Toward an ultrasound curriculum for critical care medicine

Luca Neri, MD; Enrico Storti, MD; Daniel Lichtenstein, MD

Accurate assessment and rapid decision-making are essential to save lives and improve performance in critical care medicine. Real-time point-of-care ultrasound has become an invaluable adjunct to the clinical evaluation of critically ill and injured patients both for pre- and in-hospital situations. However, a high level of quality is necessary, guaranteed by appropriate education, experience, credentialing, quality control, continuing education, and professional development. Although educational recommendations have been proposed by a variety of nonimaging specialties, to date they are still scattered and limited examples of standards for critical and intensive care professionals. The challenge of providing adequate specialty-specific training, as encouraged by major medical societies, is made even more difficult by the diversity of critical care ultrasound utilization by various subspecialties in a variety of settings and numerous countries. In order to meet this educational challenge, a standard core curriculum is presented in this manuscript. The proposed curriculum is built on a competence, performance, and outcomes-based approach that is tailored to setting-specific training needs and prioritized according to critical problem-based pathways, rather than traditional organ-based systems. A multiple goal–oriented style fully addresses the specialty-specific approach of critical and intensive care professionals, who typically deal with disease states in complex scenarios rather than individual organ complaints. Because of the variation in the concept of what constitutes critical care worldwide, and the rate of change of information and technology, this manuscript attempts to present a learning system addressing a variety of needs for a rapidly changing world. (Crit Care Med 2007; 35[Suppl.]:S290–S304)

KEY WORDS: point-of-care ultrasound; bedside ultrasound; critical care; intensive care; ultrasound training; transversal competencies; critical thinking

Diagnostic ultrasound is a rapidly developing imaging technology that can be found in both industrialized and developing countries. Recently, its point-of-care use has been investigated in a number of primary, emergency, and critical care applications (1–11). The rate at which bedside ultrasound use is spreading, and the continuing development of new applications, may outpace training of adequate numbers of qualified users. This presents the risk of practicing under conditions of inappropriate training or quality control. The lack of uniform and generally accepted standards for training at the international level compounds the problem. The effectiveness of acquiring, interpreting, and incorporating real-time sonographic information into the critical clinical decision-making process remains largely operator-dependent. When appropriate training and quality assurance is provided, results can be highly accurate and reliable; standards for ultrasonography training are thus a prerequisite for provision of high-quality "ultrasound-enhanced" services (12–16).

The scientific community has an urgent need to provide guidelines for continuing ultrasound education in critical care medicine from medical school through to residency, specialty training, and ongoing practice. These guidelines are required to facilitate standardization of physician competence and performance at local, national, and international levels. The European Federation of Societies for Ultrasound in Medicine and Biology has recently proposed minimal training requirements for the practice of medical ultrasound, addressing "the growing demand from many medical specialists in undertaking ultrasound examinations on patients [. . .] as a direct extension of their clinical exam (17)." Supporting the strategy of other medical societies and organizations, the European Federation of Societies for Ultrasound in Medicine and Biology acknowledged that ultrasound can be fully embedded within the scope of practice of several nonimaging specialties, provided they specify their own educational pathways and guidelines. To date, several educational and scientific bodies have produced specialty specific recommendations, protocols, and curricula for nonimaging medical professionals performing ultrasound (cardiac, vascular, gynecologic, and obstetric specialists, and, to a lesser extent, gastroenterologists, surgeons, urologists, and others).

However, there are no currently widely acknowledged international guidelines, and only a few scattered national examples exist that address ultrasound training for physicians, nurses, and paramedics performing ultrasound examinations in emergency (18–23) and critical care (24, 25) settings. With regards to intensive and critical care medicine, there are some outstanding exceptions basically limited to echocardiography (transthoracic and transesophageal) (26–28) and a few interventional areas (drainages, vascular access, nerve blockage) (29–31). Critical care physicians, and particularly general intensivists and anesthetists, provide critical and intensive care to patients whose problems relate to all anatomical regions. They manage complex multisystem disease states and perform multiple interventional procedures throughout the body in a coordinated fashion. Any ultrasound curriculum or instructional design should take into account this special-

From the General Intensive Care Unit "Bozza," Niguarda Ca' Granda Hospital, Milan, IT (LN, ES); Service de Reanimation Medicale, Paris-Ouest, Hopital Ambroise-Pare, Boulogne, FR (DL).

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Address requests for reprints to: Luca Neri, MD, Niguarda Ca' Granda Hospital, SSUEm 118-Milano, Milan, IT. E-mail: luca.neri@winfocus.org

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ty-specific, rapidly evolving, critical care approach—effectively abandoning "vertical" systematic organ-based training for a multiple-goal, problem-based approach. This model represents the core of a competency-based ultrasound instructional model, designed to impart not a simple body of knowledge, but all the relevant skills and attitudes to improve patient outcomes and performance at the individual and system levels. Whatever competency-based training is undertaken, it has to be carefully tailored to the targeted audience's needs, since critical care is delivered quite differently throughout the world by medical and allied health providers in diverse settings (Tables 1 and 2).

Critical care professionals who perform diagnostic ultrasound examinations should be credentialed through training programs or institutions, requiring evidence of completed training and competency requirements to meet the accepted standards in their area(s) of practice. Many small studies have looked at the efficacy of different instructional programs for nonimaging specialists, lasting from a few hours (with some even self-taught using software on CD-ROM) to days to months. Almost all of these showed that short or minimal training was effective for focused emergency-ultrasound indications, even in the hands of a relative novice (see bibliography in the section about minimal requirements).

The aforementioned educational studies refer mostly to emergency medicine and surgical settings, whilst educational data strictly from critical care services are still rare and essentially related to echocardiographic competencies (14, 15, 32–34), interventional procedures (35–37), and setting-specific training modules (e.g., prehospital emergency care, tactical medicine) (38–42). This shortage of data largely reflects the current situation at the world level, where few critical and intensive care services have definite ongoing specialty-specific training programs, credential systems, and quality-assurance plans for general ultrasound development.

The international standard core curriculum that we propose attempts to address this shortage of guidance, taking into account previous and currently available recommendations, particularly those from the World Health Organization (43, 44), European Federation of Societies for Ultrasound in Medicine and Biology (17), American College of Emergency Physicians (ACEP) (18), American College of Surgeons (ACS) (19), Royal College of Radiologists (24), and World Interactive Network Focused on Critical Ultrasound (25). It also adds new elements to the current debate.

A "transversal" approach to problems and solutions, at different levels of ultrasound practice, is consistent with the multiple-goal–directed, multisystem, time-dependent vision of critical care professionals, and actually refers to their specialty-specific competence. Nevertheless, the variety of personnel and service models for delivery of critical care in both hospital and extra-hospital settings does not support any unique and specialty-specific model; rather, it calls for a competence- and performance-needs–based approach. This approach can be tailored to various national and local training programs and curricula. The continuing, rapid change of ultrasound technology and critical care practice compels us to emphasize continuing education, rather than a rigid curriculum content.

Table 1. Critical care ultrasound scenarios

In Hospital	Out of Hospital
• Critical and intensive care service • Emergency department • Resuscitation room, trauma bay • Operative room and perioperative area • Imaging department and other wards, etc.	• HEMS/EMS • Mass casualty and disaster setting • Austere and remote scenario • Peacekeeping and tactical field • Scarce resource health setting, etc.

HEMS, helicopter emergency medical services; EMS, emergency medical services.

