The application of ultrasound in the critical care setting Part I. Critical Care Echocardiography

Echocardiography as a diagnostic tool in the care of the critically ill patient has been used since the 1980s, when it became readily available for the routine haemodynamically stable cardiological patient. However the value of the modality in assessing the haemodynamically unstable patient, or a patient with ventilatory failure, has moved echocardiography from the periphery of intensive care practice into the mainstream over the past two decades. The implications are profound in that the use of pulmonary artery catheters (PAC), once routinely used in the management of severely ill patients, has fallen dramatically around the world, with echocardiography replacing it in most clinical situations. Indeed specialist trainees may encounter the PAC on few, if any occasions, during their training in many large or medium sized intensive care units (ICU) around Australia and New Zealand in 2012.

Initially, when echocardiography was introduced into the critical care setting in the 1980–1990s the training and practice was assumed to be similar, if not identical, to that undertaken by cardiologists. Recognition that the technique could supplant invasive methods for the evaluation and monitoring of the patient's cardiovascular state altered the emphasis, when it became apparent that this aspect was as important as that of diagnosis. An example of this evolution is found in France, where a single body oversees the training and credentialling of echocardiography for cardiologists and intensivists. There is a common syllabus and examination the first year and speciality-specific syllabus/examination the second year. In Australia, courses dedicated to Critical Care Ultrasound have gradually evolved with the CCPU and DDU exemplifying the basic and advanced levels as per international recommendations. Echocardiography takes the lion's share of the syllabus, although other applications are important and will be discussed in Part 2.

The basic level of critical care echo is goal directed, designed to assist the attending physician in the acute setting. Here, time is of the essence and the goal is directed to assessing four aspects that can rapidly assist in management of the patient. These include assessment of:

1 Left ventricular contraction
2 Right heart function
3 Pericardial effusion/tamponade
4 Intravascular fluid status.

Over the years there has been intense debate about the inclusion of Doppler techniques, especially colour Doppler, but generally it is considered that accurate use of Doppler raises training requirements considerably, and that a combination of M-Mode and 2D can readily provide sufficient information in the majority of patients. Anecdotally, the basic echo examination results in more requests for subsequent formal echocardiograms; however these can be undertaken the following day, during regular working hours, or at a time when the regular service is available. On achieving answers to the specific questions, an adequate working diagnosis leads the physician in the relevant direction. If the haemodynamically unstable state or respiratory failure is associated with an impaired left ventricle, then heart failure therapy can be undertaken. Should the right heart demonstrate signs of dysfunction or elevated right ventricular pressures then further evaluation of the pulmonary circulation may be warranted, especially if a pulmonary embolus is of concern. A tamponade, which cannot wait until the daylight hours for treatment, should be treated by immediate paracentesis. Fluid status evaluation has become a central aspect in the use of ultrasound in the critically ill patients, both at the basic and advanced levels.

Competency at the basic level of critical care echocardiography for all advanced trainees should be the goal in those medical specialities where haemodynamically unstable patients are often encountered, such as emergency medicine, intensive care, anaesthetics or retrieval medicine. The introduction of a CCPU in critical care ultrasound has been a major step forward in providing a training structure in this increasingly popular practice.

The advanced level requires the student to commit considerable time and effort and therefore it is anticipated that only a small number who achieve competency at the basic level will progress to the advanced level. Here the emphasis moves from assessing four basic cardiac diagnoses to more advanced diagnoses and haemodynamic assessment. Non-cardiac ultrasound examinations are also included in the curriculum of the DDU (Critical Care) and will be dealt with in a subsequent article (Part II). The cardiac component covers a range of diagnostic skills although the more advanced aspects such as those dealing with congenital heart disease, neonatal echocardiography or prosthetic valve evaluation is considered the domain of cardiology not critical care. However, the advanced critical care echo practitioner should readily assess valvular dysfunction, left ventricular diastolic function and be competent in the use of tissue Doppler imaging, in addition to the advanced evaluation of left and right ventricular systolic function. As mentioned above, fluid status evaluation is very important in many critical care settings and the operator should be knowledgeable about a number of the diagnostic techniques available.

Broadly, the areas covered in advanced critical care echocardiography include:

1 Evaluation of intravascular fluid status
   a) assessment of left ventricular filling pressures
   b) dynamic maneuvers to assess fluid responsiveness
2 Haemodynamic evaluation – e.g.cardiac output.
3 Valvular function
4 Ventricular function – left ventricular systolic function

- left ventricular diastolic function
- right ventricular systolic function

5 Pulmonary hypertension including evaluation of acute pulmonary embolus.

Haemodynamic assessment and monitoring can focus on a particular parameter or multiple, the patient's condition often dictating what to chose. A single parameter such as cardiac output in hypotension or shock may suffice but generally, the sicker the patient the more parameters used.

It would be commonplace in a shocked patient to monitor the cardiac output, left atrial filling pressure, and pulmonary artery pressure. In select situations, left ventricular diastolic dysfunction may be of paramount importance when the administration of positive inotropes to treat hypotension or tissue hypoperfusion can exacerbate an already parlous situation. A detailed understanding of pulsewave Doppler, continuous wave Doppler, tissue Doppler imaging techniques is essential.

Knowledge of alternative modes of assessment to the classical ones is important, such as the need to evaluate pulmonary hypertension when no significant tricuspid regurgitation exists, or where inadequate endocardial delineation prevents the use of Simpson's method to assess stroke volume. The limitations of any method must be understood, whether it be an inherent limitation in every situation or just in the presence of that particular patient. The frequency of monitoring may preclude relying on echocardiographic assessment alone, such as when minute-to-minute systolic pulmonary artery pressure is necessary with a patient on intravenous pulmonary arterial vasodilators and where a pulmonary artery catheter may be preferred. Interestingly, in the majority of critically ill patients intermittent echocardiographic assessment is adequate, reducing the need for invasive techniques, which carry risks.

Despite the challenges in the use of transthoracic echocardiography in supine, positive pressure ventilated patients, an experienced operator will obtain adequate views in many patients. Transoesephageal echocardiography (TTE) will assist in those patients with inadequate TTE views and also preferred in certain situations, such as assessing fluid status in ventilated patients using the superior vena cava collapse, searching for intracardiac thrombi, or diagnosing or evaluating valve vegetations. Therefore, the operator with advanced skills, at the DDU level, requires training and expertise in TOE also. The recommended training requirements are 50 TOE studies, with 25 of these as the primary operators, complimenting 300 TTE performed/reported in addition to another 150 reported. It is anticipated this experience will be gained over a two year period.

Internationally and nationally, there has been considerable development of critical care echocardiography training programs and competency assessments, often university based. National standards are desirable to ensure transparency, ongoing evaluation and application of competency assessments. ASUM is most suitably placed to fulfill this responsibility.

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