Advancing clinician-performed sonography in the twenty-first century: building on the rich legacy of the twentieth century pioneers

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In their first clinical application about 70 years ago, ultrasound machines were the size of automobiles and required water immersion of the patient to obtain shadowy suggestions of internal anatomy [1]. The physics involved were the same as those used to track icebergs and submarines, adapted by innovators to the delicate task of finding a tumor or looking for a gallstone [2, 3]. Within 20 years of its initial clinical use, scientists had advanced the technology to a point where ultrasound machines were much more compact and offered image quality sufficient to evaluate the fetus in obstetrics care [4]. Since then, diagnostic applications of sonography have incrementally increased to encompass literally every field of health care, from physical medicine and rehabilitation to obstetrics and gynecology, emergency medicine to pulmonology, critical care to disaster management, oncology to trauma and emergency surgery, and pediatrics to gastroenterology [5–10].

As clinical applications of ultrasound have expanded and image resolution has improved, the actual sizes of machines and probes have progressively become smaller [11–13]. This portability has allowed ultrasound studies to occur at a patient's bedside, largely eliminating the need for

patient transport in the new point-of-care testing paradigm [14]. From simple diagnostics and interventions, sonography has blossomed into more advanced applications, such as real-time guidance for bedside procedures (e.g., venous catheter placement, thoracentesis, lumbar puncture, and even endotracheal intubation) [15–18]. By facilitating a procedure that results in fewer unsuccessful interventional attempts and increases patient safety [19, 20], sonography actively enhances the overall value of health-care services offered. Moreover, the marriage of miniaturization and minimally invasive techniques has also allowed for high-resolution endocavitary studies, such as transesophageal echocardiography, endovascular ultrasound, endoscopic ultrasound, or transvaginal studies, giving medical providers detailed visualization of structures not previously seen outside of the operative theater [21–26]. This includes minimally invasive interventional applications [25–27]. Indeed, the increasing portability and affordability of this technology has allowed for its ever-expanding and evolving use, both within and outside the hospital's walls [28, 29]. Now, ultrasound is finding a role even earlier in the care of the patient, including the pre-hospital arena where studies are performed by emergency medical providers to assist in decisions regarding triage and resource allocation [29]. Point-of-care sonography has been used successfully in developing countries, resource-poor areas, and mass casualty/disaster settings [6, 30].

Supporters of ultrasound technology have touted it to be the “new stethoscope” of the twenty-first century, moving it conceptually from its traditional role as a diagnostic modality to a necessary and central part of a good physical examination performed by a medical practitioner [31, 32]. This moniker illustrates the ubiquitous nature of ultrasound application. Much like the basic use of the stethoscope, ultrasound technology can be effectively employed by technicians,

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students, nurses, mid-level practitioners, primary care physicians, and subspecialists [28, 33–37]. However, how sonography is practically implemented and used is somewhat different from the traditional “stethoscope” concept, with key differences related to image acquisition, interpretation, and the subsequent generation of a professional report [38, 39]. Consequently, future growth of sonography will require significant educational and system-based coordination efforts among health care’s various providers.

Our patients are the focus of a continuous quest to provide the best care, in a sustainable manner, at optimal quality and value points. For each individual provider, this process starts with solid educational background. Ultrasound in health care and medical education has a rich history, with ultrasound education being an important cornerstone for future advances in the area of clinician-driven diagnostics. Sonography has always had the stigma of being operator dependent. In this respect, the technology seems to have outpaced the education. Consequently, starting ultrasound didactics early in the education of students and residents will help enhance subsequent physician education and the overall level of sonography expertise and acceptance. Integrating ultrasound into existing curricula can be useful, as can starting afresh with ultrasound as a main focus [40, 41]. Collaborating between specialties seems to be the long-term answer to educational challenges faced by both medical schools and medical centers. One must also remember that educating the various learners who have different levels of pre-existing knowledge (e.g., medical school, residency, fellowship, practicing physician) demands different approaches. No matter where diagnostic ultrasound is used, the key components must be taught to produce minimally competent practitioners who understand the indications, acquisition, and interpretation nuances of point-of-care ultrasound [5]. Interlacing ultrasound didactics with other knowledge a student is exposed to during his or her standard medical education seems to be the most optimal manner in which sonography can achieve the desired level of enmeshment.

Ultrasound is “the future” and, although one could easily accuse the authors of being too forward looking, we must remember that humanity’s progress will result in increasing the number of ventures into interplanetary (and perhaps even interstellar) space. Various disease states are likely to follow humans on this quest, necessitating the presence of reliable diagnostic (and therapeutic) tools. Ultrasound is one tool that can identify normal and abnormal fluid or air, help visualize structural characteristics of healthy and inflamed tissues, and provide information on key physiology and hemodynamics of our organs and tissues, regardless of the location of the patient [42–45]. Early experiences with sonography on the International Space Station provide a glimpse of what space medicine might look like on our voyages to other planets and stars [42–44, 46].

Future clinicians will be well served to have a scaffold of vision and clear outcomes for each part of their ultrasound education. Even though the impact of sonography in clinical practice is evidence-based, commonly deployed general and trauma surgeons are reluctant to embrace the ultrasound probe as a daily tool for clinical problem solving. Fully aware of this problem, of the particular needs of adult learning, and even the need to optimize the on-site “hands-on” part of learning for time-constrained acute care surgeons, a novel educational format was developed by the European Society for Trauma and Emergency Surgery (ESTES) [47]. Modular UltraSound ESTES Course (MUSEC) was designed *a priori* as a blended educational format tailored to the surgeons’ requirements and centered on ultrasound-driven surgical decision-making. The results of this novel approach, both in terms of learning gain and of overall satisfaction, fully support this educational initiative. Modularity, flexibility, continuous correlation with clinical practice, and hands-on training utilizing realistic original phantoms and healthy models are intended to narrow the gap between the ultrasound as a clinical tool and the acute care surgeon as the operator.

As the Guest Editors of the second “Focus on Ultrasound” issue of the European Journal of Trauma & Emergency Surgery, we hope that you find the current contributions educational, practical, and thought provoking. From a basic review on FAST and E-FAST sonography for the injured, through an overview of ultrasound-guided bedside procedures, a focused review of sonography in disaster settings, to the latest trends from MUSEC, we hope to captivate your attention and enhance your knowledge on this topic of growing importance for all practitioners of trauma, critical care, and emergency surgery. As ultrasound use in clinical practice continues to expand, let us work together to identify best educational practices and implementation pathways. Let us also make this a global affair, no longer confined to countries or continents. Patients around the world are listening.

Compliance with ethical standards

Conflict of interest Rebecca Jeanmonod, Stanislaw P. Stawicki, David P. Bahner, and Mauro Zago declare no conflicts of interest in relation to this work.

Ethics statement The authors declare that this manuscript conforms to the established guidelines for ethical conduct of research.

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