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RECENT ADVANCES IN ICU

Using ultrasound in ICU

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Ultrasound (US) imaging has undoubtedly changed the practice of intensive care medicine (ICM). With the use of ultrasound for diagnosis, monitoring and as a procedural aid becoming more established and refined, there have been several publications tracing its history and identifying its role and the research priorities within ICM [1, 2]. We reflect on advancements in technique and devices to highlight important recent publications and how they may define the future of critical care ultrasound (CCUS).

Ultrasound technique

Speckle tracking, strain imaging, contrast-enhanced and 3D US are all technological developments that will lead to more research into US-based parameters in multiple diseases. However, their critical care applications are significantly limited due to the expense and to the advanced training needs associated with such technology.

Whilst generally accepted as a more sensitive and objective marker of cardiac contractility, the clinical applications of strain analysis within critical care is still in its infancy. Certainly, early studies suggest abnormal left ventricular strain may be associated with poorer outcomes in septic patients [3]. Right ventricular strain analysis is also technically feasible, but again supporting data are scarce [4]. Separately, the increasing availability of 3D transthoracic and contrast echocardiography will allow for more detailed assessments of cardiac anatomy and function including potential novel applications such as the evaluation of left ventricular (LV) twist and torsion, wall motion analysis, and dyssynchrony analysis. Enhanced intra-operative guidance and positioning of intracardiac devices and catheters are other potential advantages [5, 6].

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Contrast-enhanced ultrasound (CEUS) refers to the use of microbubbles which are purely intravascular to study the perfusion (and re-perfusion) of various organs. It has been used to highlight areas of infarction in lungs of patients affected by coronavirus disease 2019 (COVID-19) [7] and to show differential blood flow in septic acute kidney injury (AKI) and hence to predict patients in whom renal function is likely to recover [8]. The development of cardiac US contrast agents with microbubbles small enough to cross the pulmonary circulation, along with newer pulse sequencing methods, allows for a clear delineation of the left-sided endocardial border.

Device and technological advancement

Advances in digital image processing have resulted in a proliferation of hand-held devices that provide good 2D spatial resolution as well as colour and spectral Doppler modalities. Along with increasing affordability, this has transformed US into a truly bedside assessment tool that can be routinely used by physicians [9] across the world and in a variety of healthcare settings.

Complementing this, software-based and artificial intelligence-based solutions have been developed to provide real-time image analysis and feedback to the user [10] both on traditional and hand-held ultrasound devices.

From a training perspective, how the availability of such solutions, as well as simulation, manikins and telementoring, impacts skill acquisition and image interpretation is unknown though presumed to be positive. This has relevance in refining/updating the various competency documents that have been previously published, as these tended to define competency achievement based on the number of scans before such technology existed. Further research is required in order to define the optimal way to train future colleagues.

From a clinical perspective, software advancements can aid the clinician in several critical care applications. A few examples of such features include (1) aiding anatomical

