Review Article

Field guide to critical care echocardiography: the UK view

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Abstract: This article provides an overview to the development and current position occupied by critical care echocardiography (CCE) in clinical practice in the UK. We discuss the key clinical and political drivers to the development of the subspecialty and give a detailed outline of the available levels and processes of accreditation in the UK. Discussion of clinical situations from our own practice is used to throw light on how the technique can contribute to clinical practice and how to introduce and maintain quality within that practice.

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Introduction

Critical care echocardiography (CCE) can be defined as the contemporary and regulated practice of direct imaging of the heart through ultrasound to manage, assess, diagnose and monitor those experiencing a period of critical illness.

The subspecialty of CCE overlaps with critical care medicine, cardiology, and the practice of cardiac ultrasound in a stable population. CCE combines many aspects of these disciplines and therefore occupies a unique place in clinical echocardiography.

In the UK, practice is clearly divided into the transthoracic approach and the transoesophageal approach. In this paper and in UK practice CCE refers to the transthoracic approach applied to a general population of unwell intubated and non-intubated patients who are assessed and managed by front door clinicians and general intensivists. The transesophageal approach is the echo route of choice in UK cardiac critical care units and this is a separate and surgical discipline requiring close imaging of the heart during the operative and peri-operative periods.

The three main drivers for the development of CCE have been critical care practice itself, the quality of portable imaging technology and the recognition that cardiac physiology is mobile throughout a period of critical illness.

Since the inception of critical care medicine as a circumscribed practice; delivered by trained intensivists and being separate from pure anaesthetic practice, investigators have sought to maximise the power of the circulation under systemic stress with various degrees of success. Attempts to address multi-organ failure with supranormal oxygen delivery driven by a supranormal cardiac output failed, in part due to a lack of awareness of the impact of critical illness on the heart itself and a lack of knowledge about the importance of circulatory 'adequacy' in the face of changing cardiac 'load' (1).

Developing portable echocardiographic technology has given us the power to observe these effects at first hand and has made us alert to the dangers of assuming anything about baseline or current cardiac function in the critically ill (2).

These clinical and technological developments have created the subspecialty of CCE, and as we observe our patients better through this practice we are learning more and more about specific illness effects on the heart, and the general patterns of cardiac behaviour under different physiological stresses.

Training

In the UK we are lucky to have three different levels of regulated CCE practice. The Focussed Intensive Care Echo (FICE) protocol was introduced in 2010 to address

two key factors:

(I) To provide a useful global cardiac assessment in patients being seen by critical illness services;
(II) To enable rapid therapeutic decisions to be made on initial patient encounter.

The protocol comprises a parasternal long axis view (PLAX), a parasternal short axis view (PSAX), a four-chamber view (A4Ch) and a subcostal view (SC) designed to allow the practitioner to look at the key proportions of the heart and the movement of the right and left ventricles in real time.

The protocol is not intended to act a screening tool or to be a comprehensive cardiac assessment. The following cardiac changes can reliably be identified if on axis views are obtained:

(I) Left ventricular systolic failure;
(II) Right ventricular dilatation and/or failure;
(III) Gross hypovolaemia;
(IV) Pericardial fluid.

The Intensive Care Society (ICS) manage and regulate the FICE protocol, and certification is achieved after collection of a suitable log book (usually 50–75 scans) and sign off by a local mentor following a triggered assessment. A significant proportion of intensive care registrars and consultants have completed this process and recertification and regulation of imaging quality remain a key focus and area of debate (3).

Following the development of the FICE protocol, the ICS and the British Society of Echocardiography (BSE) also launched an Advanced Critical Care Echo accreditation in the same year. This examined process sits alongside the existing accreditations offered by the BSE in outpatient transthoracic echocardiography and transoesophageal echocardiography.

The process comprises a written examination including the interpretation of echo images and practical scanning in an examined setting. The final stage of the process looks at a candidate's logbook of 250 cases and examines in detail five cases of specific pathologies that are discussed with the examiners. To date, twenty candidates have achieved this accreditation process across the UK and they represent the standard expected by a clinical lead in echocardiography supervising and teaching others within a department, known as Level II training (4).

Allied to these developments, the UK government, represented by the Department of Health have engaged the help of the BSE in addressing the needs of all acutely unwell patients admitted to hospital outside of the standard working week. This 'seven-day working' initiative has generated the development of a new Level I protocol designed to safely detect reversible cardiac pathology on admission to hospital.

This protocol builds on FICE and incorporates major cardiac structural triggers. This is not a screening process to reduce the number of level II studies performed. Level I echocardiography represents a complete process aimed at the identification of acute reversible pathologies on admission to hospital.

The protocol incorporates the PLAX, PSAX, A4Ch and SC views and also adds the apical five-chamber (A5Ch) view with the use of colour Doppler over the aortic and mitral valves.

Using the protocol an extended set of pathologies can be confidently ruled in or out:

(I) Left ventricular systolic failure;
(II) Right ventricular dilatation and/or failure;
(III) Gross hypovolaemia;
(IV) Pericardial fluid;
(V) Aortic root abnormalities visible on transthoracic echocardiogram (TTE);
(VI) Major disruption or dysfunction of the mitral valve;
(VII) Major disruption or dysfunction of the aortic valve.

This accreditation process requires collection of a suitable log-book which is presented to examiners who check the candidate has adequate scanning and optimisation abilities. The candidate also needs to demonstrate their ability to identify abnormal findings on images demonstrating the pathologies listed above and to demonstrate that they know when to trigger immediate expert help. This accreditation was launched in 2018 and numbers of candidates accrediting through this process remains to be established (5).

The FICE protocol, Level I and Level II accreditations, now provide a comprehensive choice for those wishing to train in CCE to various targeted levels depending upon their overall workload and requirements.

Unique functions of CCE

Crisis management

CCE has carved out a vital role in the assessment of patients who are deteriorating at rapidly and where seconds will make a difference to management. CCE is highly suited to this function because it requires minimal patient preparation to obtain essential therapeutic information. It does however require clinical systems to be organised and for echo equipment to be ready to use at speed.

We recommend that in areas where CCE may be immediately required the machine is left attached to a mains supply to ensure battery life, and switched on or in sleep mode to allow rapid boot up. Most modern machines require up to two minutes to fully boot up from the off position and this is often too slow for acutely deteriorating patients.

One recent example of this was a young patient returning from theatre having received a pancreas and kidney transplant. During her 12-hour surgery she received over 20 litres of crystalloid and several units of blood products. She was delivered to the critical care unit in a stable condition but within five minutes her blood pressure had deteriorated to less than 50 mmHg systolic. Immediate CCE demonstrated a completely empty left ventricle in keeping with massive fluid shift from the vascular compartment to the abdominal compartment, which was notably now acutely swollen. She was resuscitated with cardiac massage and multiple site colloid and blood injections. She was returned to theatre within ten minutes and her acutely thrombosed transplant pancreas was removed.

Fluid responsiveness

CCE is uniquely placed to enable clinicians to anticipate fluid responsiveness rather than to assess the impact of giving further fluid aliquots. Intubated and ventilated patients have a unique cardiac physiology. The two ventricles are pressure divided by the effect of the positive ventilation the lungs are receiving. This means that the right heart is no longer dominant during inspiration and vice versa in expiration for the left ventricle.

We can exploit this as clinicians since variations in cardiac output during a positive pressure driven ventilator cycle then accurately reflect the filling 'seen' at that moment by the right side of the heart. We can therefore assess fluid responsiveness without the need for fluid delivery a priori (6).

One startling example of this from our practice was a 32-year-old lady with stress induced peri-partum cardiomyopathy. This patient had suffered multiple gastrointestinal bleeding episodes in the context of a twin delivery. She had established left and right heart systolic failure and subsequent tricuspid and mitral regurgitation. Her left ventricle was dilated and clinically she had very cold peripheries with globally poor tissue perfusion.

Despite treatment with dobutamine and low dose noradrenaline to offset the vasodilating effects of the dobutamine, her perfusing pressure remained life threateningly low and her lactate was raised.

Although we acknowledge that all failing ventricles will demonstrate a degree of fluid responsiveness, we used CCE to discover that surprisingly there was very strong evidence of preload deficiency with 50% variation in her transaortic velocity time integral with each positive pressure breath delivered. We managed this lady with echo-observed aliquots of colloid and she extubated later that day. She had full cardiac recovery within six weeks of her admission.

Managing sepsis

Sepsis is without doubt the most complex cardiovascular situation that an intensivist encounters. CCE is uniquely placed to assess the circulation and heart in each individual patient as the circulation undergoes the myriad of changes seen during a septic process. The advent of critical care echo has not only allowed us access to a tool through which we can visualise these changes, but it has changed our understanding of the impact of sepsis on the circulation.

Previously septic shock was often described as either vasodilatory or distributive. We now know that this is an overly simplistic description and that sepsis can alter the circulation and cardiac function on an hour by hour basis. CCE allows us direct visual access to these changes improving our decision-making and responsiveness (7).

We witnessed a potent example of this function of CCE in a 42-year-old lady who presented with profound pneumococcal sepsis and no measurable systolic blood pressure in her limbs. She was maintaining central perfusion of her brain and organs through profound peripheral vasoconstriction. Echocardiography revealed extremely limited cardiac output, which we attributed to the direct effect of sepsis-induced toxin on her ventricle.

We managed her circulation without blood pressure measurement for six hours using CCE, gently correcting her pH, scrupulous electrolyte management and delivering tiny aliquots of fluid and very low level adrenaline until her cardiac output began to improve enough for us to measure her blood pressure peripherally. We elected not to intubate her based on her extremely poor cardiac state and since our main method of monitoring her was to maintain consciousness.

She survived her septic episode with full neurological recovery but suffered bilateral below knee amputations as a consequence of her extremely poor cardiac output. Following resolution of her sepsis, her cardiac function returned to normal.

Managing left ventricular diastolic pressure (LVEDP)

There are many common clinical situations where we expect the LVEDP to be raised for example in severe left ventricular systolic failure. However, in many critical illness situations the LVEDP can change abruptly having a marked effect on lung compliance and ventilation. CCE is the only non-invasive tool, which can rapidly and accurately assess LVEDP and often demonstrate the cause.

In critical illness left ventricular relaxation capacity and LVEDP should be assessed as two separate although related parameters. Patients should not be labelled as having any permanent degree of diastolic dysfunction until they have reached a steady physiology state, by definition after their period of critical illness has resolved (8).

We witnessed this effect recently in a 72-year-old lady who is normally fit and well who became suddenly very short of breath. Her chest radiograph demonstrated bibasal shadowing in keeping with pneumonia and she was managed on the ward with antibiotics. Unfortunately she experienced a severe and sudden increase in her work of breathing and required emergency intubation. Examination of the praecordium and the chest radiograph were compatible with progressive consolidation. Auscultation of her heart sounds by experienced clinicians revealed normal heart sounds with a soft systolic murmur suggestive of aortic stenosis.

Following 24 hours of ventilation her oxygen requirements were dramatically improved which was thought to be out of keeping with severe bibasal consolidation. CCE demonstrated an acutely raised LVEDP due to mitral valve chordal rupture and free flowing mitral regurgitation. Despite having descended into four organ failure due to reversed systolic flow she underwent emergency mitral valve repair and was discharged eight weeks later symptom free. The discordant clinical findings on auscultation were due to the very anterior direction of the mitral regurgitation.

Quality in critical care echo services

Rapid subspecialty development and the desire for intensivists to be trained in CCE has driven a parallel awareness of the dangers of under-regulation in CCE.

A complete CCE should be viewed as the completion of a process which begins with good patient positioning, full knowledge of the patient's current and previous condition and current therapy, and excellent practitioner training to achieve good quality diagnostic images with context driven interpretation.

We recommend that a CCE should be viewed as a three-part process incorporating equal time spent on preparing the patient, achieving the image set required and interpreting and communicating with the caring team (9).

The pillars of a safe and auditable service are many and include all of the following:

- ❖ Adequate, serviced and frequently updated echo platforms;
- ❖ Near-patient reporting interpreted in the context of the current and previous illnesses;
- ❖ Interpretation of the CCE finding to the requesting team;
- ❖ Documentation of findings and interpretation;
- ❖ Effective study archiving;
- ❖ Equipment cleaning;
- ❖ Service leadership;
- ❖ Delivery by adequately trained and supported personnel with pathways to access senior review in a timely manner;
- ❖ Collegiate working with the parent cardiology and echo departments to create an environment for learning and senior consulting, and to prevent silo working.

Without each of these components CCE will fail to deliver on its potential and will ultimately fail to flourish.

This has been recognised by the BSE and the wider UK echo community with newly developed quality standards currently being put in place. Within two years we expect to see the first BSE accredited satellite CCE services (10).

Impact of echo on clinical practice

CCE has now reached a critical mass and impetus where we can begin to shed light on clinical situations which were previously opaque.

One recent example of this arose from our management of a case of life-threatening anorexia nervosa in a 17-year-old who presented to our service with an extremely low systolic blood pressure and acute hypoglycaemia. We were able to observe the changes to her cardiac structure and function with controlled re-feeding, and document the severity and range of changes seen in progressive severe malnutrition.

On admission we observed global left ventricular wall thinning, left ventricular dilatation and severe systolic and diastolic dysfunction. The right heart was dilated and dysfunctional with evidence of pulmonary hypertension and pericardial effusion. Over the next three months her BMI rose from 9 to 16 with resolution of these changes

culminating in reorganisation of her left ventricular wall structure to a normal configuration and thickness. We now recommend that all patients with malnutrition resulting in a BMI of 16 or less need careful consideration of direct cardiac imaging and we hope changes will be made to the MARSIPAN guidelines for the management of severe anorexia nervosa as a result of our findings (11).

Direction of travel

In order for CCE to develop further from this position we need multiple national and international centres of excellence to work together to address the current limitations to training positions in CCE and to collaborate through knowledge sharing and research.

Currently in the UK there are less than five centres attracting advanced CCE trainees. There are however many more centres who aspire to offer this provision. Incorporation of basic level CCE into the current intensive care medicine curriculum will drive up the number of advanced CCE training positions, however this long-awaited change remains several years off since many centres fear they will not be able to offer this and risk losing senior trainees as a result.

The answer to this conundrum probably lies in a network approach to training and service provision with regional centres training CCE clinical leads from local centres and then acting as a point of contact for review of complex echocardiograms and support of clinical services around them.

This structure was and remains the intended aim of our own training programme in Oxford, which was set up in 2009. We have so far trained 12 future CCE clinical leads and we will continue to work towards our goal of providing CCE leads to other networks as this care-changing subspecialty continues to develop (12).

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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