Table 2. Critical care ultrasound providers

Consultants or Physicians Temporarily in Charge of the Critical Patient (Major World Component)	Physicians Specifically Trained in CCM	Allied Health Personnel
• Emergency physicians • Cardiologists, pneumologists, nephrologists • Internists, gastroenterologists • Emergency/trauma surgeons, general surgeons • Cardiothoracic or vascular surgeons, urologists • Obstetricians and gynecologists, neonatologists, pediatricians • Radiologists and imaging specialists, etc.	• General intensivists • General anesthetists • Critical and intensive care subspecialties	• Nurses • Paramedics • Technicians • Midwives *[Assistants, remotely guided, or direct providers]*

CCM, critical care medicine.

Competence- and Problem-Based Training Solutions

Competence is composed of an individual's knowledge, skill, and attitude to ensure excellent performance and outcome in a certain situation, function, or job. Over the last several years, several societies and university boards, as well as quality-assurance bodies, have implemented educational projects based on competence, performance, and outcomes assessment to ensure that physicians are appropriately trained in the knowledge and skills of their specialties. Also, in many emergency and critical care medicine curricula and job profiles, lists of generic professional tasks and duties are becoming replaced with lists of core competencies and outcome measures (45–47).

The successful diffusion of ultrasound beyond traditional imaging specialists to the critical care setting has been driven by such a competence-based model. Current guidelines attempting to address the training needs of nonimaging specialist physicians in primary, emergency, and critical care medicine support a competence-based approach. However, many of them still reflect the largely traditional systematic discipline-based use of ultrasound, with training and competencies split into organ- or system-based categories (17). Over the last decade, focused approaches arising from various emergency-medicine and trauma-surgery bodies have also developed as modular goal-directed disease-based systems, highlighting subjects such as hemoperitoneum, abdominal aortic aneurysm, and hydronephrosis rather than

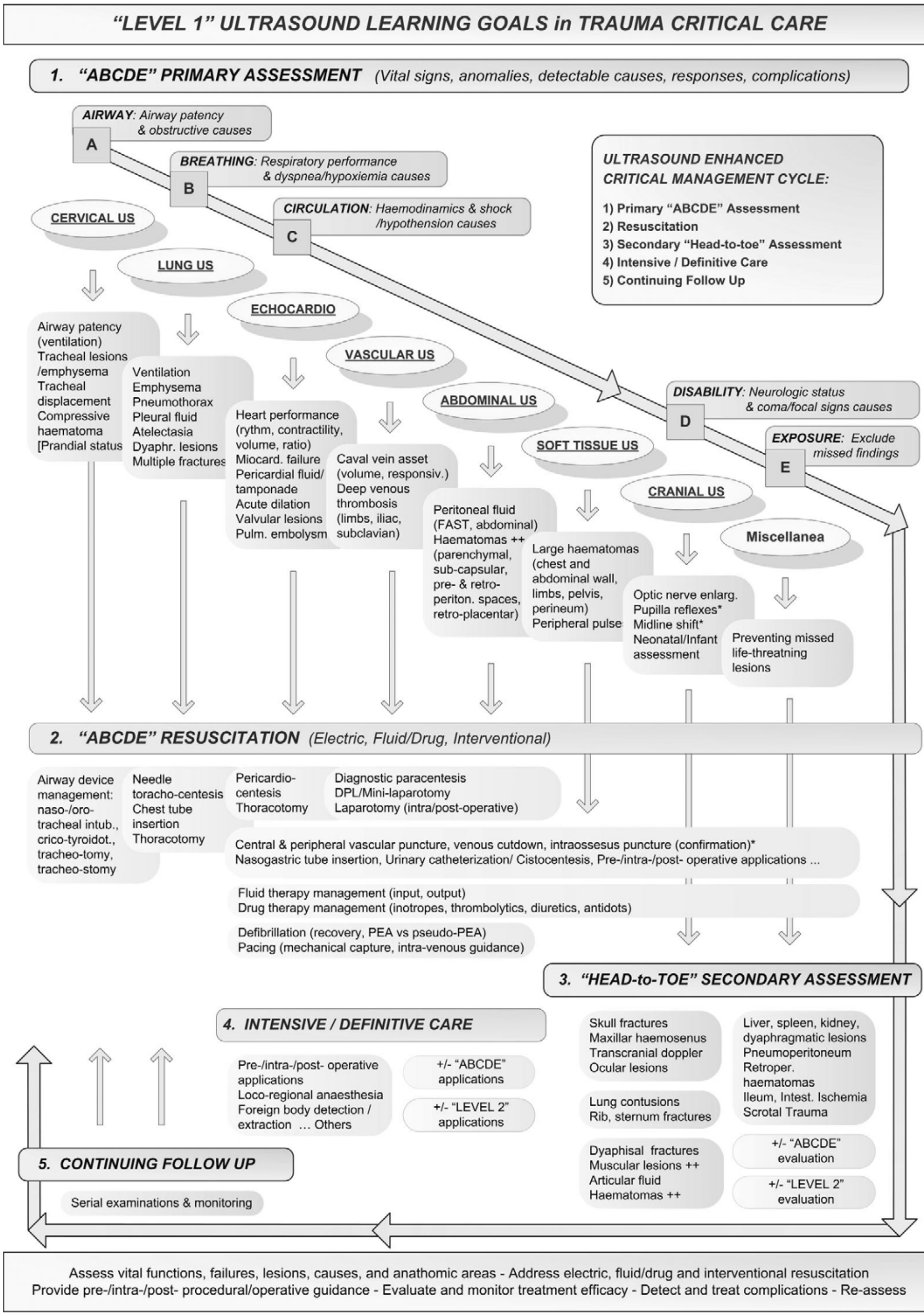

Figure 1. Level 1 ultrasound competencies in trauma care: the FAST-ABCDE.

organs or anatomical regions (18–21). In response, this still evolving point-of-care perspective, recent multidisciplinary guidelines, and even those curriculums developed within radiologic bodies have started to incorporate batches of "setting-specific" procedures for use in emergency departments and intensive care units, including disease-based (aneurysm, hydronephrosis, peritoneal free fluid, etc.) and "problem-based" (hypotensive-patient assessment) applications (24, 25).

While ultrasound education is addressing this new problem-based transversal approach, actual practice and the research community already have moved far ahead. The history of the acronym *FAST* is quite paradigmatic: born as a focused abdominal sonography for trauma assessment (system-based), it quickly shifted to focused assessment with sonography for/in trauma (problem-based) (48, 49). Now, it is being incorporated into more elaborate protocols, such as EFAST (extended FAST, to PTX assessment) (50), FASTER (FAST including extremities and respiratory tract) (51), and FAST-ABCDE (FAST including airway-breathing-circulation-disabilities/deficits and exposure) (Fig. 1; Tables 3 and 4).

Table 3. Ultrasound (US) learning goals for the primary management of the critical patient (problem-based setting, ABCDE type, trauma and non-trauma, US basic level 1

Problem	Ultrasound-Enhanced ABCDE Assessment	Ultrasound-Enhanced Resuscitation
A	Airway ● Airway: patency, spontaneous/manual lung ventilation ● Trachea: displacement, lesions/emphysema, adjacent compressive hematomas/masses ● Stomach: endotracheal-tube displacement, prandial status	Airway ● Endotracheal intubation, other devices ● Cricothyroidotomy and emergent tracheostomy guidance
B	Breathing ● Lung, pleura, diaphragm: — Absence/asymmetry of ventilation — Pneumothorax, emphysema subcutaneous — Large pleural effusion/hemothorax — Pulmonary edema/interstitial congestion — Diaphragm lesions/dysfunction/paralysis	Breathing ● Needle aspiration: pneumothorax ● Tube thoracostomy: pneumothorax, hemothorax ● Resuscitative thoracotomy: hemorrhage
C	Circulation ● Cardiac/hemodynamic qualitative assessment: — Asystolia confirmation, PEA vs. pseudo-PEA — Tamponade — Severe left ventricular systolic dysfunction — Acute cor pulmonale — Biventricular dysfunction — Cardiac hypovolemic profile (severe) — Valvular gross lesions or intracardiac masses — Inferior vena cava (preload): size, variations, collapsibility ● Pericardial sac: fluid/hemorrhage, tamponade ● Pleural space: fluid/hemorrhage ● Peritoneal space fluid/hemorrhage ● Retroperitoneal spaces: gross hematomas ● Placenta: previa with vaginal bleeding, detachment ● Veins: femoropopliteal and central deep vein thrombosis ● Aorta: abdominal and proximal arch aneurysm	Circulation ● Defibrillation: recovery confirmation ● Pacing: mechanical capture, transvenous ● Evacuative pericardiocentesis ● Evacuative pleurocentesis ● Peripheral and central vascular puncture ● Venous cutdown ● Intraosseous access[a] ● Diagnostic paracentesis/peritoneal lavage
D	Disability (neurologic status) ● Optic nerve (cerebral hypertension): sheath enlargement ● Neonatal/infant brain: hemorrhage ● Pupils: size, symmetry, reactiveness (if not accessible)[a] ● Brain: cerebral midline shift[a] ● Cervical spine: gross displacement[a]	
E	Exposure ● Full access to all anatomical areas ● Preventing the misdiagnosis of life-threatening ABCDE lesions and emerging complications	Exposure ● Urinary catheterization ● Nasogastric tube insertion ● Further ABCDE procedures
F	Additional assessments — ABCDE reassessment (if necessary) — Secondary assessment (system- or problem-based) — Intra-operative assessment — Intensive/subintensive care assessment — Definitive assessment — Follow-up (serial re-evaluations, monitoring)	Additional treatments — Further ABCDE resuscitation — Secondary assessment procedures — Intraoperative procedures — Intensive-care procedures — Definitive-care procedures — Follow-up procedures

[a]To be considered still under initial investigation.
PEA, pulseless electrical activity.

The latter protocols extend the primarily abdominal assessment of hemoperitoneum, initially to the chest (fluid and PTX) and later to the limbs (fractures and hematomas), while focusing on the problems relevant to ABC/ABCDE surveys, and emphasizing a clinical transverse focused assessment. Similarly, emergency point-of-care echocardiography (performed by noncardiologist providers), while initially limited to the subxyphoid view for pericardial fluid, has gradually extended to evaluate abnormal motion and volumes status (16, 33, 52–54).

These are relatively new concepts for the ultrasound community. While most radiologists, cardiologists, and gynecologists perform emergency ultrasound assessments daily, few of them will have scanned more than one or two anatomical areas in the same patient, and probably none more than three areas. In the first few minutes of the primary and secondary assessments of the trauma patient, a trained critical care physician looking for abnormal movements, air, and fluid collections could quickly go through airway, respiratory, cardiovascular, neurologic systems (or through skull, chest, abdomen, and limbs), getting a critical real-time insight to refine and dramatically improve diagnosis, treatments, and procedures.

Traditionally, most general ultrasound courses, after addressing physics and instrumentation, move on to abdominal applications, focusing first on the easiest and most common (normal and abnormal) findings such as liver anatomy, cysts, and steatosis. Ultrasound-guided procedures and maneuvers are usually discussed only in advanced general modules. However, in

Table 4. Ultrasound learning goals for the secondary management of the critical patient (system-based setting, head-to-toes type, trauma and non-trauma, US advanced level 1)

System	Ultrasound-Enhanced "Head-to-Toes" Assessment	Ultrasound-Enhanced Treatment
Head/neck	● Skull/facial bones: fractures ● Maxillary sinus: hemosinus, sinusitis ● Eye: gross lesions ● Transcranial Doppler: focused findings ● Soft tissues: hematomas, septic lesions, foreign bodies	● Eventual ABCDE procedural support ● Pre-/intra-/post-operative (general, orthopedic, cardiovascular, thoracic, neurologic, obstetric and gynecologic surgery) ● Soft-tissue collections diagnostic/evacuative drainages, foreign-body detection/extraction ● Limbs: arthrocentesis, fracture alignment, basic loco-regional anesthesia
Thorax	● Lung: interstitial syndromes, contusions, neonatal respiratory diseases, acute respiratory distress syndrome ● Rib, sternum, and clavicle: fractures ● Heart performance/filling state (semiquantitative/simple quantitative assessment): — Overall heart chambers, abnormal dimensions — Left ventricular function "visual" and "measured" (fractional shortening, fractional area change) — Gross preload estimation of left ventricle and of whole heart — Right ventricular function — Pulmonary embolism cardiac findings — Gross valvular dysfunction — Suspected infective endocarditis — "Contrast enhanced echocardiography" for suboptimal chamber imaging (optional) ● Soft tissues: hematomas, septic lesions, foreign bodies	
Abdomen	● Liver, spleen: gross lesions/hematomas ● Gallbladder: cholecystitis, hydrops, gross cholelithiasis ● Kidney: gross lesions/hematomas, gross urolithiasis, hydronephrosis ● Diaphragm: gross lesions, dysfunction/paralysis ● Peritoneum: pneumoperitoneum ● Intestinal tract: ileum, ischemia, appendicitis, abscesses/trapped collections ● Pre-/retroperitoneum: gross hematomas ● Aorta: gross aneurysmatic dissection/rupture ● Caval vein/iliac: thrombosis ● Bladder: gross calcula/sediment/coagula, distension, retention, catheter balloon ● Perineum: hematomas, acute scrotum (trauma, inflammation, torsion) ● Uterus: intrauterine pregnancy, fetal/placental/amniotic basic assessment ● Soft tissues: hematomas, septic lesions, foreign bodies	
Limb	● Diaphysis (fractures) ● Joints (fluid) ● Soft tissue (gross hematomas, abscesses, muscle lesions)	
Further assessment	● Further ABCDE re-evaluation ● Eventual problem-based secondary assessment: cardiac arrest, shock/hypotension, dyspnea/hypoxemia/thoracic pain, coma/focal signs/headache, acute abdomen, abdominal/lumbar/pelvic/limb pain, oligoanuria, sepsis, fever of unknown origin, multiple organ failure, obstetric and gynecologic issues, etc. ● Intensive- and subintensive-care assessment ● Follow-up — Serial re-evaluations — Continuous monitoring (intensive/subintensive care, transport to other units/hospitals)	● Definitive care procedures ● Intensive care procedures ● Eventual ABCDE resuscitation

critical care, undifferentiated problems are primarily approached according to the ABCDE or the "head-to-toes" sequence based on physiologic priority. The abdomen is an important region to examine sonographically, but not before the airway, lungs, and heart. Free fluid is a major finding to detect, but not before assessing critical function or movement (heart and pleural motion) or for intrapleural air (pneumothorax). Performance- and outcome-based introductory ultrasound training should always follow the same pathways and priorities, encompassing easy and "critical" findings in the real order of importance. Recently, an increasing number of focused applications directed at the airway, lung, heart, head, and limbs have been shown to be feasible and accurate in the hands of adequately trained emergency and critical care physicians. New, fully developed ABCDE and head-to-toes management approaches should be strongly recommended in any ultrasound training for emergency and critical care professionals (Fig. 1; Tables 3 and 4).

