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Validation of a Focused Basic Transthoracic Echocardiography Training Programme for Irish Critical Care Doctors

Roisin O'Mahony
Technological University Dublin, arrow.admin@tudublin.ie

VALIDATION OF A FOCUSED BASIC TRANSTHORACIC ECHOCARDIOGRAPHY TRAINING PROGRAMME FOR IRISH CRITICAL CARE DOCTORS

By

Róisín O'Mahony

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Supervisors:

Prof Pat Goodman Ph.D

Prof Frances Colreavy

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Abstract

Introduction

Transthoracic Echocardiography (TTE) is a technique for scanning the human heart using ultrasound. It enables us to acquire vital information about the size, structure and function of the heart. This test is a crucial cardiac diagnostic test. Historically TTE was used only in cardiology departments, undertaken by trained personnel called cardiac physiologists or cardiology doctors. More recently, TTE has been recognized to be very useful in the management of critically ill patients in the intensive care and high dependency units of our hospitals. Currently bedside TTE on these patients is performed by cardiac physiologists who are generally only available during the hours of 8am to 5pm Monday to Friday or by the cardiology registrar who may be only available on a limited basis.

In 2012 a pilot training programme in TTE for intensivists was undertaken at the Mater Misericordiae University Hospital (MMUH) Critical Care Complex. The aim of the programme was to teach basic echocardiography skills to intensive care fellows over a six month period. This overall study expands on that pilot study and evaluates a training course for critical care fellows in practical and cognitive aspects of basic echocardiography.

Purpose of study

Achieving competency in TTE by intensive care fellows has become officially endorsed by ICU training bodies. During 2013 the Joint Faculty of Intensive Care Medicine Ireland, formally recognized TTE as an important and desirable skill for the ICU fellow in training. Since 2014 the Australian College of Intensive Care Medicine requires all ICU fellows in training to complete an approved basic TTE training course. Therefore, it is clear that the future of intensive care medicine programmes in Ireland must include formal echocardiography training.

Methodology

In January 2014 we introduced data collection sheets on our bi annual hands-on training course in the MMUH Intensive Care Department. At the end of the 20 week training programme the fellows were given a written exam, video cases and a practical exam and the results were collated in data sheets. The study was a comparison between expert and fellow – with expert being the gold standard/reference – in acquiring the echo views and assessing the specific clinical domains required for a critical care fellow.

Results

The results showed that after 20 weeks (40 hours) of training the fellows showed competency in acquiring the standard echo views, and also showed a favourable comparison with expert in terms of assessing the clinical domains required for a critical care fellow.

Conclusion

It is recommended that basic echocardiography should be part of the curriculum for Irish critical care fellows.

This study demonstrates that a suitably structured 20 week training programme in TTE for intensive care fellows can achieve competency in performing a TTE in the intensive care setting.

Declaration

I certify that this thesis which I now submit for the award of Master of Philosophy, is entirely my own work and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

This thesis was prepared according to the regulations for postgraduate study by research of the Dublin Institute of Technology and has not been submitted in whole or in part for an award in any other Institute or University.

The work reported on in this thesis conforms to the principles and requirements of the Institute's guidelines for ethics in research.

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Signature_______________________________________Date___________________

Candidate

Acknowledgements

I would like to extend huge thanks to my two supervisors. Professor Pat Goodman for always keeping me focused as the years rolled on and for making it look and sound so easy. Professor Frances Colreavy for her constant patience, encouragement and huge commitment to this project. I can never thank her enough.

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Thanks to all my colleagues in Connolly Hospital.

Finally, a big thank you must go to all the enthusiastic intensive care and emergency fellows who took part in this study and to all the wonderful staff of the Intensive Care Unit in the Mater hospital in Dublin. They are a fantastic group of people and I am so privileged to have had the opportunity to work with them.

Alphabetical list of abbreviations

ACCP – American College of Physicians

AMAU – Acute Medical Assessment Unit

AR – Aortic Valve Regurgitation

ASUM – Australian Society of Ultrasound Medicine

BCCE – Basic Critical Care Echocardiography

BSE – British Society of Echocardiography

CCE – Critical Care Echocardiography

CW – Continuous Wave Doppler

ECG - Electrocardiograph

ECHO – Echocardiograph

ECLS – Extra Corporeal Life Support

ECMO – Extra Corporeal Membrane Oxygenation

ED – Emergency Department

EF – Ejection Fraction

FICE – Focused Intensive Care Echocardiography

FN – False Negative

FP – False Positive

HDU – High Dependency Unit

ICU – Intensive Care Unit

IVC – Inferior Vena Cava

JFICMI – Joint Faculty of Intensive Care Medicine Ireland

LA – Left Atrium

LV – Left Ventricular

MCS – Mechanical Circulatory Support

MMUH – Mater Misericordiae University Hospital

MR- Mitral Valve Regurgitation

NBE – National Board of Echocardiography

PLAX – Parasternal Long Axis View

PSAX – Parasternal Short Axis View

PW – Pulsed Wave Doppler

RA – Right Atrium

RV fx – Right Ventricular Function

RWMA – Regional Wall Motion Abnormality

TN – True Negative

TOE – Transoesophageal Echocardiogram

TP – True Positive

TR – Tricuspid Regurgitation

TTE – Transthoracic Echocardiogram

SRLF – La Societe de Reanimation de Langue Francaise

VAD – Ventricular Assistance Device

VSD – Ventricular Septal Defect

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CHAPTER 1

Introduction

Transthoracic Echocardiography (TTE) is a method of scanning the human heart using ultrasound. Ultrasound is a sound pressure wave with a frequency greater than the upper limit of the human hearing range. Transthoracic Echocardiography is also known as or abbreviated to the term “echo”. An echo scan enables us to acquire vital information about the size, structure and function of the heart. It allows us to assess the four chambers in the heart, the four valves – the mitral valve, the tricuspid valve, the pulmonary valve and the aortic valve and the aorta itself which is the main blood vessel coming from the heart. The echo examination is a crucial diagnostic test in cardiovascular medicine.

Historically TTE was used only in cardiology departments, and only undertaken by trained personnel, called cardiac physiologists, or by cardiology doctors. More recently, TTE has been recognized to be very useful in the management of critically ill patients who are located in Intensive Care Unit (ICU) and High Dependency Unit (HDU), as it can provide immediate information about the condition of the patient’s heart at their bedside. Many critically ill patients are too unstable to transfer from the ICU or the HDU for imaging studies at other locations. However very few Intensive Care doctors (called intensivists or fellows) possess the technical skills required to perform a TTE examination at the bedside.

1.1 Aim of the Study

The aim of this study is to evaluate a newly developed training programme for intensive care doctors (fellows) to acquire the basic skills in TTE.

1.2 Background to the Study

Currently bedside echocardiograms in critically ill patients are performed by cardiac physiologists or cardiology doctors, who are highly skilled and experienced in echo, but are only available on a limited basis to the ICU/HDU area, generally during the hours from 8am to 5pm Monday to Friday. Outside of these hours their availability is even more limited. As critically ill patients may rapidly develop changes in their cardiac status at any time of the day or night, this limited availability of bedside echo is suboptimal.

A pilot training programme in TTE for intensive care fellows (hereafter referred to as fellows), was undertaken at the MMUH Critical Care Complex during 2012. The aim of the pilot programme was to teach basic echocardiography skills to fellows over a six month period. The programme included weekly "hands-on training sessions" by an experienced cardiac physiologist and lectures delivered by a consultant intensivist skilled in echocardiography. Following the initial three months of "hands-on training" the intensive care fellows who were on the training programme, performed thirty TTE examinations over the next three months which they documented in a log book. This log book was formally inspected and signed off by either the cardiac physiologist or the intensivist. The results of this pilot study demonstrated that fellows could perform a satisfactory basic level TTE examination following six months of training. These findings were presented to the European Society of Intensive Care Medicine annual meeting in Barcelona, October 2013 (Kuriakose *et al.*, 2013).

Commensurate with this local initiative, the importance of competency in TTE for fellows in training has become officially endorsed by ICU Training Bodies (A*ppendix* 6). During 2013, the Joint Faculty of Intensive Care Medicine Ireland, which is responsible for training Intensive Care fellows in Ireland, formally recognized TTE as an important and desirable skill for the ICU fellows in training (Phelan, 2013). Since January 2014, the Australian College of Intensive Care Medicine requires **all** ICU fellows in training to complete a basic approved TTE training course (College of Intensive Care Medicine of Australia and New Zealand, 2014). It is clear that in the future, that Irish Intensive Care Training Programmes will need to provide formal echocardiography training for all intensive care fellows to meet national and international standards.

1.3 Study Plan

Against this background, the study builds on the experience and data obtained from the pilot TTE training programme (2012). In addition to the established "hands-on training" and lecture series, the current programme includes off-line course material in the form of text and digital transthoracic echocardiography images. The validation process comprises of 30 supervised echo cases as in the pilot training programme, formalized into a log-book. In addition, the fellows are assessed by written and practical examination at the end of their six month period. Formal certification of competency in basic level TTE requires passing all parts of the examination.

1.4 References

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CHAPTER 2

Intensive Care Unit – Mater Misericordiae Hospital Dublin

2.1 Introduction

The echo training programme is based at the ICU and the HDU of the MMUH which is a university teaching centre. The facility includes 17 Intensive Care and 12 High Dependency beds with individual rooms for each patient. This multidisciplinary complex receives approximately 2,400 admissions per year. The average length of stay is 5.6 days in the ICU and 4 days in the HDU. The median age of admissions is 64 years.

2.2 Admissions

The ICU and HDU wards receive critically ill patients, on a 24 hour basis, from all disciplines within the MMUH and the Rotunda Maternity Hospital. The units comprise a level three critical care complex meaning they also receive critically ill patients who require multiple organ support from other hospitals within Ireland. There is a prioritized admission policy to the national services based at the MMUH which include the national Cardiothoracic Unit and the national Acute Spinal Service. The National Extra-Corporeal Life Support (ECLS) service is located at the Mater ICU. The national Mechanical Circulatory Support service is also located at the MMUH.

There are over 1,000 admissions per year to the ICU. During 2011, 1058 were admitted. Thirty-six per cent of the 2011 ICU case-mix were non-operative admissions and included the following; respiratory diagnoses 11% (pulmonary infection, chronic obstructive airways disease), cardiovascular diagnoses 7% (cardiac arrest, cardiogenic shock, acute myocardial infarction), haemodynamic shock 6% (septic shock, hypovolaemic shock), neurological diagnoses 4% (seizures, intracranial haemorrhage, head injury), renal diagnoses 3%, trauma 3%, gastrointestinal diagnoses 1% and deliberate drug overdose 1%. The mortality for this group is 24%. Sixty-four percent of the ICU case-mix were post-operative admissions and included the following; post cardiothoracic and vascular surgery 45%, post gastrointestinal surgery 7%, post thoracic surgery 3%, post spinal and trauma surgery 7%, post nephrology surgery 1% and patients who were admitted with perioperative complications 1%. There were 1,288 episodes of ventilator support for the 1058 patients admitted during 2011, meaning that some patients required more than one episode of mechanical ventilation.

2.3 Personnel and Training

The Intensive Care Medicine service is led by six Consultant Intensivists. The unit is approved for postgraduate training in intensive care medicine by the Joint Faculty of Intensive Care Medicine of Ireland (JFICMI) and by the College of Intensive Care Medicine of Australia and New Zealand. There are two advanced trainees of Intensive Care Medicine who rotate through the Intensive Care Unit every six months. Three of the Intensive Care consultants have received training in echocardiography. One of the Intensivists, who is a supervisor of echocardiography training, has level III competency in transthoracic echocardiography according to the European Association of Cardiovascular Imaging Guidelines (Popescu *et al.*, 2009).

2.4 Indications for TTE in ICU

The indication for TTE in critically ill patients is often focused on a very specific clinical question. The timely performance of an echo and interpretation of the results are essential as critically ill patients may suffer sudden haemodynamic deterioration. In particular the main clinical questions to be addressed by TTE, in critically ill patients comprise the following:

1. assessment of the size and function of the left heart chamber (left ventricle, LV),
2. assessment for poor function in specific areas of the left ventricle called regional wall motion abnormalities (which may indicate a heart attack),
3 assessment of the size and function of the right heart chamber (the right ventricle),
4. rule out of a collection of fluid around the heart (pericardial effusion) which may exert extreme pressure on the heart chambers (called cardiac tamponade),
5. assess the four heart valves for infection (called endocarditis),
6. assess the state of body hydration (called "filling status"),
7. assess two of the heart valves (the mitral and aortic valves) for severe leakage (called regurgitation),
8. assess the heart for complications of a heart attack including a hole in the heart called a ventricular septal defect (VSD), and
9. assess the heart for clots or tumour that could cause a stroke (called looking for a source of embolus).

The utilization of TTE at the MMUH ICU/HDU complex was audited for 6 months before (March –August 2012) and 6 months after (September – February 2012) echocardiography training commenced. The results indicated a marked increase in the utilization of TTE (Table 2.1) that led to significant management changes outlined below (Table 2.2). This provided a basis and an impetus to develop a more structured training programme in TTE for intensive care fellows and to formally evaluate such a programme.

Indications for TTE	*Period 1* *Before Training* (n=47)	*Period 2* *After Training* (n=144)
Assessment of Left Ventricular Function	34	68
Assessment for Regional Wall Motion Abnormalities	3	11
Rule out cardiac tamponade	3	26
Possible Endocarditis	3	7
Assessment of pulmonary oedema	1	8
Possible Ventricular septal defect	1	1
Possible Intracardiac source of embolus	1	1
Assessment of filling status	1	5
Possible pulmonary embolus (acute cor pulmonale)	0	9
Assessment right ventricular function	0	5
Possible acute mitral regurgitation	0	1
Positioning ECMO cannulae	0	2

n= number of patients

Table 2.1. Indications for Transthoracic echocardiography during 2 audit periods

Therapy change	*Period 1* (n=14)	*Period 2* (n=49)
Administer fluid therapy	1(0)	8(7)
Diuresis +/- ACE inhibitors	3(1)	9(3)
Inotrope dose change	3(1)	8(4)
Inotrope, vasopressor dose change	0	6(4)
Inotrope, vasopressor dose change plus fluid therapy	0	4(4)
Afterload reduction	2(2)	1(1)
Anticoagulate for presumed PE	0	2(1)
Surgical drainage pericardial fluid/clot	1(0)	2(2)
Valvular vegetation; antimicrobials plus surgical consult	2(1)	1(1)
Other	2(0)	8(4)

Table 2.2 Change in management following a TTE study during 2 audit periods.

2.5 Evidence for Change in Clinical Management Following TTE

The results of the audit were consistent with information obtained from a literature review. Studies have indicated that the management of critically ill patients is altered by TTE findings in 25-51% of cases *(*Alam *et al.*, 2013, Orme *et al.*, *2009,* Vignon *et al.*, 2011, Vignon *et al.*, 1994*)*. The management change is often very specific and immediate. For example, an echocardiogram demonstrating a pericardial effusion and tamponade would lead to immediate drainage of the fluid around the heart. In the assessment of left ventricular (LV) function, if the echocardiogram showed reduced function of the left heart chamber, then medication to improve the pump function of the heart (called an inotrope) or heart failure therapy (medications called Ace inhibitor, or diuretic) would be commenced. In situations where organ donation is being considered, the ability to assess the LV function is crucial in deciding if heart transplantation can proceed. A finding of infection on a heart valve (called vegetation) would lead to immediate commencement of antimicrobial therapy. Another very common condition where TTE findings can change the management is severe dehydration (called hypovolaemia) when fluid therapy must be administered immediately.

2.6 References

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CHAPTER 3

The Fundamentals of Cardiac Ultrasound

3.1 Introduction

Echocardiography is the science and practice of cardiac diagnosis by means of ultrasound. At present, four broad approaches are used to gather, process and display the diagnostic data. These are:

- M-mode system
- 2-D imaging system
- Doppler technique of blood flow measurement
- Doppler colour flow imaging

This chapter introduces the physics and technology of ultrasound used in these four diagnostic modalities.

Any modern echo machine is made up of the following functional components:

- the power supply converts the A.C. voltage supply to D.C. supply to power the electric circuits in the scanner
- the electronic circuits drive the transducers to create the ultrasound wave, and to process the ultrasound signals from the tissues of the body
- the computer controls the timing and processes the data and creates the electronic display on a monitor
- the computer memory or an off-line image management system makes a permanent record of the patient data obtained from the examination

All echocardiography machines allow the recording of electrocardiograms (ECGs) to facilitate correlation between the bioelectrical and mechanical events in the cardiac cycle.

3.2 Introduction to the Physics of Ultrasound

An ultrasound is an oscillating mechanical sound wave whose frequency is above the normal audible range of 20 kHz. The *frequency* is the number of ultrasound waves per second and the SI units of measurement are Hertz (Hz). The *wavelength* is the distance from peak to peak of an ultrasound wave. The wave propagation through the body is indicated in Figure 3.1 (Waves, 2014), showing *amplitude* and wavelength. The speed that a sound wave moves through the body is the *velocity of propagation* (m/s).

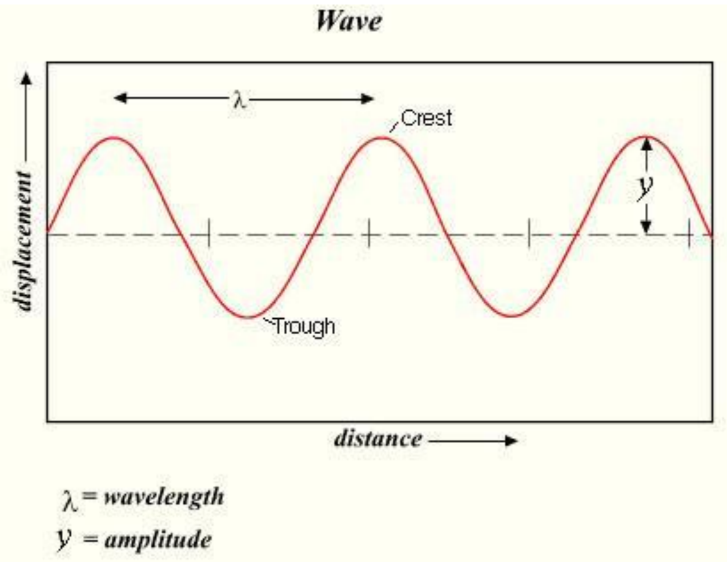

Figure 3.1 Basic Diagram of a Wave (Waves, 2014)

The propagation velocity is determined by the material through which the wave travels. Sound travels faster through more solid materials. For example, it travels through air at speeds of 330 m/s, through water at 1480 m/s, through bone at 2800m/s and through soft tissue such as the heart at speeds of 1540m/s. Shorter wavelengths result in higher resolution but lack of depth of penetration.

When ultrasound travels through human tissue the following can be observed:

- Some of the waves are absorbed by the tissue with no effect.
- Some travel through tissue at a velocity of 1540 m/s
- Some are reflected from an area of interest

In the heart the reflecting interfaces are usually between the blood and the heart valves or myocardial tissue. Strong echos will be reflected from dense structures such as calcified valves and weaker echos will be reflected from normal soft tissue structures within the heart. Because the goal of ultrasound is the precise identification of small structures, the use of high frequencies, usually between 1.7 and 3.5 MHz are used for adult echocardiography (Asmi and Walsh, 1995).

The reduction of ultrasound intensity as it propagates through a medium is called attenuation. Attenuation always increases with depth. Attenuation has three components: reflection, absorption and scattering.

Acoustic impedance is a product of the velocity and density of a medium. Within our bodies the tissues through which an ultrasound beam has passed have different acoustic impedances. When an ultrasound beam has passed between two tissues some of the energy is reflected and some is refracted and it is these interactions which form the basis of ultrasound imaging (Tole and Ostensen, 2005).

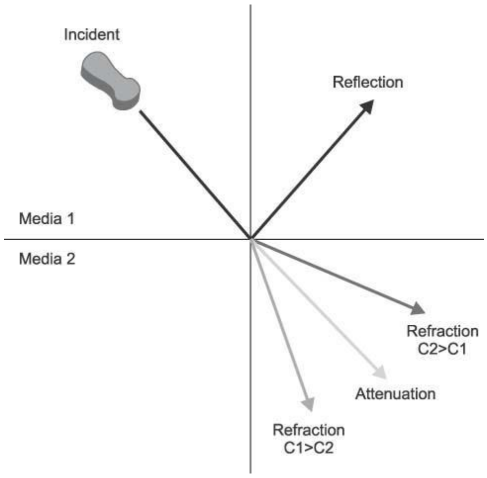

Figure 3.2 Diagram of Refraction and Reflection (Sang-Jin Shin, M.D., *et al*., 2013)

3.3 The Transducer

The transducer is the most fundamental component of any echo machine. The transducer is used to create an ultrasound wave with an electrical impulse or signal to detect the ultrasound wave and forms an electronic signal representative of that wave for further processing. The transducer consists of one or more thin discs of piezoelectric crystal, each with thin metal electrodes positioned on two flat faces, a layer of matching material attached to the front face looking outwards, and a block of damping material against the back face. This is all contained within a holder. Electrical leads connect the electrodes to electronic circuits in the main unit of the scanner (Tole and Ostensen, 2005).

3.3.1 Functionality of the Transducer

When an electrical field in placed across the thickness of the disc, the piezoelectric crystal changes or becomes deformed, i.e. made thicker or thinner depending on the polarity of the electrical field. When an electrical signal is supplied to the crystal, an ultrasound wave is transmitted from the front face of the transducer. Conversely, when an ultrasound wave coming from the tissues strikes this transducer, a replica of this wave in the form of an electronic signal is generated by the crystal and sent to the electronic circuits. A transducer can both generate and detect/receive ultrasound waves (Tole and Ostensen, 2005).

At ultrasound frequencies the transducer creates a beam of ultrasound, its direction being defined by the axis of the beam, the centre-line of the beam, usually perpendicular to the centre-point of the transducer. Directionality is the key property of the beam, allowing it to be transmitted along the known direction of the beam axis into the tissues, and to be reflected from and transmitted by structures along that line only.

Many echocardiography instruments have multi-crystal array transducers, either linear or annular. These are arrays of crystal elements mounted in a transducer, but insulated and isolated from each other. One application of the linear array is the phased array in which there is electronic steering of the beam while the composite beam remains within the plane of the array (Tole and Ostensen, 2005).

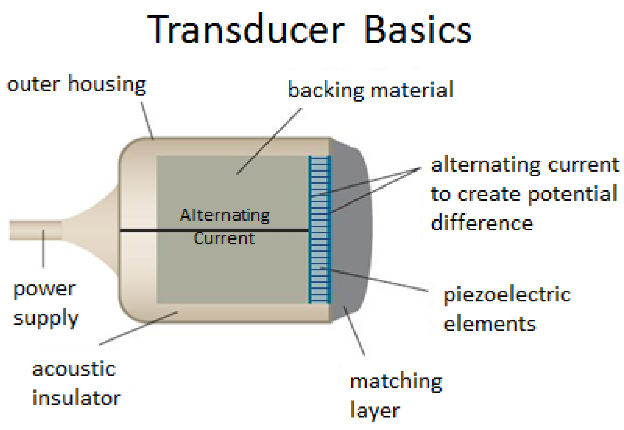

Figure 3.3 Diagram of the Transducer (Endermed, 2016)

3.4 Acquiring the Views

As mentioned above ultrasound propagates or travels in a straight line through homogenous tissue but is reflected at interfaces between tissues of different acoustic impedance. The greater the acoustic mismatch between the two media, the greater the reflection of sound. Consequently, at boundaries between tissues of high difference in impedance, such as between soft tissue and bone, or between soft tissue and gas, virtually all of the ultrasound is reflected. In such cases the echo reflected is very strong, but the amount of ultrasound energy remaining in the beam to pass through deeper tissues and produce echoes from them is negligible. Such deeper tissues are in the acoustic shadow of the strongly reflecting boundary. Because the heart lies within the ribcage, and sits between two air-filled lungs, it is largely shadowed from an ultrasound beam approaching from the skin surface.

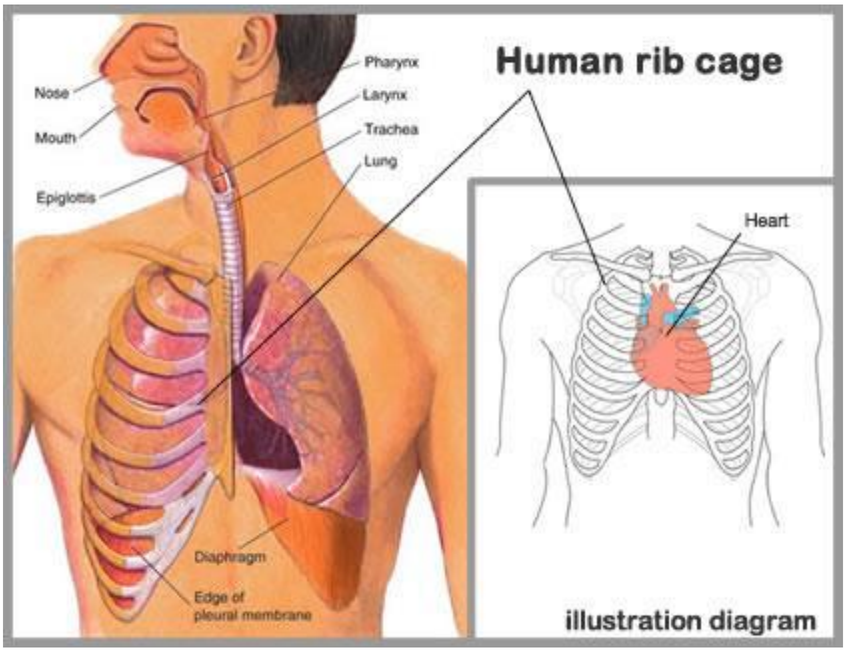

Figure 3.4. Human Ribcage (Accessible Image Sample Book, 2017)

3.4.1 Echo Windows and Echo Views

The number of possible acoustic windows to obtain ultrasound access to the heart is limited, and hence the number of echocardiographic views of the heart that may be obtained is also limited**.** The windows used on any echo examination of the heart include the parasternal window, the apical window, the subcostal window, the suprasternal window and the right parasternal window. In the parasternal window the heart can be viewed in the parasternal long or short axis abbreviated to PLAX and PSAX, by placing the transducer in the parasternal area between the 2nd and 4th intercostal space. This is done by certain manipulation of the transducer. The apical window is where the apical views are obtained – apical 4 chamber view, apical 5 chamber view, apical 2 chamber view and apical long axis view. The apical window is found near the apex of the heart. The subcostal window allows the subcostal views of the 4 chambers, pericardium and inferior vena cava (IVC) again acquired by angling, tilting and rotating the transducer. This view is achieved by placing the transducer in the sub xyphoid area and once again manipulating it correctly to visualize the heart. The suprasternal view is not used very often in intensive care units, as in order to attain this view, the probe has to be placed in the suprasternal notch and this is not feasible if the patient is intubated (Asmi and Walsh, 1995).

3.4.2 Ultrasound Gel

All diagnostic ultrasound systems require the head of the transducer to be placed on the skin of the patient, with a gel or oil coupling-medium between the transducer face and the skin to eliminate air between them. Ultrasound gel is therefore an acoustic impedance matcher (Tole and Ostensen, 2005).

3.5 Modalities of Echocardiography

3.5.1 M Mode

Inge Edler and Hellmuth Hertz of Malmo General Hospital in Sweden were the first to use ultrasound for cardiac diagnosis in 1953. They placed the transducer of a reflecto-scope, used for non-destructive materials testing, over the chests of patients and could detect moving echoes. They thereby recorded the first "ultrasound cardiogram" to examine the mitral valve of the human heart (Edler *et al.,* 1954).

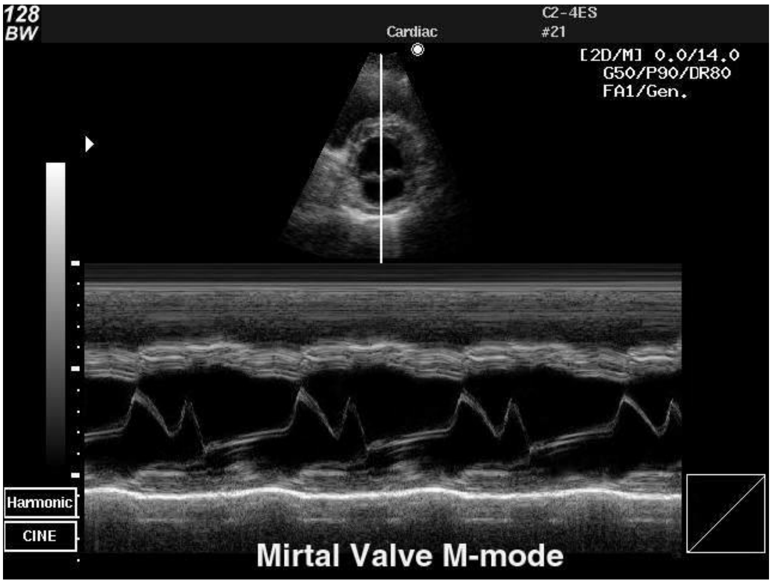

Figure 3.5 Diagram of M Mode Display of the Mitral Valve (Critical Echo, 2009)

In M-mode echocardiography the transducer emits a single pulse of ultrasound along a directional beam in a straight line, through a particular region of the chest and heart. Cardiac structures encountered by the beam on its path through the heart reflect some of the ultrasound, which then returns as echoes that are detected by the transducer. The time delays between the original ultrasound transmission and the detection of each subsequent echo allow the depth of each reflecting intracardiac structure to be calculated. M Mode is essentially displayed as a graph looking at fast moving structures in the heart, over time. However, it can be used to study the thickness of the heart walls and the movement of cardiac structures, as well as to obtain other cardiac dimensions. A limitation of the M-mode modality is that it represents a one-dimensional ("ice-pick") view of the heart, thus displaying the cardiac structure information in an unfamiliar form that bears no resemblance to their cardiac anatomy and providing no information regarding their spatial orientation (Tole and Ostensen, 2005).

3.5.2 2D Imaging

The B-mode display or image is a two-dimensional (2-D) representation of a cross-section through the tissues. The ultrasound beam is scanned repeatedly, usually in a fan-shaped plane, and the 2-D pattern of reflecting tissues in this fan-shaped cross-section, yield the depths and echo strengths from each reflector along each beam line in the scan plane to enable the computer to construct the image. This 2-D image is displayed on a TV monitor, with the image periodically repainted at a frame repetition frequency of 25 Hz, 50 Hz or greater. If features within the image are moving, there is then smooth transition between each frame, and the motion is seen as smooth. Such an electronic image is termed a *real-time* or dynamic image (figure 3.6).

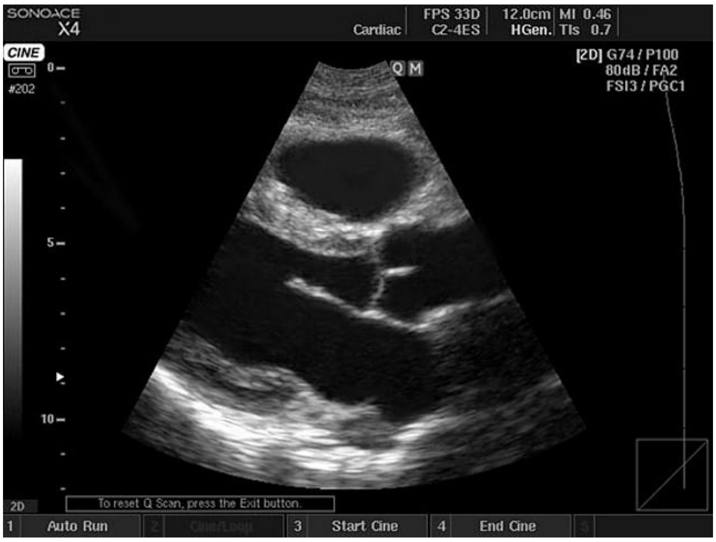

Figure 3.6 2D Ultrasound Display (Critical Echo, 2009)

In a phased array transducer system commonly used in echocardiography, the beam from the set of the piezoelectric elements is electronically scanned to produce a fan shaped image. Each scan line in the fan-shaped image is created by first sending out a pulsed beam of ultrasound in a specific direction into the issues, and then collecting the corresponding sequence of echoes. A finite time is required to collect the sequence of echoes and hence the data for each scan line. When imaging fast-moving structures like the heart, a high frame rate is required so that continuous movement can be visualized with no perceived jump from one frame to the next. Therefore, there is trade-off between the scan line density and image frame rate. In 2-D imaging, a high frame rate of at least 30 frames per second is desirable for accurate display of heart and its structures. Roughly, this frame rate allows 128 scan lines per 2-D image at a displayed depth of 20 cm. (Feigenbaum, 1994)

3.5.3 Doppler Technique of Blood Flow Measurement

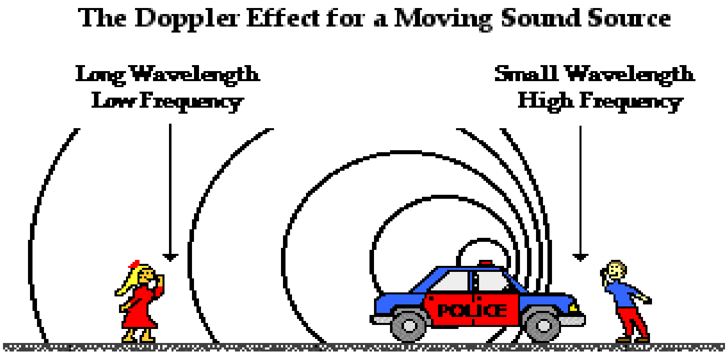

Figure 3.7 Doppler Effect for a Moving Sound Source. (The Physics Classroom, 1996)

Doppler equation: $v = \frac{c \text{ x } \Delta f}{2 \text{ x } f \text{ x } (\cos\theta)}$

Equation 3.1

v = speed of moving reflector, θ = angle between direction of incident ultrasound and direction of reflector motion, c = speed of propagation of ultrasound in the tissues between transducer and reflector, Δf = doppler shift in frequency, f = ultrasound frequency.

Doppler echocardiography is an important technique in detecting and measuring moving structures – such as red blood cells – through the heart. The Doppler Effect was first described in 1842 and states that when an observer moves towards a sound source (like a siren for example) the frequency measured by the observer is higher than the frequency transmitted by the source. Conversely when the observer moves away from the source, the perceived frequency decreases as depicted in figure 3.7 (the Physics Classroom, 1996). In cardiac Doppler, high frequency ultrasound is transmitted into the heart by means of a crystal transducer. The frequency of the received ultrasound signal is compared with the frequency of the original transmitted signal so signals from fast moving objects such as the red blood cells will shift in frequency. If ultrasound is reflected from a stationary interface there will be no shift in frequency -v = 0.

3.5.4 Continuous Wave Doppler

In a continuous wave (CW) Doppler system, the ultrasound beam is transmitted continuously, and the returning echo signals are also received continuously. This requires two separate side-by-side transducers to be used, one dedicated to transmission and the other dedicated to reception.

Since the transmitter transducer is constantly transmitting ultrasound, all reflecting structures in the beam, both stationary and moving, are constantly returning echoes to the receiver transducer in the probe. This means that the receiver transducer is constantly receiving echoes of frequencies equal to the originally-transmitted frequency (from stationary structures) as well as Doppler-shifted frequency echoes (from moving structures). The spectrum of the received echo signals includes the operating frequency. An example of CW Doppler of Aortic valve regurgitation is seen in figure 3.8

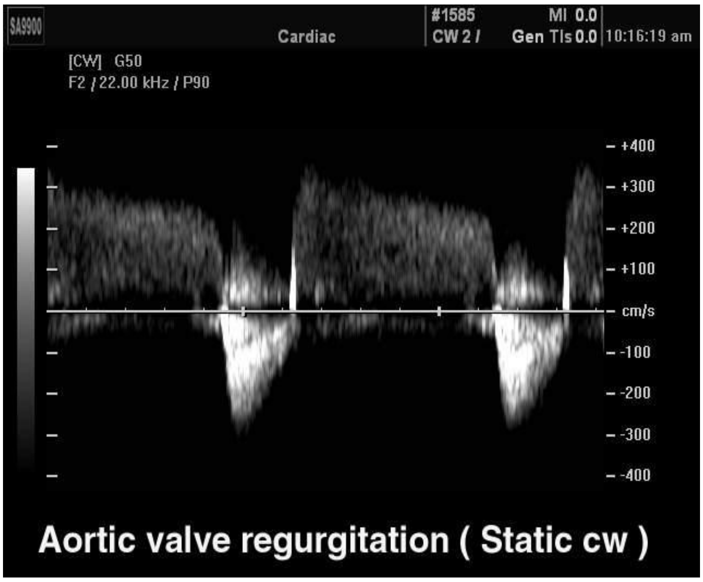

Figure 3.8 Aortic Valve Regurgitation as seen with static CW Doppler. (Mediace Co., Ltd., 1997)

3.5.5 Pulse Wave Doppler

In Pulse Wave (PW) Doppler the transducers have only one crystal, which acts as a transmitter and a receiver of ultrasound. In this case the transducer emits a short burst of ultrasound first and then acts as a receiver for the returning signals. The controls on the ultrasound machine can alter the position, depth and size of this sample volume to suit local anatomy. The location at which the sample volume is positioned determines the time interval between the firing and transmitted signal and receiving and returning signal. When the returning signals are received, the crystal can then emit another pulse. The frequency at which these pulses are emitted is known as the pulse repetition frequency. An example of PW Doppler is shown by the TTE image in figure 3.9 **The Nyquist limit** is the maximum value of Doppler frequency that can be measured accurately with a given pulse repetition frequency. The inability of the pulsed Doppler to detect high frequency shifts is known as aliasing. Aliasing occurs when the Nyqusit limit is exceeded. So, if the speed of the blood for instance exceeds twice the pulse repetition frequency of the transducer, aliasing will occur.

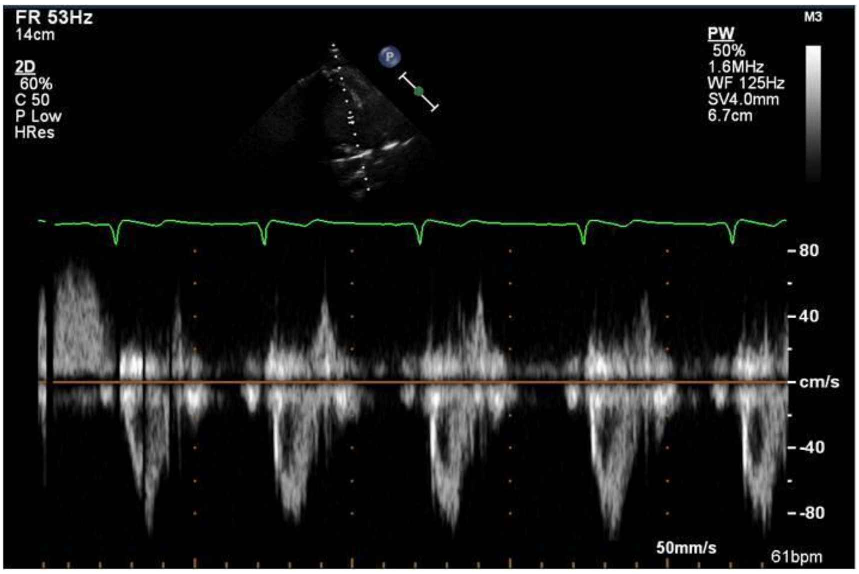

Figure 3.9 TTE Utilising Pulsed Wave Doppler (Echocardiographer, 2016)

3.5.6 Colour Flow Doppler

Blood velocity information can also be obtained using colour flow mapping. Here a large number of sample volumes is used along the scan lines in the display. This allows the display of colour coded blood velocity information, in a particular sector of interest. The returning signals are received as mean velocity information, and this is converted into colour coded information by an algorithm. The colour coded sequence is then superimposed on the 2D image obtained simultaneously. The coding is standard on all echo machines – flow away from the transducer is coded blue with flow towards the transducer coded red. This is known as **BART**. Turbulent flow from a stenotic or incompetent valve, can be seen as a mixture of these colours to form a mosaic pattern i.e. aqua marine, green and yellow.

The velocity range of colour flow mapping is also determined by the Nyquist Limit. The range can be altered by shifting the baseline, changing the pulse repetition frequency (PRF) or altering the depth of the image. (Feigenbaum, 1994)

3.6 Instrumentation Used in This Work

GE Vivid I, Vivid Q, both portable echo machines progressing to GE SE high specification echo machine purchased by Mater ICU 2014.

Figure 3.10 The two ultrasound scanners used in this study (GE Ultrasound Systems)

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CHAPTER 4

Literature Review

4.1 Introduction

It is widely established that the use of transthoracic echo (TTE) in the intensive care unit (ICU) is essential for a prompt and efficient diagnosis and therefore management of critically ill patients. Many centres around Europe, America and Australia have tried to validate a curriculum in Basic Echo for their intensive care fellows so it is timely that Ireland too embraced this essential service and set up a recognized training programme for their intensive care fellows. (Cholley *et al*., 2011).

It is well known there are many limitations to performing an echo in a critical care setting, mainly related to patient factors (Price *et al*., 2006). Critically ill patients are often intubated and lying completely supine. This position, in itself, is difficult when performing an echo. A transthoracic echo is usually performed with the patient lying in the left lateral position with the left arm placed above the head. This not only pushes the heart out towards the chest but opens out the ribcage thus enabling the sonographer to get the best possible windows and views. In the intensive care setting, not only is the patient lying supine but there may be chest drains, dressings, tubes and lines all making access very challenging. It is necessary therefore, to not only teach a fellow how to perform a basic echo but to teach specific *technical* skills in the setting of a critically ill patient (Price 2006). Historically in the ICU setting, transoesophageal echocardiography (TOE) was used to overcome these technical difficulties. (Colreavy *et al*., 2002). However, TOE is an invasive procedure and requires a trained physician to perform the test. A TOE also takes more time in terms of preparation and application. (Price *et al*., 2006).

Technological advances in TTE have helped to overcome the difficulties of performing echocardiography on critically ill patients and greatly improved the diagnostic yield of an echo in ICU (Beaulieu, 2007). The assessment of LV size and systolic function, and calculation of ejection fraction (EF), can easily be performed in real-time at the bedside of the critically ill patient. Doppler echo is also useful for estimation of stroke volume and cardiac output. Beaulieu *et al*., particularly emphasise the utility of bedside TTE echo to assess LV and RV function, volume status, and rule out tamponade, and assess valve function. Another previous limitation to the use of TTE in the ICU setting, was the size of the echo machine in an already crowded space at the bedside of a critically ill patient (Salem *et al*., 2008). This has now changed with the development of high specification portable ultrasound machines, some the size of a simple laptop computer. In the above study by Salem *et al*., the authors state that TTE is the main cardiac image modality in their ICU to provide the answer to an unexplained haemodynamic change – such as tamponade – in a patient.

Beaulieu *et al*., also discuss the possible therapeutic role of TTE findings on the subsequent management of critically ill patients (Beaulieu, 2007). These therapeutic changes include introduction or discontinuation of inotropes, use of anticoagulants, administration of fluid therapy, and introduction of antibiotic medications This paper outlines the benefit of having trained personnel, i.e. the ICU fellows, on site within the unit, to perform the TTE's rather than relying on sonographers or cardiology fellows who are not available on a 24 hour basis seven day a week.

A paper by Arntfield and Millington in 2012, states that not only is it possible to teach ICU fellows to perform TTE but also to make a diagnosis which impacts on patient management as has been demonstrated with point of care TTE echo in many intensive care and emergency departments (Arntfield and Millington, 2012). Salem *et al*., talk about the echo views when teaching the fellows. As mentioned, there are a lot of challenges to TTE in ICU, but Salem puts emphasis on teaching the subcostal view to ICU doctors as this is a view which can generally be obtained even if the chest and therefore parasternal and apical views – cannot. It is also a view which is obtained with the patient lying supine (Salem *et al*., 2008). This paper states that the subcostal view can be used by "any critical care physician with rapid cardiac ultrasound training". This view allows visualization of the left and right heart chambers, the pericardium and the IVC all essential in the assessment of volume status, and of course, pericardial effusion and/or tamponade. Teaching this view alone, would enable the ICU doctor to assess a number of diagnostic possibilities, in a critically ill patient.

Salem *et al*., also proposed the idea of the '**pyramid',** shown in Figure 4.1 when speaking in terms of the skills required by the ICU fellow when performing an echo. They strongly recommend that each critical care fellow should be trained at least to the base of the 'pyramid' of echocardiography which includes recognizing severely abnormal LV function, the ability to measure the IVC size, recognize marked RV dilatation and detect large pericardial effusion and therefore tamponade.

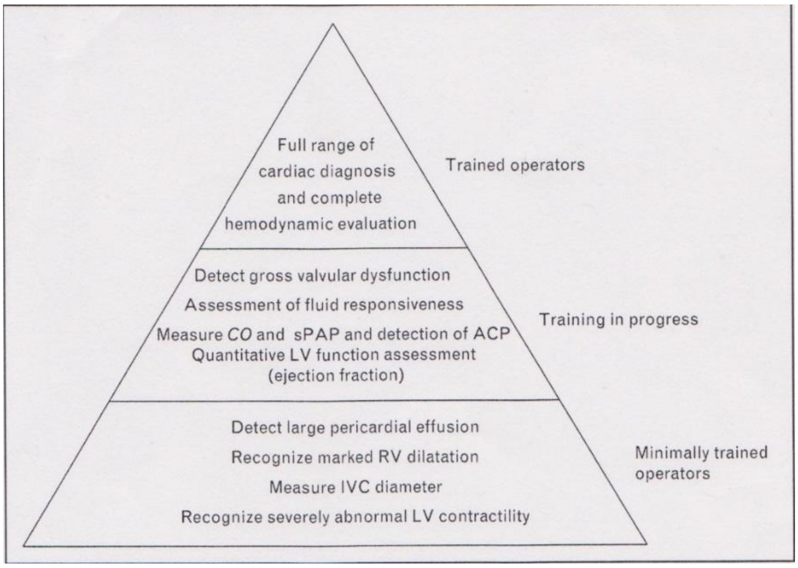

Fig 4.1 Pyramid of Echocardiography Skills (Salem *et al*., 2008)

4.2 Echocardiography Training in the ICU

Vignon *et al*., (2011) describe their experience of developing an echo course for ICU fellows in France. The course was run over a 3 month period with ICU fellows who did not have any previous experience in echocardiography. The curriculum included didactic lectures, tutored hands-on training and interactive clinical cases. The course was set and run by ICU fellows experienced and certified in echo. Hands-on sessions were initially performed on normal volunteers and later, on ventilated patients. Over the course of the training period, care was taken to answer all clinical questions that present every day in a busy ICU. Each patient requiring a TTE during the study period was scanned by the fellow and subsequently by the expert unless no windows were obtained. In all, 201 patients were scanned over a six month period, or two 3 month periods. (Vignon *et al*., 2011).

This study by Vignon and colleagues has many limitations. Firstly, the equipment used was a hand-held battery-operated system with basic 2D imaging and limited Doppler modalities. Secondly a three month training period provided limited time to acquire competency in the skill of scanning and interpreting echo data. Thirdly, no recordings were stored making retrospective analysis difficult. The trainees had the opportunity to practice their TTE scanning skills on 201 patients recruited during the study period. The authors concluded that a 12-hour training programme blending hands-on tutoring with didactics is well suited for reaching competency in basic critical care echo (Vignon *et al*., 2011). The authors in this study placed the emphasis on the validation of the curriculum rather than evaluating the potential therapeutic benefits of bedside TTE.

Paul H Mayo in a review of echo training in ICU (Mayo, 2011) states that the key element to any training process is to define the goals and that competency is the goal of any training programme. The key to a good training process is to have an interested and effective expert willing to take on and train the fellow who has little or no experience in echocardiography. He also states, that just trying to achieve numbers is not necessarily reaching appropriate goals, so the training should be more about quality rather than quantity, even though many other papers speak around the whole subject of number of cases performed required for achieving competency. (Charron *et al*.,) and (Veillard-Baron *et al*.,). Mayo also addresses the problem that even a well-defined training programme may not necessarily guarantee competency because not all trainees progress at a same level and some will have a more intrinsic talent to others. This leads to the whole question of certification and how best to achieve this for a valid training course. It is also still not clear as to the time frame required to achieve competency. For example, the one paper of Manasia *et al*., describes 10 hour training programme sufficient for focused echo while another study refers to an even shorter programme of just 6 hours. However, these are more *focused* training courses for emergency medicine, intent on making an initial diagnosis (Manasia *et al*.). Anne-Sophie Beraud alludes to the evaluation of proficiency in TTE and states that on their training course the amount of training per fellow was an average of 15 hours and tested the fellows' ability to obtain and interpret images. A simulator test was included in the training which enabled different pathologies to be tested thus making this training course very focused on the needs of a critical care fellow. *(*Beraud *et al*., 2013*)*. This paper concluded that focused TTE can be effectively integrated into critical care medicine fellowship programmes.

Most of the literature when they refer to training discuss competency and certification. