CARDIAC IMAGING IN THE ICU

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Assessment and monitoring of cardiovascular function in the intensive care setting is of fundamental importance in virtually all patients. This ranges in complexity from monitoring of pulse and blood pressure to invasive, continuous, haemodynamic monitoring. The use of continuous invasive monitoring of right heart/pulmonary wedge pressures is waning in light of observations that patients with this form of monitoring fare worse than those without. There remains, however, a need in many patients to gain more functional and structural information about the cardiovascular system, and hence the commonest reason for specialised cardiology input in the intensive care setting is to enable further assessment of cardiac anatomy and function.

PLAIN FILM RADIOLOGY OF CHEST

Plain film radiographic assessment (CXR) still has a role in the assessment of the heart in the ICU setting despite the advances in other imaging modalities. It is not only widely available, with a long history of clinical use but displays information in a form that all clinicians can readily interpret. CXR still remains the best technique for displaying the many monitoring devices that can be used in the ICU environment. The CXR gives some information regarding cardiac size, aortic dimensions and the presence of pulmonary oedema, but unfortunately its usefulness in assessing these areas in the intensive care setting is limited, because many patients have pulmonary shadowing which arises from non-cardiac disorders eg adult respiratory distress syndrome (ARDS). Other imaging techniques are often required for cardiac assessment that complement the plain film, of which echocardiography is the most frequently used.

TRANSTHORACIC ECHOCARDIOGRAPHY

Echocardiography is a highly portable technique that uses ultrasound, and in its various modalities can provide considerable information on cardiac structure and function. Its portability is a considerable advantage in the ITU setting as some patients are too ill to transport to CT or MRI scanners.

The conventional mode of echocardiographic study is a two-dimensional image combined with Doppler echocardiography. In 2D imaging, the ultrasound beam is moved in a sector so that a pie-shaped cross section of the heart and great vessels is seen. In a standard study the heart is examined in three orthogonal planes using different transducer positions. The routine 2D study also includes an M-Mode study, in which the heart is visualised along a 'pencil beam' of ultrasound. This enables accurate measurements of cardiac structures to be obtained.

Doppler echocardiography uses high-frequency ultrasound to detect the direction and velocity of blood flow. This is most useful in assessing valvular heart disease, or intracardiac shunts. Colour-flow Doppler is an extension of this, in which blood movement in a sector of the heart is colour encoded and displayed on top of the 2D image.

Figure 1. Echocardiographic imaging console with transoesophageal probe. The imaging system is capable of performing two-dimensional and M-mode imaging together with colour flow, continuous wave and pulsed Doppler.

The major limitation of transthoracic echocardiography is image quality. The narrow sites of access to the heart prevent adequate visualisation in 20% of studies in general cardiology patients. This number is even greater (up to 64%[1]) in patients in the ICU setting because of coexisting lung disease, inability to move the patients into the best imaging position, and lack of access to the precordium because of dressings. Transoesophageal imaging avoids the problems of poor image quality, and in the same study[1] was found to be sub-optimal in only 3%.

TRANSOESOPHAGEAL ECHOCARDIOGRAPHY

Transoesophageal echocardiography (TOE) was first introduced into clinical cardiology in the early 1980s[2] but was little used at first because of bulky probes with poor quality images and only one imaging plane. Modern probes have been miniaturised, provide high quality images and can be used in any imaging plane across a 180° arc (omniplane or multiplane). The major indications for TOE for critically ill patients include

- diagnosis of unexplained hypotension
- suspected endocarditis
- native or prosthetic valve dysfunction
- cardiac trauma
- complications of myocardial infarction
- suspected aortic dissection,
- pulmonary embolism
- suspected cardiac tamponade
- evaluation of sources of embolisation.

In critically ill patients TOE may add information to the transthoracic imaging in up to 59% of patients and, perhaps more crucially, alter treatment in 25% of patients[3,4]. In ICU patients with hypotension, TOE diagnosis of the cause of hypotension carries important prognostic information. Patients with hypotension secondary to pericardial or valvular heart disease have the best outcome, whereas those with noncardiac hypotension or poor ventricular function have the worst[1].

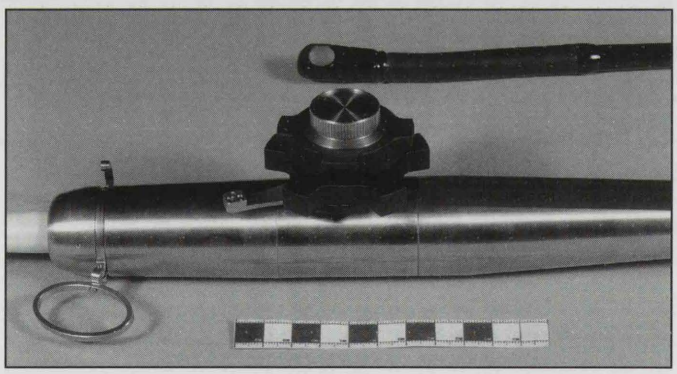

Figure 2. Transoesphageal echocardiography probe. A close-up of the external rotatory controls and the ultrasound transducer at the tip of the probe.