Levels of Proficiency

We propose three consecutive levels of proficiency, as generally acknowledged by a growing international consensus: level 1 (general: common and focused), level 2 (comprehensive: specialized and subspecialized), level 3 (expert: cutting edge in clinical application, research, and education) (17). Each level has at least two sublevels, basic and advanced. A basic level 1 (BL1) curriculum would be ABCDE training in trauma and nontrauma cardiopulmonary arrest, shock/hypotension, dyspnea/hypoxemia, and coma/neurologic signs. The advanced level 1 (AL1) student also would learn to use the head-to-toes protocol and to evaluate additional critical syndromes, such as acute abdomen, cardiac failure, oligoanuria, chest/abdominal/lumbar/pelvic pain, obstetrics and gynecology issues, etc. Level 2 competencies would be more specialized, targeted toward clusters of professionals or departments; they would be learned and credentialed during specific additional modules. Level 3 expertise denotes experts with significant experience and specific educational responsibilities. Modular subspecialty instructional insights should be available to begin, integrate, support, and maintain competence at all levels.

These standard core competencies would have a high level of definition, particularly at level 1. They could be the basis for any ultrasound curriculum, including introductory courses, proctored practice, credentialing and accreditation, continuing education and professional development, quality assurance, and development planning. Proficiency goals, integrated with the supporting educational science topics, are the basis for the training program and accreditation processes targeted to trainers (instructors) and course directors. Focused modular (or multimodular) approaches to organs, systems, diseases, or problem-based sets of competencies are also acceptable, provided that full competence in the targeted area(s) is demonstrated and future clinical practice is confined to those field(s) alone.

Levels of Ultrasound Practice in Intensive and Critical Care

Three consecutive levels of training, experience, and proficiency are outlined both for providers and instructors: general, comprehensive, and expert ultrasound in critical care medicine (respectively, USCCM levels 1, 2, and 3). Two or three further sublevels for each level of expertise are identified as single-application, basic, and advanced, as follows:

- *Level 1*: General (set of common, focused competencies)
  - — Single-application competent [US-CL1]
  - — Basic (ABCDE-conformed) [US-BL1]
  - — Advanced (problem- and system-based) [US-AL1]
- *Level 2*: Comprehensive (set of specific, thorough competencies)
  - — Basic (specialized, problem-based) [US-BL2]
  - — Advanced (subspecialized, system-based) [US-AL2]
- *Level 3*: Expert (high expertise in clinical usage, research, and/or teaching)
  - — Basic (specialized, problem-based) [US-BL3]
  - — Advanced (subspecialized, system-based) [US-AL3]

Each level of proficiency encompasses general problem-based profiles (such as US-BL1, US-AL1, US-BL2, and US-BL3, consistent with transversal or multiple uses in critical care). Levels 2 and 3 also encompass system-based subspecialty practices (e.g., echocardiography for intensivists at US-AL2 and US-AL3). Those professionals who undertake to master specific ultrasound-assisted tasks can be acknowledged as having level 1 expertise in a single application (e.g., internal jugular vascular access, as US-CL1). Credentialed, competent physicians and boards should always directly supervise trainees' or residents' performance until outcome measures certify them as independent, competent operators at a certain level. At present, strictly defined boundaries between the three main steps are difficult to precisely define, and this schema should be regarded as an overview to comprehend the different levels of practice. These main three categories are drawn and adapted from the World Health Organization (44), and recent European Federation of Societies for Ultrasound in Medicine and Biology (17) and Royal College of Radiologists (24) guidelines addressing medical and surgical practice, as well as most of the actual echocardiographic or cardiology societies' recommendations. Levels I, II, and III, as reported in ACEP guidelines, refer to the trainee's learning process through didactics, proctored experience, and credentialing (18); similarly, the ACS credentials three levels respectively for course attendance, competence acquisition, and instructor status (19). Both of the latter two categorizations could be functionally incorporated into any level of the overall grading system.

Training Program Models

Competence-, performance-, outcome-, and problem-based multistep modular training appears to be the most feasible and effective instructional pathway, compared with an organ-based curriculum. According to the training needs of the target audience, two kinds of instructional programs are highlighted:

- *Standard*: general-purpose training (including specialty-specific, subspecialty, or monothematic standardized modules).
- *Needs-based*: customized training (fully tailored to specific demands or system-needs analysis).

Considering the entire spectrum of specialty-specific USCCM, possible standard and customized training and credentialing pathways could be further differentiated and arranged as follows:

- *Standard sequence:* to achieve USCCM standard certification as a provider.
  - — Level 1, general training, basic and advanced modules for providers (US-BL1 and US-AL1).
  - — Level 2, comprehensive training, basic and advanced modules for providers (US-BL2 and US-AL2).
  - — Level 3, expert training, basic and advanced modules for providers (US-BL3 and US-AL3).
- *Instructor modules*: credentials for instruction at provider level or lower.
- *Refresh modules*: accelerated course structure to renew lapsed certification.
- *Customized sequences*: special courses for a variety of purposes.
  - — Single-application credentials, as discussed previously, giving a specialized US-CL1 rating that could be promoted to US-BL1 with completion of the entire basic course structure. A variety of US-CL1 ratings would be available, one for each appropriate specialized usage of ultrasound.
  - — Non-standard credentialing: For those with previous formal or informal training, experience, and proficiency—who have nonetheless accumulated a set of competencies—this category of training might be made available to accelerate their credentialing. This category recognizes those who have learned on their own, or in some other fashion that lacks documentation, and can prove their competence if provided the opportunity for an appropriate evaluation and acknowledgment by the appropriate boards.

Educational Module Structure

Particularly at level 1, each module requires candidates to attend an introductory course and workshop with didactic and practical components. They will perform and record a requisite number of proctored examinations, and pass a final exit examination designed to assess these competencies:

1) Introductory workshop (prerequisite to parts 2 and 3)
   a) Theoretical sessions (knowledge base)
      — Methods: didactic sessions.
      — Tools: multimedia lectures, interactive cases, syllabi, textbooks, video, web-based and computer-assisted learning, etc.
      — Precourse training (printed or electronic/online format).
   b) Practical sessions (core skills and attitudes)
      — Methods: demonstrations and hands-on training.
      — Tools: practical work-stations on patients, models, or simulators.
2) Proctored practice (sets of minimal requirements)
   a) Logging supervised scanning, with real-time review
   b) Logging independent scanning, with delayed or remote over-reading
3) Credentialing evaluation (parts 1 and 2 must be completed beforehand)
   a) Introductory workshop and proctored practice documentation
   b) Case studies, research, and therapeutic-plan presentation
   c) Multiple-choice test and video interpretation
   d) Competence-based practical exam on simulated or real patients
   e) Theory and practical teaching simulations (only for instructors)

Several studies and recommendations addressing emergency and critical care–medicine educational needs highlight the effectiveness of such a sequence. However, study-time and repetition quotas remain in dispute. Previously suggested figures have ranged from 2 hrs to 40 hrs of introductory lectures, and from 10 mins to 40 hrs of hands-on training. The number of recommended practice scans has ranged from 15 to 50 per applications, and from three to 600 total examinations, depending most on procedural type and targeted goals, contents, structure, duration, and audience (17–26, 31–38, 42–44, 55–77). Considering the documents and experiences reported in the provided bibliography, we defined and suggested several detailed study-time and repetition quotas (Tables 5 and 6)

Recommended Learning Content

Standard Competencies. The standard competencies (see online-only table: www.ccmjournal.org) represent the general theoretical and practical basis of any standard and customized training in critical care ultrasonography, encompassing main ultrasound functions and responsibilities such as image generation, acquisition, interpretation and administration, clinical decision-making, problem-solving, and developmental planning. The outlined skills are grouped systematically according to the main categories of functions and responsibilities. General and specific sets of standard competencies should be further tailored to the targeted audience and the training goals, organizing the content according to different outcome- and problem-based priority settings.

