Introduction to the use of ultrasound in critical care medicine

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Ultrasound is a safe and proven diagnostic imaging modality that has been in use for many years. Many technological developments since its inception have enhanced the fidelity of ultrasound images and increased the scope of organ and physiologic process imaging possible. Although radiologists and certain specific groups have long appreciated the usefulness of ultrasound, clinicians in general have only quite recently begun to appreciate the many benefits of this technology to the critically ill or injured patient—a myriad of benefits may be obtained.

Many experienced clinicians have lamented the loss of the “art” of the physical examination in critical care medicine, and in medicine as a whole. Art truly is the correct terminology. However, as in painting or sculpting, there are masters, and then, there are the rest of us. When evaluated scientifically, the physical examination is typically quite inaccurate and often cannot be trusted in the assessment of the critically ill or injured (1–6). Given the inaccuracy of the physical examination, a reliance on imaging and other confirmatory techniques may be unavoidable. Unfortunately, this is often manifested as a loss of physical interaction between the patient and the doctor, with a heavy reliance on “numbers.”

We believe, however, that bedside clinical ultrasound has the potential to revitalize the physical examination, improving the accuracy and clinical utility, expanding the scope, and enhancing the teaching of physiology. Bedside ultrasound marries the human hand to the digital age, allowing the examiner to interrogate anatomy and physiology with instantaneous visual gratuity. Further, this information is now available for storage and documentation, transmission, consultation, manipulation, or fusion to other medical informatics (7). The concept of peritonitis differs among examiners; this examination might become more objective and mean more when qualified with the determination of obvious free fluid and air. Further, the exploding scope of the sonographic examination suggests that every facet and nuance of the human physical examination requires consideration of the sonographic features. By spending only seconds to minutes at the bedside, “papilledema” can be quantified as optic nerve sheath distension (8), “decreased breath sounds” can be correlated to lung sliding and other pleural characteristics (9), “shocky” can be visualized as having either a dynamic or sluggishly contracting ventricle (10), the swollen tender limb can not only have the fracture confirmed but also anatomically realigned during early splinting (11).

Sonography will also expand the physical examination to new areas that previously limited the human senses. Advances in technique and technology allow us to penetrate the skull, assessing and predicting neurologic function and recovery. The very characteristics that once were assumed to limit the evaluation of the bones and lungs are being used to describe their status (11, 12). Adjuncts such as Doppler analysis or the use of ultrasound contrast agents may allow the earliest diagnosis of life-threatening pathology, before it manifests as obvious organ failure (13–15).

With such an exploding scope of the potential uses of the sonographic examination, coupled with reduced training time available for students and residents, it is likely impossible for any one average clinician to master all ultrasound techniques. This does not discount, but rather enhances, the acknowledged expertise of the board-certified and actively practicing sonographer/radiologist as the master of the diagnostic ultrasound. However, as plastic surgeons are not available to place every suture, nor cardiologists to auscultate every precordium, neither can radiologists be available or expected to perform every physical assessment of every critically ill patient. Thus, we believe that at least basic ultrasound skills should be part of the armamentarium of critical care. Therefore, the critical care community needs to tackle the significant issues of providing the appropriate training for focused sonography and the delicate balance with expert referral services such as those providing diagnostic quality ultrasound, echocardiography, and interventional procedures. Finally, every clinician must realistically appraise how much to trust the urgently performed, focused evaluation in real-time clinical decision making.

Bringing ultrasound to the bedside will not be infallible and might even be harmful if undue importance is attributed to erroneous or inconsequential findings. Like any procedural technique, problems are most likely to arise with inadequate training and experience. The greatest benefit to the patient will be realized when this diagnostic technology is seamlessly incorporated into thoughtful patient assessments incorporating all possible information (data) considering the patient’s physiology and illness. Critical care physicians must currently do this regardless of whether sonographic data are available. In such decision making, a positive sonographic interpretation based on a recognizable image that corroborates the clinical impression is invaluable; a negative interpretation, or one based on poor quality or indeterminate images, is less so or even noninforma-
tion. The latter is a situation that leaves the clinician no further behind; further testing is not compromised, diagnostic imaging consultants may still be engaged, and there are no side effects of testing if misinterpretations do not occur. Widespread and safe utilization by nonexperts, however, will rely on integrity and discipline. Just as admitting “I cannot hear it” requires courage; so does admitting “I cannot see it.” A further attribute of focused bedside sonography, however, is the examination’s repeatability; whether an evaluation has been performed in the previous minutes, a repeat examination is always warranted if the situation or physiology changes.

The developed world now lives in the Information Age (16), where electronic communication replaces speech with the colleague in the next room, money is replaced with digital passwords and accounts, and when we do speak to each other, real-time video conferencing is required. Intensive care medicine is no different; the majority of the information that guides clinical decision making is digital, collected and analyzable as bytes of data rather than the sounds, temperature sensations, or odors that guided earlier clinicians. Satava (7) has stressed the information systems integration benefits of total body scans (holomers). Although conceptualized as separate tests, computed tomography (CT), ultrasound, and magnetic resonance imaging are thus simply information systems with different eyes (17). In the future, it is probable that all information acquired about a patient in the developed world will be automatically compiled to build an increasingly elegant holomer from the time point of the first patient encounter.

Unfortunately, these technological marvels will likely not be available for the majority of mankind, unless unlikely changes rapidly occur in the developmental, political, religious, and societal realities of these countries. Global numbers of deaths are projected to increase from 57 million in 2002 to 64.3 million in 2015 and 74.3 million in 2030, with a shift from communicable, maternal, perinatal, and nutritional causes to noncommunicable disease and trauma (18). In the developing world (and many operational settings), issues such as the increased fidelity of CT compared with ultrasound for imaging the retroperitoneal space, or the increased accuracy of a dedicated echocardiographer over a committed clinician for determining left ventricular ejection volume, become abstract thoughts rather than realistic arguments.

Besides limited resources, there is also a severe predicted shortage of healthcare workers, notably in the least developed countries (18). In such settings, the attributes of ultrasound, which include portability, lack of radiation, repeatability, absence of consumables, being battery powered, and a scope limited only by human ingenuity, become paramount. A technical note is also that the epidemic of obesity facing the developed countries, a marked impediment to ultrasound, is largely not an applicable concern in the developing world. With limited resources, the principle of distributive justice is of utmost importance (19). The cost of a CT scan or magnetic resonance imaging machine would provide for many simple ultrasound units. The critical care community should thus not just concern itself with how to educate and train practicing clinicians in the developed world with comparatively limitless alternatives to improved diagnosis with ultrasound, but also how to empower those without any other diagnostic options.

Even in the developed world, there is a need to develop reliance on ultrasound as a bedside tool without radiation that complements those imaging modalities that use ionizing radiation, such as CT scan, for repeated examinations and clinical follow-up. It is unquestionable that CT scanning has dramatically advanced in the ease and elegance of the images it can acquire and, used appropriately, has a large balance in favor of benefit over risk. This had led to the routine use of near-whole-body CT scanning in many acute conditions, especially traumatic injury (20). Although invaluable, CT scanning greatly increases radiation exposure (21, 22). With liberal use, this imparts a small but finite risk of later cancer, especially in younger patients (22, 23). In one study, CT contributed 97.5% of the total effective radiation dose from all imaging in traumatized children (22). The doses of radiation involved from a single whole-body CT scan are only slightly lower than mean doses in groups of atomic bomb survivors, in whom statistically significant increases in cancer risks are seen (24). If an additional sense is added to the current human bedside capabilities, it must be as safe as touching, listening, or smelling. Ultrasound seems to satisfy this requirement.

This supplemental issue has attempted to provide an overview of a dynamic and multidisciplinary area of medicine. It provides basic historical and physical facts. It attempts to survey the human systems that are quickly assessed by ultrasound, including the brain, heart, lungs, intestines, vascular system, and kidneys. It further elaborates on the potential uses of these techniques, both for processes such as infection and for locations such as outside of the hospital and in the surgical suite. It further suggests how clinicians might be trained. These articles, however, can only be considered a survey. This supplement is really intended only to stimulate dedicated clinicians to consider how a focused ultrasound examination might aid their daily practice by illustrating what others have accomplished, sometimes with complicated equipment and technology, but more often with simple machines and approaches. We strongly believe that the more clinicians who pick up ultrasound probes, the more innovative solutions to the challenges of providing accurate and timely critical care will emerge.

REFERENCES

tended focused assessment with sonography for trauma (EFAST). J Trauma 2004; 57: 288–295