
45. Mendiratta-Lala M, Williams T, de Quadros N, et al. The use of a simulation center to improve resident proficiency in performing ultrasound-guided procedures. *Acad Radiol.* 2010;17:535-40.
46. Sekiguchi H, Bhagra A, Gajic O, et al. A general Critical Care Ultrasonography workshop: results of a novel Web-based learning program combined with simulation-based hands-on training. *J Crit Care.* 2013;28:217.e7-12.
47. Ericsson KA. Acquisition and maintenance of medical expertise: a perspective from the expert-performance approach with deliberate practice. *Acad Med.* 2015;90:1471-86.
48. Lewiss RE, Pearl M, Nomura JT, et al. CORD-AEUS: consensus document for the emergency ultrasound milestone project. *Acad Emerg Med.* 2013;20:740-5.
49. Blehar DJ, Barton B, Gaspari RJ. Learning curves in emergency ultrasound education. *Acad Emerg Med.* 2015;22:574-82.
50. Mateer J, Plummer D, Heller M, et al. Model Curriculum for Physician Training in Emergency Ultrasonography. *Ann Emerg Med.* 1994;23:95-102.
51. Strauss R. US is an embedded requirement for EM Residencies. Atlanta, Georgia: SAEM meeting; 2001.
52. Akhtar S, Theodoro D, Gaspari R, et al. Resident training in emergency ultrasound: consensus recommendations from the 2008 Council of Emergency Medicine Residency Directors Conference. *Acad Emerg Med.* 2009;16 Suppl 2:S32-6.
53. Counselman FL, Borenstein MA, Chisholm CD, et al. The 2013 Model of the Clinical Practice of Emergency Medicine. *Acad Emerg Med.* 2014;21:574-98.
54. Emergency Ultrasound Fellowship Guidelines - An Information Paper. July 2011. Accessed June 18, 2018, at https://www.acep.org/globalassets/uploads/uploaded-files/acep/membership/sections-of-membership/ultra/eus_fellowship_ip_final_070111.pdf

55. Lewiss RE, Tayal VS, Hoffmann B, et al. The core content of clinical ultrasonography fellowship training. *Acad Emerg Med*. 2014;21:456-61.
56. Adhikari S, Raio C, Morrison D, et al. Do emergency ultrasound fellowship programs impact emergency medicine residents' ultrasound education? *J Ultrasound Med*. 2014;33:999-1004.
57. Adhikari S, Fiorello A. Emergency ultrasound fellowship training: a novel team-based approach. *J Ultrasound Med*. 2014;33:1821-6.
58. Hoppmann R, Cook T, Hunt P, et al. Ultrasound in medical education: a vertical curriculum at the University of South Carolina School of Medicine. *J S C Med Assoc*. 2006;102:330-4.
59. Cook T, Hunt P, Hoppman R. Emergency medicine leads the way for training medical students in clinician-based ultrasound: a radical paradigm shift in patient imaging. *Acad Emerg Med*. 2007;14:558-61.
60. Fox JC, Chiem AT, Rooney KP, et al. Web-based lectures, peer instruction and ultrasound-integrated medical education. *Med Educ*. 2012;46:1109-10.
61. Dreher SM, DePhilip R, Bahner D. Ultrasound exposure during gross anatomy. *J Emerg Med*. 2014;46:231-40.
62. Bahner DP, Jasne A, Boore S, et al. The ultrasound challenge: a novel approach to medical student ultrasound education. *J Ultrasound Med*. 2012;31:2013-6.
63. Hall MK, Mirjalili SA, Moore CL, et al. The student's dilemma, liver edition: incorporating the sonographer's language into clinical anatomy education. *Anat Sci Educ*. 2015;8:283-8.
64. Ahn JS, French AJ, Thiessen ME, et al. Training peer instructors for a combined ultrasound/physical exam curriculum. *Teach Learn Med*. 2014;26:292-5.
65. Swamy M, Searle RF. Anatomy teaching with portable ultrasound to medical students. *BMC Med Educ* 2012;12:99.
66. Fodor D, Badea R, Poanta L, et al. The use of ultrasonography in learning clinical examination - a pilot study involving third year medical students. *Med Ultrasound*. 2012;14:177-81.