CT/MRI SCANNING

Both of these techniques have a role in cardiac imaging, and, notably, there is increasing use of MRI in general cardiological practice. Their role in the ICU setting is limited, because neither technique can be taken into ITU, and the complexities of patient transport and confinement in the imaging machinery pose clear logistic difficulties. Despite this, they still have a role in many units for the detailed assessment of suspected aortic disease and pericardial disease.

CARDIAC FAILURE

Cardiac failure is common in ICU, at presentation with hypotension, pulmonary oedema or oliguria. It can also develop as a complication in other patients (eg systemic sepsis, or complicating major vascular surgery). Further imaging is frequently needed to determine the specific cause of cardiac failure. Clearly, severe valvular heart disease (which can be silent on auscultation) requires considerably different treatment to that of cardiac failure complicating left ventricular systolic dysfunction. Cardiac failure can be clinically difficult to recognise, particularly when multiple conditions coexist eg severe respiratory failure in addition to LV systolic dysfunction. Yet again echocardiography provides the imaging method of choice, being able to give a detailed structural and functional assessment.

INFECTIVE ENDOCARDITIS

The possibility of infective endocarditis in patients with pyrexia of unknown origin, particularly those with indwelling venous catheters, is a real one. The traditional hallmarks of endocarditis are:

- fever
- new or changed cardiac murmurs
- cutaneous signs or embolic events

but echocardiography enables direct visualisation of endocarditic lesions. Indeed the widely-used Duke criteria[5] lists the presence of vegetations as one of three major diagnostic criteria to enable definite diagnosis of endocarditis. The incidence of culture negatie endocarditis is increasing as a result of frequent treatment with antibiotics before blood cultures are taken[6]. The use of echocardiography in suspected endocarditis should be even more frequent.

Transthoracic echocardiography detects approximately 70% of vegetations, which increases to 90% with transoesophageal imaging. The diagnostic accuracy of TOE is even more pronounced with prosthetic valves, where transthoracic imaging can miss more than 50% of endocarditic lesions. Echocardiography also aids in management by helping to make decisions about early surgery in patients with large vegetations, abscess formation or prosthetic dehiscence. TOE can detect pyogenic complications of endocarditis such as abscess and fistula formation much more readily than can transthoracic imaging. These findings occur in approximately one-third of endocarditis cases, and usually require operative intervention. Failure of TOE to detect vegetations in suspected endocarditis has a high negative predictive accuracy. A negative TOE has a negative predictive power of over 90%[7], and if repeated a few days after the initial negative study is the most convincing clinical way to exclude endocarditis, with accuracy over 95%.

AORTIC DISEASE

Aortic dissection can be referred to the ITU setting for aggressive blood pressure control, with central arterial monitoring, or present with the complications of aortic dissection. Accurate detection of the dissection site is essential, as is detection of potential complications eg aortic valvular disruption, pericardial effusions, or coronary artery occlusion. CXR is helpful in suggesting the diagnosis of aortic dissection in >80% of cases but unfortunately a normal X-ray does not exclude the diagnosis. Currently available and

accurate non-invasive imaging modalities include CT scans, MRI and echocardiography. The choice of imaging modality depends on the particular institution, and the haemodynamic stability of the patient. Trans-thoracic echocardiography (TTE) can be very accurate in detecting dissections involving the ascending aorta, and can show most of the major complications. Dissections involving the descending aorta are much less clearly seen. TOE is highly accurate, with the clear advantages of portability and ability to detect complications. It needs to be performed by experienced operators in this setting in particular, because the stress of oesophageal incubation can elevate blood pressure and further extend the dissection. CT scanning is the most widespread technique in the UK, but lacks portability and the ability to detect complications. MRI gives excellent images, and is undoubtedly the best for patients with previous aortic surgery, but again is non-portable and lacks widespread availability.

TOE is an important tool in the evaluation of suspected aortic trauma. It can be performed rapidly and safely in trauma patients with a high degree of accuracy in detecting significant aortic disruption[8]. Aortic trauma most often involves the aortic isthmus, with subadventitial disruption being clearly seen as a dense mobile flap. Pseudoaneurysm formation can also be seen, albeit with a lesser degree of accuracy.

OTHER APPLICATIONS OF ECHOCARDIOGRAPHY IN ITU

TOE is also often useful in the diagnosis of suspected central pulmonary emboli, and is the only truly portable technique to allow direct visualisation. The main pulmonary artery and the proximal portions of the major pulmonary arteries can be clearly seen with TOE and, therefore, thrombi in transit between the right heart and proximal pulmonary vessels can be clearly identified with reported 97% sensitivity, and 88% specificity[9]. Smaller emboli in the distal pulmonary bed cannot, however, be detected using this technique.

THE FUTURE

The role of echocardiography is well-established in the ICU setting, and will undoubtedly increase with the increased availability of TOE imaging. Further advances in the field of echocardiography are already beginning to enter the field of general cardiology with newer techniques such as power harmonic imaging which can detect the passage of microbubbles through the myocardium, thereby giving insight into coronary perfusion itself. The future is likely to lead to increasing demands on echocardiographic services in the ICU setting. Indeed, there is a growing need for anaesthetists and intensivists to learn the procedure themselves to perform structural and functional assessment of cardiac performance without recourse to cardiology colleagues.

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