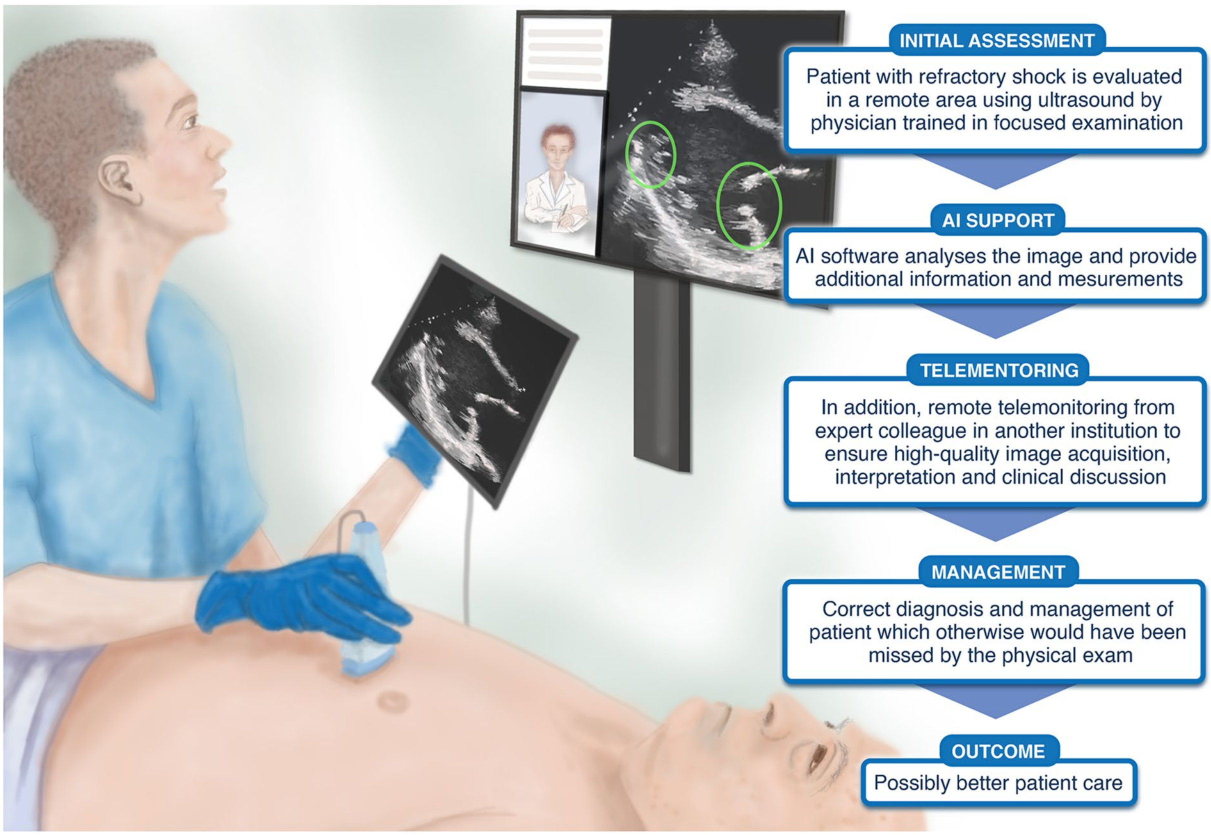

Fig. 1 What the future might hold. *AI* Artificial intelligence

identification (chamber identification), (2) quantitative analysis such as assessment of left ventricular ejection fraction (LVEF)/strain and B-lines on lung ultrasound and (3) preset multi-system protocols as an aid-memoire for scanning in specific scenarios, e.g. trauma, shock, etc. However, it must be acknowledged that the introduction of such new technology does not necessarily improve patient care and may conversely slow down the dissemination of CCUS.

The ability of several online platforms to offer two-way teleguidance (Butterfly™, Philips Lumify Reacts™) has been priceless in several ICU scenarios, especially during the pandemic where US became a major diagnostic modality in critical care. More novice practitioners are able to assess expert feedback not just on image acquisition and interpretation but also to discuss the clinical management in real-time irrespective of geography.

Clinical implications

The measurement/estimation of cardiac output and its integration with other US modalities are core skillset of the intensivist. Two particular trends have emerged.

First, the ability to measure flow to individual organs brings us a step closer to optimising organ perfusion rather than cardiac output per se. Doppler-based techniques to assess flow within splanchnic, renal and splenic circulations have demonstrated a correlation between abnormal flow, peripheral perfusion and organ dysfunction [11, 12].

Second, in addition to the assessment of arterial flow, Doppler assessment of the venous circulation has highlighted the importance of venous congestion and its potential utility within a fluid de-resuscitation strategy [13]. The VEXUS score describes a technique to assess the various intra-abdominal veins as a measure of venous congestion. Early evidence has shown that an increase in VEXUS score and subsequent treatment tracks the incidence of AKI [14].

With these techniques applied together, a multimodal and holistic US-based approach to monitor and guide shock resuscitation may be feasible. Three critical US variables (systemic blood flow as represented by velocity-time integral (VTI), splanchnic organ flow, and venous congestion indexes) may be combined to tailor fluids and vasoactive drugs to increase systemic blood flow until organ perfusion is restored while avoiding congestion.

In addition, during the COVID-19 pandemic, it is perhaps unsurprising that the utilisation and understanding of lung US have taken a significant leap forward. 'Traditional' lung US techniques based on B- and M-mode examination are now supplemented with CEUS and Doppler-based techniques. These will potentially impact the way clinicians set ventilatory parameters such as positive end-expiratory pressure (PEEP), weaning strategies, etc., to individualise therapy [15].

Take-home message

In conclusion, the way we utilise and integrate CCUS into clinical practice will continue to evolve (Fig. 1). The technological advancement should not compromise the required training and understanding of physiology which underpin good clinical care. Telementoring and telemedicine have the potential to improve accessibility to US training and clinical expertise. However, it is important to remember that despite all these advancements, at the heart of everything that we do, is the patient. Future research in CCUS will remind us of the mantra—just because we can, does not mean we should.

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Declarations

Conflicts of interest
The authors have no competing interest to declare.

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