67. Decara JM, Kirkpatrick JN, Spencer KT, et al. Use of hand-carried ultrasound devices to augment the accuracy of medical student bedside cardiac diagnoses. *J Am Soc Echocardiogr*. 2005;18:257-63.
68. Arger PH, Schultz SM, Sehgal CM, et al. Teaching medical students diagnostic sonography. *J Ultrasound Med*. 2005;24:1365-9.
69. Knobe M, Munker R, Sellei RM, et al. Peer teaching: a randomised controlled trial using student-teachers to teach musculoskeletal ultrasound. *Med Educ*. 2010;44:148-55.
70. Jeppesen KM, Bahner DP. Teaching bedside sonography using peer mentoring: a prospective randomized trial. *J Ultrasound Med*. 2012;31:455-9.
71. American Medical Association. H-230.960 Privileging for Ultrasound Imaging. Accessed June 20, 2018, at <https://policysearch.ama-assn.org/policyfinder/detail/privileging%20for%20ultrasound%20imaging?uri=%2FAMADoc%2FHOD.xml-0-1591.xml>
72. American College of Emergency Physicians. Emergency Ultrasound Certification by External Entities [policy statement]. Approved June 2014. Accessed June 20, 2018 at <https://www.acep.org/patient-care/policy-statements/emergency-ultrasound-certification-by-external-entities>
73. OPPE and FPPE: Tools to help make privileging decisions. The Joint Commission, 2013. Accessed December 20, 2015, at http://www.jointcommission.org/jc_physician_blog/oppe_fppe_tools_privileging_decisions/
74. American College of Emergency Physicians. Clinical Ultrasound Accreditation Program. 2015. Accessed June 20, 2018, at <http://www.acep.org/CUAP>
75. American College of Emergency Physicians. Emergency Ultrasound Standard Reporting Guidelines. Accessed June 20, 2018 at https://www.acep.org/globalassets/uploads/uploaded-files/acep/by-medical-focus/ultrasound/eus_srgs_111511_edited0116.pdf.

76. American College of Emergency Physicians. Emergency Ultrasound: Workflow White Paper. 2013. Accessed June 20, 2018 at <https://www.acep.org/globalassets/uploads/uploaded-files/acep/membership/sections-of-membership/ultra/workflow-white-paper.pdf>
77. Mandavia DP, Aragona J, Childs J, et al. Prospective evaluation of standardized ultrasound training for emergency physicians. *Acad Emerg Med*. 1999;6:382.
78. Stein JC, Wang R, Adler N, et al. Emergency physician ultrasonography for evaluating patients at risk for ectopic pregnancy: a meta-analysis. *Ann Emerg Med*. 2010;56:674-83.
79. Ideal Ultrasound Machine Features for the EM and Critical Care Environment. 2014. Accessed May 13, 2016 at <http://www.acep.org/Clinical---Practice-Management/Ideal-Ultrasound-Machine-Features-for-the-Emergency-Medicine-and-Critical-Care-Environment-2008/>
80. Sutherland JE, Sutphin D, Redican K, et al. Telesonography: foundations and future directions. *J Ultrasound Med*. 2011;30:517-22.
81. Labovitz AJ, Noble VE, Bierig M, et al. Focused cardiac ultrasound in the emergent setting: a consensus statement of the American Society of Echocardiography and American College of Emergency Physicians. *J Am Soc Echocardiogr*. 2010;23:1225-30.
82. Sonosite iViz. 2016. Accessed March 30, 2016, at <http://www.sonosite.com/sonosite-iviz>.
83. Philips Lumify. Accessed March 30, 2016, at <http://www.lumify.philips.com/web/>.
84. Acuson Siemens Freestyle Ultrasound System. Siemens. Accessed March 30, 2016, at <http://www.healthcare.siemens.com/ultrasound/ultrasound-point-of-care/acuson-freestyle-ultrasound-machine>.
85. VScan portfolio. Accessed March 30, 2016, at http://www3.gehealthcare.com/en/products/categories/ultrasound/vscan_portfolio.
86. Sutherland JE, Sutphin HD, Rawlins F, et al. A comparison of telesonography with standard ultrasound care in a rural Dominican clinic. *J Telemed Telecare*. 2009;15:191-5.