Outcome-Based Categories. Critical care ultrasound training or curricula should be shaped and developed in relation to specifically targeted outcome categories, such as technical, clinical, organizational, and social effectiveness. Technical effectiveness refers to the feasibility and consistency of the applied imaging technology, and the adequacy and accuracy of machines and providers in performing image generation, acquisition, interpretation, and administration. The set of associated core competencies should enable the provider to effectively handle ultrasound equipment, scanning procedures, sonographic semeiotics, as well as administrative, legal, and ethical issues. Each ultrasound-training curricula must encompass and assess technical outcome-related competencies. Clinical effectiveness is consistent with the impact on clinical outcome measures, depending on the accurate and timely incorporation of the sonographic information into clinical management. Organizational and social effectiveness

Table 5. Requirements for ultrasound in critical care medicine (USCCM) credentialing

Standard Specialty-Specific Minimal Requirements for USCCM Credentials	Prerequisite for Admission to Credentialing Competence Assessment			Prerequisites for Maintenance of Credentials After Competence Assessment			
	Formal Course Timing	Preliminary Practice (Proctored): Exams	Preliminary Practice (Proctored): Period	Continuing Practice Annual Exams	Refresh or Revalidation Frequency	Continuing Education	Quality Assurance
Level 1—general						Audits, updates (literature, technology), meetings & congresses, professional development, etc.	Supervision, over-reads, gold standards testing, patient outcome review, development plans, etc.
Single-competence [US-CL1]	1 day (8 hrs)	15–30 25–50	1–3 months	15–30 25–50	2 yrs		
Basic [US-BL1]	2 days (16 hrs)	200	3–6 months	100	2 yrs		
Advanced [US-AL1]	3 days (24 hrs)	300	6–12 months	200	2 yrs		
Level 2—comprehensive							
Specialized [US-BL2]	5 days (40 hrs)	800 (cumulative)	1 yr (at level 1)	300	3 yrs		
Subspecialized [US-AL2]	Discipline-specific	Discipline-specific	Discipline-specific	Discipline-specific	Discipline-specific		
Level 3—Expert							
Specialized [US-BL3]	Optional	2000 (cumulative)	3 yrs (at level 2)	500	5 yrs		
Subspecialized [US-AL3]	Discipline-specific	Discipline-specific	Discipline-specific	Discipline-specific	Discipline-specific		

US, ultrasound; CL, single-competence level; BL, basic level; AL, advanced level.

Table 6. Level 1 basic and advanced minimal requirements

Basic and Advanced Level 1 of Sonography (US-BL1 and US-AL1) in Intensive and Critical Care Medicine		
Structure and Sequence	Recommended Subcomponents	Recommended Minimal Requirements
Introductory course	Theory Precourse training Didactic sessions	Didactical content or e-learning Formal classes or computer/web-based learning Lectures, interactive cases Ratio of students/faculty = maximum 30–40:1 Contents: see US-BL1 and US-AL1 theory syllabus
	Practical Demonstrations and hands-on training	Applications on real or simulated patients, simulators Ratio students/tutor/machine/model = maximum 5:1:1:1 Contents: see US-BL1 and US-AL1 practical syllabus Course duration: 2 days (16 hrs) US-BL1, 3 days (24 hrs) US-AL1 Ratio practical/theory: 1:1 or more
Proctored practice	Technical Clinical Organizational Supervised and independent practical performance	Exams/key competence: 15–30 or 25–50, 1–3 per month Exams/module (US-BL1): 200/3–6 months Exams/module (US-AL1): 300/6–12 months Review: real time (>30%) and delayed Frequency: 5–10 exams/week; inactivity <1 month Clinically indicated: at least 50% Pathologic finding: at least 10–20% Logbook (at least 5–10% illustrated) Applications on real or simulated patients, simulators Contents: see US-BL1 and US-AL1 practical syllabus
Credentialing evaluation — Competence-based — Modular assessment — Continuing process	Presentations Case-study reports Research study Development planning Teaching	Involvement in research, education, quality assurance, planning 3 relevant logged cases (plus illustrations, follow-up) 1 study to be proposed or published 1 plan (or component) to be presented 1 simulated or real session (only for instructors)
	Theory test Multiple-choice test Video interpretation	Required overall performance: >75% 25–50 questions/3–5 answers each 5–10 pathologic video clips
	Practical test Competence-based practical exam	Required modular performance: 100% Application on real or simulated patients/scenarios
	Administration Modular competence-assessment sheet Prerequisite for admission Prerequisite for maintenance	Inventory of assessed/credentialed competencies Temporary validity (see prerequisite for maintenance) Introductory workshop: 100% attendance Practice: minimal requirements to be achieved Annual numeric goals of practice (minimum, logbook) Periodic refresh/revalidation, CME/CPD, quality assurance

Table 7. Point-of-care critical ultrasound modalities

Modality	Function and Goals	Targeted Patients
Primary ultrasound	• PHC-conformed ultrasound practice, for developing essential, acceptable, accessible, and sustainable healthcare systems	• Communities accessing scarce resource health services with no referral systems and significant socioeconomic constraints
Triage ultrasound	• Secondary field triage, for improving treatment and evacuation priority scoring	• Large number of injured patients in mass or disaster events
Screening ultrasound	• Primary or secondary screening, for improving diagnostic workup	• Patients with subacute or uncertain clinical presentations
Emergency ultrasound	• Primary emergency assessment, for improving emergency care (including procedural guidance)	• Patients with acute or emergency clinical presentations
Observational ultrasound	• Secondary serial evaluation for monitoring focused parameters (and/or detecting emerging complications)	• Stable patients under observation, with uncertain diagnosis or prognosis, after initial full assessment
Intensive ultrasound	• Screening, emergency, and observational ultrasound performed in those with critical multisystem illness	• Selected critically ill patients requiring intensive assessment, monitoring, and treatment

refers to the ability of managing improvement and development plans, as well as impacting organizational and social systems at different levels (departmental, local, regional, national, international). All levels of effectiveness and the overall performance are quite consistent with the "transversal competencies" of the critical care physician and would be further enhanced by a point-of-care team-centered practice.

Setting-Specific Training Needs. The outlined standard outcomes and competencies are developed to meet the common demands of the critical care physician. Nevertheless, looking from a broad perspective to the variety of critical care scenarios throughout the world, we notice several different approaches and providers within similar settings in different countries. After a literature review and critical appraisal, we identified point-of-care ultrasound-delivery formats that, irrespective of country or scenario, present similar objectives and requirements in terms of funding, equipment, education, and organization (Table 7). At one extreme of this set of modalities, we find "primary" ultrasound providers, trying to serve hundreds of thousands of patients, with very scarce resources, thus targeting public health (e.g., the prevention of fetal-maternal disorders in developing countries' rural areas). At the other end of the scale, "intensive care" providers are totally focused on small clusters of critically ill patients, targeting individual vital functions and providing very costly intensive care (e.g., the trauma patient assisted by highly specialized units).

