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It is Time to Embrace Clinical Ultrasound and Echocardiography into Anesthesiology Practice

Colin Royse*

Professor of Anaesthesia, Department of Surgery, The University of Melbourne, and Consultant Cardiothoracic Anaesthetist, The Royal Melbourne Hospital, Australia

"An invasion of armies can be resisted, but not an idea whose time has come"-Victor Hugo

Ultrasound was developed in the 1950s following developments in sonar technology in World War II [1] This technology was widely adopted by cardiologists, radiologists, and obstetricians, though the technology was bulky and expensive and of poor quality compared to today's standards. Echocardiography entered anaesthesiology practice in the last 25 years as Transesophageal Echocardiography (TEE) for cardiac surgery, where it revolutionised the conduct of cardiac anesthesiology [2]. However, TEE is invasive and requires an anesthetised patient, restricting its use to intraoperative monitoring or intensive care unit monitoring in ventilated patients. Few non-cardiac anesthesiologists embraced this technology.

The first real use of clinical ultrasound other than echocardiography by anaesthesiologists was to help guide procedures such as vascular access or regional anesthesia. This has now become a standard of care for many centers worldwide, and is no longer new or controversial [2].

For the anesthesiologist, the "new areas" are Transthoracic Echocardiography (TTE) and other surface officer and uses such as lung ultrasound. This has been facilitated by development of smaller, mobile yet high quality ultrasound machines capable of multiple probes and different types of imaging. Furthermore, the concept of physician-performed goal-focused echocardiography is an important emerging development, with increasing evidence base that clinicians will frequently make new diagnoses and change their management based on their own echocardiography findings [3-6]. It has been well known for many years, that a novice with an ultrasound machine is more accurate than an expert with a stethoscope [7]. There are few data suggesting that improved diagnostic information will lead to improved surgical outcomes, though there is proof of concept data supporting this [8].

For those who regularly practice echocardiography and clinical ultrasound, this concept is completely intuitive. In cardiac surgery, the use of routine TEE changed the way anesthesiologists practice. Firstly, undiagnosed ventricular or valvular pathology was identified early in the operation, leading to changes in surgical and perioperative management. Secondly, the TEE acted as a continual "feedback loop" to the anesthesiologist allowing them to better manage ventricular filling and function, and perhaps more importantly, predict when haemodynamic instability is likely to occur. Goal focused transthoracic echocardiography provides the same diagnostic and feedback information, allowing anesthesiologists to better predict when haemodynamic perturbations are likely to occur, and to manage the patients in a proactive manner. This last point is perhaps the most important effect of routine echocardiography.

Anesthesiologists are typically reactive rather than proactive in how they manage cardiovascular disorders. That is, there are unlikely to alter their preconceived management plan until haemodynamic abnormality occurs, after which they will rescue the situation. A good example is anesthesia for fractured neck of femur surgery in a patient with undiagnosed severe aortic stenosis. Whether a spinal or general anesthetic technique is used, there is a high risk that the patient will become clinically unstable and require fluid or vasoactive therapy. For some patients, this may be too late, resulting in an increased mortality. However, if the anesthesiologist knows that there is severe aortic stenosis, and may additionally have identified diastolic heart failure, then the management might be entirely different. They may use a number of strategies to maintain normal vascular resistance, and minimise the impact of anesthesia, such as fluid loading, vasopressor infusion, invasive blood pressure monitoring, and post-operative high dependency care. They are better able to prevent haemodynamic collapse because of the additional knowledge gained from echocardiography.

Lung scanning is a relatively new application of clinical ultrasound, but is remarkably simple to do [9]. This provides additional information to echocardiography, such as pulmonary edema, atelectasis, pneumothorax or effusion. For example, a patient with poor exercise tolerance may have relatively normal systolic left ventricular function, but a pattern suggestive of diastolic heart failure. If there are prominent comet tail artefacts seen in the lung scan, this would be consistent with pulmonary venous congestion, indicating a greater degree of severity and risk to the patient.

So how do we get there? In order to get the majority of anesthesiologists to incorporate clinical ultrasound and echocardiography into their practice, there needs to be philosophical and organisational changes as well as a widely available education platform. The philosophical change is to accept that the majority of clinically important diagnostic information can be obtained from a limited ultrasound examination. This is the concept behind goal-focused echocardiography and lung scans. There are data showing that echocardiography will change the diagnosis in a quarter to a third of patients, and will lead to management changes in up to 50% of patients who are at risk of cardiovascular disease [3-6]. Goal-focused echocardiography is a quick procedure to perform at the patient's bedside, facilitating patient management without unduly interfering with workflow.

The major organisational change is to increase the number of ultrasound systems available to anesthesiologists. It is also important to consider more than one modality when purchasing machines. The optimal non-cardiac anesthesiology setup includes the system

***Corresponding author:** Colin Royse, MBBS, MD, FANZCA, Professor of Anaesthesia, Department of Surgery, The University of Melbourne, and Consultant Cardiothoracic Anaesthetist, The Royal Melbourne Hospital, Cardigan St Carlton, Australia, E-mail: Colin.royse@unimelb.edu.au

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and transducers capable of transthoracic echocardiography, surface ultrasound (nerve blocks and vascular access) and a curved linear array transducerfor imaging deeper structures such as the spine and abdomen. Within a department, availability of TEE will still be an advantage for anesthetised patients who present with hemodynamic instability and have's suboptimal transthoracic imaging windows.

Education is the most important change that will enable widespread uptake of clinical ultrasound. Diagnostic echocardiography or general (radiology) sonography requires a large knowledgebase and considerable expertise to become highly proficient. Learning, however, is analogous to climbing a series of hills, with each hill becoming slightly higher until the peak is reached. The first "hill" of learning is to obtain basic skills and knowledge to enable limited interpretation of clinically important pathology. With echocardiography, this is the level of goal-focused studies. There are numerous named goal focused examinations including HEARTscan, FATE, FEEL, FEAR, and BLEEP which described a sequence of examination and limited scope of interpretation [10]. HEARTscan [11] is perhaps the most comprehensive of these limited studies, but is restricted to two-dimensional and color flow Doppler imaging. Interpretation is based on pattern recognition and minimal quantification (such as left ventricular dimensions). However, the vast majority of clinically important pathology will be detected with this type of limited study. The next "hill" is that of a "good basic sonographer", who is capable and confident of making diagnoses and quantifying valve lesion such as aortic stenosis. This involves a greater amount of knowledge as well as the application of quantitative Doppler. For the majority of non-cardiac anesthesiologists, this level of knowledge will be sufficient for their general practice. For many however, they will progress to the level of diagnostic echocardiography (the peak) where they'll be proficient in multiple modes of ultrasound, and be able to confidently diagnose and quantify all the common abnormalities. A few will become the superstars who head training schemes and are considered by their colleagues as exceptional in their skills and knowledge. What I'm describing is an expertise pyramid; where the broad base of the pyramid represents the majority of anesthesiologists at a basic level, and a few at the top of the pyramid who are the experts. A recent expert panel on intensive care training [12], unanimously recommended that general critical care ultrasound and basic echocardiography should be a core part of the ICU curriculum. It is time that anesthesiology followed a similar path.

We are fortunate, that there is a vast amount of learning opportunities for echocardiography and clinical ultrasound. Learning can be on-the-job (fellowships), self-taught (books and workshops), or via progression through structured courses with a focus on knowledge base. This is further refined or tailored to meet the guidelines of learned societies, or to meet credentialling requirements.

Australia is a good model for showing that education can change clinical practice. The University of Melbourne have conducted distance education courses since 2004 to teach the knowledge base of echocardiography and clinical ultrasound at both "good sonographer" and "diagnostic echocardiographer" levels through the Postgraduate Certificate and Diploma of Clinical Ultrasound. They also teach practical workshops for the HEART scan goal focused echocardiography. The Australian and New Zealand region has approximately 5000 anesthesiologists and critical care physicians. Of these, more than 1400 have completed the HEARTscan workshop, approximately 500 have completed the postgraduate certificate, and a further 500 have completed the diploma level (Colin Royse personal communication). Cardiac anesthesiologists are now the minority of trainees, and TTE rather than TEE is the most commonly performed echocardiography examination by anesthesiologists. These courses are now available as professional development programs for the Society of Cardiovascular Anesthesiologists (SCA ON-CUE level I and II, see heartweb.com), thereby increasing availability to North American and worldwide practice.

Ultrasound is becoming an integral part of anesthesiology and critical care medicine. It is a short step before it is simply considered "ultrasound assisted examination" or "ultrasound guided procedures". It is likely that medical schools will teach ultrasound as a core part of basic patient assessment in the future. Integration of clinical ultrasound into everyday practice is a very exciting development for the anesthesiology profession. It is time to get on board.

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