87. Hoffmann R, Pohlemann T, Wippermann B, et al. [Management of sonography in blunt abdominal trauma]. *Unfallchirurg*. 1989;92:471-6.
88. Ma OJ, Mateer JR, Ogata M, et al. Prospective analysis of a rapid trauma ultrasound examination performed by emergency physicians. *J Trauma*. 1995;38:879-85.
89. Plummer D, Brunnette D, Asinger R, et al. Emergency Department Echocardiography Improves Outcome in Penetrating Cardiac Injury. *Ann Emerg Med*. 1992;21:709-12.
90. Melniker LA, Leibner E, McKenney MG, et al. Randomized controlled clinical trial of point-of-care, limited ultrasonography for trauma in the emergency department: the first sonography outcomes assessment program trial. *Ann Emerg Med*. 2006;48:227-35.
91. Nandipati KC, Allamaneni S, Kakarla R, et al. Extended focused assessment with sonography for trauma (EFAST) in the diagnosis of pneumothorax: experience at a community based level I trauma center. *Injury*. 2011;42:511-4.
92. Sheng AY, Dalziel P, Liteplo AS, et al. Focused Assessment with Sonography in Trauma and Abdominal Computed Tomography Utilization in Adult Trauma Patients: Trends over the Last Decade. *Emerg Med Int*. 2013;2013:678380.
93. Durham B. Emergency medicine physicians saving time with ultrasound. *Am J Emerg Med*. 1996;14:309-13.
94. Jang TB, Ruggeri W, Dyne P, et al. Learning curve of emergency physicians using emergency bedside sonography for symptomatic first-trimester pregnancy. *J Ultrasound Med*. 2010;29:1423-8.
95. Mateer JR, Valley VT, Aiman EJ, et al. Outcome analysis of a protocol including bedside endovaginal sonography in patients at risk for ectopic pregnancy. *Ann Emerg Med*. 1996;27:283-9.
96. Panebianco NL, Shofer F, Fields JM, et al. The utility of transvaginal ultrasound in the ED evaluation of complications of first trimester pregnancy. *Am J Emerg Med*. 2015;33:743-8.
97. Kuhn M, Bonnin RL, Davey MJ, et al. Emergency department ultrasound scanning for abdominal aortic aneurysm: accessible, accurate, and advantageous. *Ann Emerg Med*. 2000;36:219-23.
98. Tayal VS, Graf CD, Gibbs, MA. Prospective Study of Accuracy and Outcome of Emergency Ultrasound for Abdominal Aortic Aneurysm over Two Years. *Acad Emerg Med*. 2003;10:867-71.

99. Goodman A, Perera P, Mailhot T, et al. The role of bedside ultrasound in the diagnosis of pericardial effusion and cardiac tamponade. *J Emerg Trauma Shock*. 2012;5:72-5.
100. Mandavia D, Hoffner R, Mahaney K, et al. Bedside Echocardiography by Emergency Physicians. *Ann Emerg Med*. 2001;38:377-82.
101. Blaivas M, Fox J. Outcome in cardiac arrest patients found to have cardiac standstill on the bedside emergency department echocardiogram. *Acad Emerg Med*. 2001;8:616-21.
102. Moore CL, Rose GA, Tayal VS, et al. Determination of left ventricular function by emergency physician echocardiography of hypotensive patients. *Acad Emerg Med*. 2002;9(3):186-93.
103. Jones AE, Tayal VS, Sullivan DM, et al. Randomized, controlled trial of immediate versus delayed goal-directed ultrasound to identify the cause of nontraumatic hypotension in emergency department patients. *Crit Care Med*. 2004;32:1703-8.
104. Volpicelli G, Lamorte A, Tullio M, et al. Point-of-care multiorgan ultrasonography for the evaluation of undifferentiated hypotension in the emergency department. *Intensive Care Med*. 2013;39:1290-8.
105. Anderson KL, Jenq KY, Fields JM, et al. Diagnosing heart failure among acutely dyspneic patients with cardiac, inferior vena cava, and lung ultrasonography. *Am J Emerg Med*. 2013;31:1208-14.