In relation to providers, scenarios (Table 1 and Table 2), and modalities (Table 7), the standard and core competencies should be further shaped for specific settings and clinical needs.

Problem-Based and System-Based Management Priorities

A multiple-goal problem-based approach represents the main criteria to prioritize ultrasound core competencies throughout any critical care specialty-specific training program. Overall, critical care performance is typically oriented toward complex disease states rather than single organs, calling for an accurate and timely transversal approach to multiple systems, rather than a comprehensive examination of a single anatomical region. Particularly for undifferentiated and unexpected scenarios, management strategies become largely dependent on ABCDE-type priority settings, focusing on life-threatening problems first. The basic ultrasound applications, performed by level 1 basic providers, should be effectively organized and prioritized according to an Advanced Cardiac Life Support/Advanced Trauma Life Support–style primary survey of the undifferentiated/unstable states such as cardiac arrest, dyspnea, shock, and coma, both in injured and uninjured patients. Sonographic serial re-evaluations or continuous monitoring should also be incorporated into the clinical follow-up process.

Further advanced and comprehensive applications should then be continued, according to a system-based (head-to-toes–like) or problem-based (ABCDE-like) secondary survey, by level 1 advanced providers (Fig. 1; Tables 3 and 4). In any phase, specific clinical markers or information could change the priority settings, suggesting specific pathways or a move straight to level 2 and level 3 procedures, or even a restart of the ABCDE protocol at step A. The whole primary and secondary management should lead the patient to definitive care, after an eventual operative and/or intensive care phase. To provide an example of clinical and sonographic point-of-care integration, we describe the thorough ultrasound-enhanced critical management cycle (USCMC) in trauma care: the extended FAST protocol with ultrasound fully integrated with ABCDE and head-to-toes assessment, treatment, and followup (Fig. 1). The sonographic applications listed would represent both the competencies and the learning goals required at advanced level 1 practice.

The overall inventory of critical care–ultrasound competencies should be prioritized and arranged throughout the different educational steps, consistent with the planned levels of certification.

Level 1—General Practice

General Requirements. Point-of-care ultrasound practice, at this level, would usually require general competence in generating, acquiring, interpreting, and administrating common and focused sonographic findings (17, 24) to incorporate them into decision-making algorithms and enhance clinical performance and outcomes in the following circumstances:

- *Triage, diagnostic, monitoring, therapeutic assessments*: CPR-ABCDE, dyspnea/hypoxemia, chest pain, shock/hypotension, coma/neurologic focal signs, acute abdomen, abdominal/lumbar/pelvic pain, oligoanuria/dysuria, fever of unknown origin, systemic inflammatory response syndrome/sepsis/multiple-organ dysfunction syndrome, FAST and extended uses, with additional focus on abdominal trauma, thoracic trauma, limb trauma, head trauma, ocular trauma, hemodynamics, cardiac failure, pulmonary embolism/deep vein thrombosis, cervical-cranial (including focused transcranial Doppler), soft tissues, ventilated patient, obstetrics and gynecology, pediatrics, geriatrics.
- *Procedural guidance*: Endotracheal intubation, cricothyroidotomy, tracheostomy, thoracostomy/needle aspiration, pericardiocentesis, pleurocentesis, paracentesis, vascular access (central and peripheral veins, peripheral arteries), intraosseous access, defibrillation, cardiac pacing, urinary catheterization, naso-gastric tube insertion, nerve blockage (basics), foreign-body detection and removal, abscess/hematoma drainage.

Level 1 ultrasound providers should demonstrate the following general competencies:

a: perform common examinations safely and accurately (image generation and acquisition).

b: describe, recognize, and differentiate normal anatomy and function; diagnose common abnormalities within organs and systems (image interpretation).

c: manage examinations and documentation according to administrative, medical, and legal duties.

d: integrate sonographic information into clinical decision-making algorithms, including interrelationship with other imaging techniques and referral criteria (clinical image integration).

e: incorporate scanning information into interventional procedures, increasing accuracy, effectiveness, and safety (ultrasound procedural guidance).

f: manage quality-assurance and development plans, enhancing point-of-care ultrasound practice, education, technology, and research, to impact organizational and social outcomes (ultrasound development plans).

g: teach ultrasound to level 1 trainees (if level 1 instructor competency is attained).

Within most medical specialties, this training could be accomplished during postgraduate practice-based pathways or conventional specialist training. In order to enhance and facilitate learning outcomes, general level 1 competencies should be differentiated into at least two levels of training and proficiency, according to relevance, prevalence, scientific evidence, and ease of learning: basic and advanced level 1 (US-BL1 and US-AL1) proficiency.

Training and Practice

- Trainees should acquire an appropriate body of knowledge.
- The level 1 basic module consists of a 2-day (16-hr) course (50% lectures and interactive cases, 50% demonstrations

and hands-on practice). The level 1 advanced module could be a 3-day (24-hr) course (same theoretical/practical ratio). Level 1 monothematic modules, particularly single-application format courses, are usually well covered by 1-day (8-hr) workshops.

- Numerous educational methods can be used to present the theory component including lectures, interactive cases, syllabi, textbooks, video, and web-based and computer-assisted learning. Precourse learning, reassessed at the beginning of the module, could partially replace the cognitive component. Introductory hands-on experience within a laboratory setting could involve scanning of live models or patients, objective structured clinical examinations, and computer simulations.
- Postcourse practical training should involve carrying out regular proctored ultrasound examinations in critical care units or services, or alternatively in emergency and imaging departments.
- Examinations should encompass the full range of pathologic states and procedures listed in the practical syllabus.
- A minimum number of scanning procedures, in each specific area of interest, should be performed.
- Most of the organ/disease-based primary applications, outlined in the level 1 syllabus (see online-only Syllabus: www.ccmjournal.org), would generally require 25 exams to 50 exams each (e.g., pleural space/effusion, lower extremity vein/thrombosis, abdominal aorta/aneurysm), even if accuracy for several specific findings and signs would be generally acquired with less practice (heart motion, sliding-lung sign, venous compressibility, etc.).
- Provided that trainees are clinically experienced and credentialed, some additional scanning could be adequate for effective sonographic integration in critical states management (e.g., dyspnea/hypoxemia, shock/hypotension, coma) or procedural guidance (e.g., vascular-line insertions, tracheal intubations).
- As a recommendation, a certain portion of logged exams should be clinically indicated (>50%) and should be positive (>10–20%); the rest could be performed on normal organs/systems or simulated patients.
- Considering submodular training, a few dozen proctored examinations could credential trainees for one or two applications (e.g., FAST exam and vascular access). Proportionally, several hundred scans should be required for fulfilling complete modules, which encompass >30–40 key competencies. Fortunately, learning outcomes significantly improve with practice extension and learning curves overlap, thus the full basic and advanced level 1 competencies would likely require 200 and 300 overall examinations, respectively, appropriately distributed among the different applications.
- Approximately 5–10 examinations performed by the trainee per week could represent a realistic reference for acquiring, retaining, and developing skills over the whole training period (3–6 and 6–12 months, respectively, for basic and advanced level 1).
- Examinations could be performed as supervised scanning with real-time reviewing, or independent scanning with delayed or remote overreading of the recorded documentation. At least 20% of initial and 10% of final scanning would be best practiced under direct supervision.
- A personal logbook should be kept listing the types of examinations undertaken. Trainees should record patient demographics, examination details, findings, and adequacy of interpretation.
- An additional logbook containing an illustrated description of at least 20 different cases in which the trainee has been personally involved may be a useful adjunct.
- During the course of training, a competency-assessment sheet should be completed, because this will determine the area or areas in which a trainee could practice independently.
- The entire practical experience should be gained under the support of a recognized trainer; the supervisor should be either someone who has obtained at least level 2 certification or a level 1 practitioner with at least 2 yrs of experience.

Physicians with extensive ultrasound experience, who currently employ point-of-care ultrasound in their clinical practice, may, at the discretion of appropriate boards, undergo the credentialing examination without attending the instructional workshop or logging proctored studies.

Core Competencies. A detailed practical and theoretical syllabus for level 1 practice is outlined in this section, encompassing common and focused applications in critical care medicine both for basic and advanced practices. Minimal requirements for skill acquisitions and retention are recommended, even though different trainees will acquire and maintain the necessary abilities at different rates and the end-point of the training program should be determined by a specific final assessment for each module. The core competencies are listed systematically according to their technical (image generation, acquisition, interpretation, and administration), clinical (decision-making and enhancement) relevance. The technical abilities—embracing management of ultrasound instrumentation, techniques, and semeiotics—are listed first, as they represent the first mandatory step for any further effective clinical performance. To avoid redundancy, we described them according to an organ- and disease-based scheme. However, we still emphasize that during the theory and practical training itself, this system-based layout should be reshaped according to problem-based ABCDE and system-based head-to-toes pathways, where technical skills should always be presented and learned as part of integrated clinical decision-making.

Level 2—Comprehensive Practice

General Requirements. Point-of-care ultrasound practice, at this level, would usually require specialized competencies in acquiring, interpreting, and incorporating specific and comprehensive sonographic imaging into decision-making algorithms, to enhance clinical performance and outcomes. Level 2 of practice in critical care medicine is a specialty-specific level of ultrasound proficiency derived from the depth and length of experience, ideally augmented by specific core knowledge and skills. We are not going to highlight detailed syllabi for this level, since we feel that further experience, data, and consensus should be reached to accurately identify the level 2 core competencies of the general critical care specialist. Level 2 usually refers to the ability to provide comprehensive ultrasound examinations over an organ or a body system. This is a concept that fits well within an organ or system-based specialty (e.g., cardiology, gynecology, gastroenterology), where a level 2 practitioner performs complete (not just focused) examinations over a targeted organ system. However, critical care does not deal with isolated organs or systems. The pathophysiology of the critically ill consists of scenarios involving symptoms and signs. We would strongly suggest emphasizing clinical approaches in level 2 focusing on the comprehensive assessment and management of these states rather than organs (e.g., hypoxia, hypovolemia, coma, sepsis rather than lung, heart, vessels, and liver). Before defining the problem-based comprehensive and transversal competencies characterizing level 2 of practice in critical care, the level 1 clinical profile should be further defined and validated. Currently, we recommend promoting the development of collateral system-based level 2 subspecializations, to strengthen critical care physician performance in certain functions (e.g., transthoracic/transesophageal echocardiography for hemodynamic assessment and management). Because of the difficulties in maintaining proficiency and credentials for several advanced skills at the same time, each trainee should plan and perform only a few subspecialized modular level 2 upgrades, eventually aiming for level 3 in the targeted fields. Such modules should not encompass applications requiring training and continuing education that would be too difficult for the practitioner to sustain. For example, certain echo-lab skills, calling for several hundred annual examinations to retain credentials, may be appropriate for a cardiologist, but not for a general intensive care practice.

Given these considerations, we propose that level 2 credentialing require at least 1 yr of experience at level 1, with regular ultrasound practice to guarantee an increased comprehensive ability in managing the set of level 1 clinical indications and applications. Level 2 ultrasound providers should then demonstrate the following competencies (17, 24):

a: to accept and manage referrals from level 1 practitioners.
b: to perform disease-based or problem-based specific examinations safely and accurately (image generation and acquisition).
c: to describe, recognize, differentiate, and assess correctly almost all normal and pathologic sonographic patterns within one or more relevant organs, systems, syndromes, or clinical procedures (image interpretation, procedural guidance).
d: to acquire and manage more specific and comprehensive sonographic information, to achieve more effectively the clinical and organizational goals outlined at level 1 practice.
e: to teach ultrasound to level 1 and 2 trainees provided that level 1 and 2 instructor competency is formally acknowledged.
f: to conduct research in critical care medicine ultrasound applications.

Monothematic subspecialized modules should also be recommended to enhance or increase the basic skill inventory of the critical care physician. Typical examples would be training focused on echocardiography (including transesophageal), vascular ultrasound, or gastrointestinal ultrasound, or on procedures, such as regional anesthesia, vascular access, airway management, etc. Specific modules could also highlight setting-related competencies, such as those consistent with perioperative or prehospital critical care functions and responsibilities. In the cluster of the level 2 subspecialized providers, we should also include the radiologists trained as sonologists, since their comprehensive competence is usually focused on the abdomen and some procedural application, and less often the other systems relevant to critical care (such as vascular, cardiac, airway). Subspecialized categories of level 2 comprehensive proficiency in CCM should also be attributed to other imaging specialists (e.g., gastroenterologist, cardiologist, gynecologists), or to the technicians trained and certified in specific areas such as echocardiography and vascular ultrasound.

Training and Practice

- At level 2, trainees should further extend the body of knowledge encompassed at level 1.
- Additional practical training should include at least 1 yr of experience at level 1, with regular ultrasound practice in critical care services, or alternatively in emergency and imaging departments.
- A further 300 examinations should be undertaken to encompass the full range of pathologic conditions and practical procedures listed in the level 1 program.
- Approximately 5–10 examinations per week could represent a valuable reference for acquiring, retaining, and developing further skills over the whole training period (12 months).
- A logbook listing the numbers and types of examinations undertaken by the trainee should be maintained, as during level 1 training.
- A further illustrated logbook of specific normal and abnormal findings should be kept, detailing 20 different cases examined by the trainee, which may be useful to document further progression of training. Bibliographic references of supporting ultrasound theory or practice should be attached, as well.
- Examinations should be reviewed or undergo other quality assurance (cross-checking with other imaging examinations, discharge report, follow-up, etc.).
- The end-point of the level 2 training program will be judged by a formal assessment of competencies, where documentation of practice and, eventually, educational and research activity, should be produced, too.
- The full practical experience should be gained under the support of a recognized supervisor; this role should be undertaken by someone who has achieved at least level 2 competence, has had at least 2 yrs of experience at that level, and would normally be of consultant status.
- Trainers, trainees, and training centers should continuously undergo quality-assurance programs to keep the whole system (and each instructional component) accredited.
- Imaging specialists and experts already practicing in specific areas (acknowledgeable at the 2nd and 3rd level) should still formalize areas of competence and meet quality-assurance and continuing-development requirements for undertaking USCCM-teaching roles.

Core Competencies. Whether the trainee's professional development plan includes subspecialty training, the teaching modules could be based on the sequence of the level 1 modules and adapted to the appropriate contents: introductory course (1–3 days), proctored practice (3–12 months), final assessment of competencies, and credentialing. A minimum number of proctored and logged scanning procedures in each module area should be recommended, together with educational and research tasks, before final credentialing. Echocardiographic training for intensivists can be acknowledged as level 2 training (or introductory to it), and is already available in some countries such as France, Belgium, the United States, Canada, Denmark, Australia, India, and Italy) (78). In an increasing number of countries, courses on U.S.-guided vascular access are available. In most, practical training is nonstandardized and focused only on peripheral and internal-jugular-vein approaches, consistent with a level 1 standard. A comprehensive level 2 approach would require more in-depth training, encompassing all the venous-access techniques over all anatomical areas. Advanced courses on multiple regional anesthesia techniques are increasingly available, too (particularly in Germany, Austria, and North America). Nearly all of the other ongoing experiences targeting critical care practitioners throughout the world are striving to develop "focused" ultrasound at level 1. As for specialty-specific level 2, the subspecialty level 2 training experiences (with the exception of echocardiography) still require further data before being definitely incorporated into a formal evidence-based curriculum with a detailed syllabus.

Level 3—Expert Practice

General Requirements. Level 3 practitioners are expected to spend a significant part of their time undertaking ultrasound examinations, teaching, researching, and developing new ultrasound knowledge. They are therefore regarded as expert in this area. They will be able to perform specialized examinations at the cutting edge of ultrasound practice and will be actively involved in developing innovative ultrasound applications within critical care. Generally, this very advanced level of practice would involve the following abilities (17, 24):

a: to accept tertiary referrals from level 1 and 2 practitioners
b: to perform specialized ultrasound examinations
c: to perform advanced ultrasound-guided invasive procedures
d: to conduct substantial research in ultrasound
e: to teach, mentor, and supervise ultrasound practitioner at all levels
f: to be aware of and to pursue new developments in clinical ultrasound

In a developed and formalized training system, level 3 experts should have spent a continuous period devoted to specialty or subspecialty-specific ultrasound training in critical care, being mentored and supervised by other level 3 practitioners. Unfortunately, at the moment, we are still far from having a critical mass of experts in ultrasound to set up and maintain such a system. If we look at critical care ultrasound subspecialties, we would find several level 3 experts practicing and publishing data throughout the world. Some are intensivists or anesthesiologists, expert in specific ultrasound fields, such as echocardiography or interventional applications. More frequently, they are experts belonging to other medical or surgical specialties who frequently perform "organ-based" ultrasound examinations in critical care services; they are physicians temporarily in charge of the critical patient, or consultants making or recommending clinical decisions accordingly (cardiologists, gastroenterologists, internists, vascular surgeons, nephrologists, urologists, gynecologists, etc.). However, if we look at critical care ultrasound as a transversal multidisciplinary tool, throughout the world we would find just a few critical care physicians practicing multiorgan and multisystem ultrasound at level 3 (1).

Maintenance of Skills

At all levels, after having been assessed as competent to practice, the physician will need continuing education and professional development, because of the natural decay of infrequently performed competencies and to keep pace with the continuous development of technology and procedures (Table 4).

- In medical practice, a critical care physician performing ultrasound should continue to perform at least 100 and 200 examinations per year respectively at basic and advanced level 1, 300 per year at level 2, and 500 per year at level 3. Level 1 trainees should continue to practice ultrasound throughout their training with no >1 month elapsing without using ultrasound skills.
- Credentialed physicians should also hold regular meetings with imaging specialists and peers, and should keep a named experienced sonographic practitioner as a mentor.
- They should also include ultrasound in their continuing medical education, audit their practice, participate in multidisciplinary team meetings and conferences, and keep up to date with relevant literature and technology development.
- Finally, at all levels, while implementing a training program, quality should be guaranteed. Providers, students, instructors, and training centers should continuously undergo quality-assurance processes, which assess technical and clinical performance through methods such as supervision, over-reads, gold-standards testing, or patient-outcome review within departmental ultrasound plans.

A Training System Approach Matrix. The outlined critical care ultrasound curricula aim to strengthen the basis for consensus around standards of ultrasound performance and education in critical care. Nevertheless, any systematic and international approach to the matter should consider the huge variety of interpretations of the critical care concept throughout the world, as well as the actual and potential differences among all the critical care ultrasound services and providers. In addition to standardized models, we should also focus on the best methods to design and implement training that meets any specific local, regional, or national demand. A performance-based needs analysis, incorporated into a system approach to training and development, is probably the most widely accepted emerging instructional model, able to meet specific requirements and goals in view of a performance-management process (79). Training and development refers to an ongoing process set up mostly to address workforce performance gaps; i.e., education required to meet performance standards of completeness and accuracy for a defined task or set of tasks (function, role, job). The performance gap is effectively indicated by the performance appraisal, which includes evaluation of all activities ensuring that organization, department, service, and individual goals are consistently being met in an effective and efficient manner.

Constructing a training program systematically involves a sequence of dynamic steps that can be grouped into five iterative phases: a) *needs analysis* (assessing organizational goals, performance standards and gaps, workforce needs for competence, learning objectives); b) *training model design*; c) *courseware development*; d) *course implementation and conduction*; and e) *continuing evaluation and improvement* throughout all of the phases. The steps in each phase should not be thought of as concrete in nature. Depending on starting points and variables, one step does not have to be completed before the next one is started. Every training project will develop its own rhythm and flow. The outlined approach is not to be considered a mechanical, linear, or algorithmic procedure, but rather an exploratory problem-solving technique that uses analyses and evaluation feedback to provide customized performance-based training and development solutions.

CONCLUSION

In the future, the accurate assessment of critical disease states and the safe guidance of interventional procedures is likely to be routinely performed by critical and intensive care physicians using ultrasound. A qualified level of practice—as verified through education, credentials, experience, and continuing medical education and professional development—is necessary to allow for the provision of a safe and effective ultrasound service. Although scientific and educational bodies, particularly for the critical care subspecialty areas, have recently made some recommendations, there are still only scattered examples of educational standards for general-purpose applications. This article strives to address this gap, by suggesting detailed performance and competence-based educational recommendations, acceptable at an international level, to facilitate the incorporation of the emerging point-of-care ultrasound usage into critical care practice.

Given the nature of the critically ill patient, these recommendations cannot be conclusive for all patients and care providers, but are intended to further the ongoing international debate on the educational and proficiency requirements necessary for the appropriate use of ultrasound in critical care. We perceive that the critical care community will easily accept the rationale regarding the level 1 of general practice, which encompasses the most common applications for the critical ABCDE and head-to-toes management processes. More complex will be the recognition of newer subspecialty areas of critical care encompassing higher levels of ultrasound practice (in concert with echocardiography) and adopting the "transversal" profile of the level 2 (comprehensive) and level 3 (expert) ultrasound providers. Regardless, the increasing availability of portable and affordable technology, together with the rational goal-directed simplification of competencies and applications, represent a tremendous opportunity for the highly sophisticated ICUs of the industrialized world, as well as for the essential critical care services of the less developed nations. There is a huge educational challenge ahead of us. At the conclusion of this article, primarily intended to define standard references for an international ultrasound curriculum, we must still underline the limit of any stiffly standardized content and model, and rather emphasize the value of any system process that enables a versatile and easily updated continuing-training solution.

To achieve a universal approach to ultrasound education in critical care, a multicentric educational study has been undertaken to apply the described and future curriculum models throughout several dozen countries over the next few years ("Continuing Medical Education for Ultrasound in Critical Care Medicine," CME USCCM Project, accessed at: http://www.winfocus.org/usccm) (25). While testing and refining goals, contents, and methods, we aim to gather and empower an interactive worldwide network, able to provide gradual consensus and evidence-based recommendations, and test the feasibility of a certification and quality-assurance international development plan.

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