106. Russell FM, Ehrman RR, Cosby K, et al. Diagnosing acute heart failure in patients with undifferentiated dyspnea: a lung and cardiac ultrasound (LuCUS) protocol. *Acad Emerg Med*. 2015;22:182-91.
107. Kanji HD, McCallum J, Sirounis D, et al. Limited echocardiography-guided therapy in subacute shock is associated with change in management and improved outcomes. *J Crit Care*. 2014;29:700-5.
108. Nagdev AD, Merchant RC, Tirado-Gonzalez A, et al. Emergency department bedside ultrasonographic measurement of the caval index for noninvasive determination of low central venous pressure. *Ann Emerg Med*. 2010;55:290-5.
109. Machare-Delgado E, Decaro M, Marik PE. Inferior vena cava variation compared to pulse contour analysis as predictors of fluid responsiveness: a prospective cohort study. *J Intensive Care Med*. 2011;26:116-24.
110. Barbier C, Loubières Y, Schmit C, et al. Respiratory changes in inferior vena cava diameter are helpful in predicting fluid responsiveness in ventilated septic patients. *Intensive Care Med*. 2004;30:1740-6.
111. Blehar DJ, Glazier S, Gaspari RJ. Correlation of corrected flow time in the carotid artery with changes in intravascular volume status. *J Crit Care*. 2014;29:486-8.
112. Lichtenstein DA, Mezière GA, Lagoueyte JF, et al. A-lines and B-lines: lung ultrasound as a bedside tool for predicting pulmonary artery occlusion pressure in the critically ill. *Chest*. 2009;136:1014-20.
113. Dinh VA, Ko HS, Rao R, et al. Measuring cardiac index with a focused cardiac ultrasound examination in the ED. *Am J Emerg Med*. 2012;30:1845-51.
114. Weekes AJ, Thacker G, Troha D, et al. Diagnostic Accuracy of Right Ventricular Dysfunction Markers in Normotensive Emergency Department Patients With Acute Pulmonary Embolism. *Ann Emerg Med*. 2016. Mar 11. pii: S0196-0644(16)00037-8. doi: 10.1016/j.annemergmed.2016.01.027. [Epub ahead of print]
115. Weekes AJ, Reddy A, Lewis MR, et al. E-point septal separation compared to fractional shortening measurements of systolic function in emergency department patients: prospective randomized study. *J Ultrasound Med*. 2012.31:1891-7.
116. Weekes AJ, Tassone HM, Babcock A, et al. Comparison of serial qualitative and quantitative assessments of caval index and left ventricular systolic function during early fluid resuscitation of hypotensive emergency department patients. *Acad Emerg Med*. 2011;18:912-21.
117. Villar J, Summers SM, Menchine MD, et al. The absence of gallstones on point-of-care ultrasound rules out acute cholecystitis. *J Emerg Med*. 2015;49:475-80.
118. Kendall JL, Shimp RJ. Performance and Interpretation of Limited Right Upper Quadrant Ultrasound by Emergency Physicians. *J Emerg Med*. 2001;21(1)7-13.

119. Miller AH, Pepe PE, Brockman CR, et al. ED ultrasound in hepatobiliary disease. *J Emerg Med.* 2006;30:69-74.
120. Ross M, Brown M, McLaughlin K, et al. Emergency physician-performed ultrasound to diagnose cholelithiasis: a systematic review. *Acad Emerg Med.* 2011;18:227-35.
121. Summers SM, Scruggs W, Menchine MD, et al. A prospective evaluation of emergency department bedside ultrasonography for the detection of acute cholecystitis. *Ann Emerg Med.* 2010;56:114-22.
122. Blaiwas M, Harwood RA, Lambert MJ. Decreasing Length of Stay with Emergency Department Gallbladder Ultrasonography. *Acad Emerg Med.* 1999;6:541.
123. Fields JM, Fischer JI, Anderson KL, et al. The ability of renal ultrasound and ureteral jet evaluation to predict 30-day outcomes in patients with suspected nephrolithiasis. *Am J Emerg Med.* 2015;33:1402-6.
124. Ng C, Tsung JW. Avoiding computed tomography scans by using point-of-care ultrasound when evaluating suspected pediatric renal colic. *J Emerg Med.* 2015;49:165-71.
125. Rosen CL, Brown DFM, Sagarin M, et al. Ultrasonography by emergency physicians in detecting hydronephrosis in patients with suspected ureteral colic. *Acad Emerg Med.* 1996;3:541.
126. Gaspari RJ, Horst K. Emergency ultrasound and urinalysis in the evaluation of flank pain. *Acad Emerg Med.* 2005;12:1180-4.
127. Smith-Bindman R, Aubin C, Bailitz J, et al. Ultrasonography versus computed tomography for suspected nephrolithiasis. *N Engl J Med.* 2014;371:1100-10.
128. Pomero F, Dentali F, Borretta V, et al. Accuracy of emergency physician-performed ultrasonography in the diagnosis of deep-vein thrombosis: a systematic review and meta-analysis. *Thromb Haemost.* 2013;109:137-45.
129. Jang T, Docherty M, Aubin C, et al. Resident-performed compression ultrasonography for the detection of proximal deep vein thrombosis: Fast and accurate. *Acad Emerg Med.* 2004;4:319-22.
130. Burnside PR, Brown MD, Kline JA. Systematic review of emergency physician-performed ultrasonography for lower-extremity deep vein thrombosis. *Acad Emerg Med.* 2008;15:493-8.
131. Theodoro D, Blaiwas M, Duggal S, et al. Real-time B-mode ultrasound in the ED saves time in the diagnosis of deep vein thrombosis (DVT). *Am J Emerg Med.* 2004;22:197-200.
132. Adhikari S, Blaiwas M. Utility of bedside sonography to distinguish soft tissue abnormalities from joint effusions in the emergency department. *J Ultrasound Med.* 2010;29:519-26.
133. Squire BT, Fox JC, Anderson C. ABSCESS: applied bedside sonography for convenient evaluation of superficial soft tissue infections. *Acad Emerg Med.* 2005;12:601-6.
134. Tayal VS, Hasan N, Norton HJ, et al. The effect of soft-tissue ultrasound on the management of cellulitis in the emergency department. *Acad Emerg Med.* 2006;13:384-8.
135. Marshburn TH, Legome E, Sargsyan A, et al. Goal-directed ultrasound in the detection of long-bone fractures. *J Trauma.* 2004;57:329-32.
136. O'Malley P, Tayal VS. Use of emergency musculoskeletal sonography in diagnosis of an open fracture of the hand. *J Ultrasound Med.* 2007;26:679-82.
137. Roy S, Dewitz A, Paul I. Ultrasound-assisted ankle arthrocentesis. *Am J Emerg Med.* 1999;17:300-1.
138. Freeman K, Dewitz A, Baker WE. Ultrasound-guided hip arthrocentesis in the ED. *Am J Emerg Med.* 2007;25:80-6.
139. Nesselroade RD, Nickels LC. Ultrasound diagnosis of bilateral quadriceps tendon rupture after statin use. *West J Emerg Med.* 2010;11:306-9.
140. Tayal VS, Nicks BA, Norton HJ. Emergency ultrasound evaluation of symptomatic nontraumatic pleural effusions. *Am J Emerg Med.* 2006;24:782-6.
141. Volpicelli G, Zanobetti M. Lung ultrasound and pulmonary consolidations. *Am J Emerg Med.* 2015;33:1307-8.
142. Volpicelli G, Boero E, Sverzellati N, et al. Semi-quantification of pneumothorax volume by lung ultrasound. *Intensive Care Med.* 2014;40:1460-7.
143. Volpicelli G. Point-of-care lung ultrasound. *Praxis (Bern 1994).* 2014;103:711-6.

144. Volpicelli G. Interpreting lung ultrasound B-lines in acute respiratory failure. *Chest*. 2014;146:e230.
145. Blaivas M, Lyon M, Duggal S. A prospective comparison of supine chest radiography and bedside ultrasound for the diagnosis of traumatic pneumothorax. *Acad Emerg Med*. 2005;12:844-9.
146. Karacabey S, Sanrı E, Gencer EG, et al. Tracheal ultrasonography and ultrasonographic lung sliding for confirming endotracheal tube placement: Faster? Reliable? *Am J Emerg Med*. 2016. Jan 26. pii: S0735-6757(16)00037-1. doi: 10.1016/j.ajem.2016.01.027. [Epub ahead of print]
147. Siddiqui N, Arzola C, Friedman Z, et al. Ultrasound Improves Cricothyrotomy Success in Cadavers with Poorly Defined Neck Anatomy: A Randomized Control Trial. *Anesthesiology*. 2015;123:1033-41.
148. Gottlieb M, Bailitz J. Can Transtracheal Ultrasonography Be Used to Verify Endotracheal Tube Placement? *Ann Emerg Med*. 2015;66:394-5.
149. Gottlieb M, Bailitz JM, Christian E, et al. Accuracy of a novel ultrasound technique for confirmation of endotracheal intubation by expert and novice emergency physicians. *West J Emerg Med*. 2014;15:834-9.
150. Tessaro MO, Arroyo AC, Haines LE, et al. Inflating the endotracheal tube cuff with saline to confirm correct depth using bedside ultrasonography. *CJEM*. 2015;17:94-8.
151. Li Y, Wang J, Wei X. Confirmation of endotracheal tube depth using ultrasound in adults. *Can J Anaesth*. 2015;62:832.
152. Das SK, Choupoo NS, Haldar R, et al. Transtracheal ultrasound for verification of endotracheal tube placement: a systematic review and meta-analysis. *Can J Anaesth*. 2015;62:413-23.
153. Vrablik ME, Snead GR, Minnigan HJ, et al. The diagnostic accuracy of bedside ocular ultrasonography for the diagnosis of retinal detachment: a systematic review and meta-analysis. *Ann Emerg Med*. 2015;65:199-203.e1.
154. Tayal VS, Neulander M, Norton HJ, et al. Emergency department sonographic measurement of optic nerve sheath diameter to detect findings of increased intracranial pressure in adult head injury patients. *Ann Emerg Med*. 2007;49:508-14.
155. Kilker BA, Holst JM, Hoffmann B. Bedside ocular ultrasound in the emergency department. *Eur J Emerg Med*. 2014;21:246-53.
156. Blaivas M. Bedside emergency department ultrasonography in the evaluation of ocular pathology. *Acad Emerg Med*. 2000;7:947-50.
157. Mallin M, Craven P, Ockerse P, et al. Diagnosis of appendicitis by bedside ultrasound in the ED. *Am J Emerg Med*. 2015;33:430-2.
158. Zeidan BS, Wasser T, Nicholas GG. Ultrasonography in the diagnosis of acute appendicitis. *J R Coll Surg Edinb*. 1997;42:24-6.
159. West W, Brady-West D, McDonald A, et al. Ultrasound and white blood cell counts in suspected acute appendicitis. *West Indian Med J*. 2006;55:100-2.
160. Terasawa T, Hartling L, Cramer K, Klassen T. Diagnostic Accuracy of Ultrasound and Computed Tomography for Emergency Department Diagnosis of Appendicitis: A Systematic Review. 2nd International EM Conference 2003.
161. Terasawa T, Blackmore CB, Bent S, et al. Systematic review: Computed tomography and ultrasonography to detect acute appendicitis in adults and adolescents. *Ann Intern Med*. 2004;141:537-46.
162. Tayal VS, Bullard M, Swanson DR, et al. ED endovaginal pelvic ultrasound in nonpregnant women with right lower quadrant pain. *Am J Emerg Med*. 2008;26:81-5.
163. Sivitz AB, Cohen SG, Tejani C. Evaluation of acute appendicitis by pediatric emergency physician sonography. *Ann Emerg Med*. 2014;64:358-64.e4.
164. Puylaert JB, Rutgers PH, Lalisang RI, et al. A prospective study ultrasonography in the diagnosis of appendicitis. *N Engl J Med*. 1987;317:666-9.
165. Poortman P, Lohle PNM, Schoemaker CMC, et al. Comparison of CT and sonography in the diagnosis of acute appendicitis. *AJR Am J Roentgenol*. 2003;181:1355-9.

166. Oshita R, Hunt M, Fox J, et al. A retrospective analysis of the use of bedside ultrasonography in the diagnosis of acute appendicitis. *Ann Emerg Med.* 2004;44:S112.
167. O'Malley M, Wilson S. Ultrasonography and computed tomography of appendicitis and diverticulitis. *Sem Roentgenol.* 2001;36:138-47.
168. Nelson M, Chiricolo G, Raio C, et al. Can emergency physicians positively predict acute appendicitis on focused right lower quadrant ultrasound? *Ann Emerg Med.* 2005;46:27-8.
169. Min YG, Lee CC, Bae Y, et al. Accuracy of sonography performed by emergency medicine residents for the diagnosis of acute appendicitis. *Ann Emerg Med.* 2004;44:S60.
170. Lam SH, Grippo A, Kerwin C, et al. Bedside ultrasonography as an adjunct to routine evaluation of acute appendicitis in the emergency department. *West J Emerg Med.* 2014;15:808-15.
171. Garcia-Pena BM, Taylor GA, Fishman SJ, et al. Costs and Effectiveness of Ultrasonography and Limited Computed Tomography for Diagnosing Appendicitis in Children. *Pediatrics.* 2000;106:672-6.
172. Hollerweger A, Rieger S, Mayr N, et al. Strangulating closed-loop obstruction: Sonographic signs. *Ultraschall Med.* 2015 Apr 15. [Epub ahead of print]
173. Hollerweger A, Wüstner M, Dirks K. Bowel obstruction: Sonographic evaluation. *Ultraschall Med.* 2015;36:216-35; quiz 36-8.
174. Jang TB, Schindler D, Kaji AH. Predictive value of signs and symptoms for small bowel obstruction in patients with prior surgery. *Emerg Med J.* 2012;29:769-70.
175. Hefny AF, Corr P, Abu-Zidan FM. The role of ultrasound in the management of intestinal obstruction. *J Emerg Trauma Shock.* 2012;5:84-6.
176. Chen S-C, Wang H-P, Chen W-J, et al. Selective use of ultrasonography for the detection of pneumoperitoneum. *Acad Emerg Med.* 2002;9:643-5.
177. Baker JB, Mandavia D, Swadron SP. Diagnosis of diverticulitis by bedside ultrasound in the emergency department. *J Emerg Med.* 2006;30:327-9.
178. Siadecki SD, Frasure SE, Saul T, Lewiss RE. Diagnosis and reduction of a hernia by bedside ultrasound: a case report. *J Emerg Med.* 2014;47:169-71.
179. Nazeer SR, Dewbre H, Miller AH. Ultrasound-assisted paracentesis performed by emergency physicians vs the traditional technique: a prospective, randomized study. *Am J Emerg Med.* 2005;23:363-7.
180. Robinson P, Hensor E, Lansdown MJ, et al. Inguinofemoral hernia: accuracy of sonography in patients with indeterminate clinical features. *AJR Am J Roentgenol.* 2006;187:1168-78.
181. Rettenbacher T, Hollerweger A, Macheiner P, et al. Abdominal wall hernias: cross-sectional imaging signs of incarceration determined with sonography. *AJR Am J Roentgenol.* 2001;177:1061-6.
182. Sivitz AB, Tejani C, Cohen SG. Evaluation of hypertrophic pyloric stenosis by pediatric emergency physician sonography. *Acad Emerg Med.* 2013;20:646-51.
183. Malcom GE, Raio CC, Del Rios M, et al. Feasibility of emergency physician diagnosis of hypertrophic pyloric stenosis using point-of-care ultrasound: a multi-center case series. *J Emerg Med.* 2009;37:283-6.
184. Leung J, Duffy M, Finckh A. Real-time ultrasonographically-guided internal jugular vein catheterization in the emergency department increases success rates and reduces complications: a randomized, prospective study. *Ann Emerg Med.* 2006;48:540-7.
185. Doniger SJ, Ishimine P, Fox JC, et al. Randomized controlled trial of ultrasound-guided peripheral intravenous catheter placement versus traditional techniques in difficult-access pediatric patients. *Pediatr Emerg Care.* 2009;25:154-9.
186. Agency for Healthcare Research and Quality. Evidence Report/Technology Assessment: Number 43. Making Health Care Safer. A Critical Analysis of Patient Safety Practices: Summary. Accessed June 20, 2018 at <http://archive.ahrq.gov/clinic/ptsafety/pdf/ptsafety.pdf>.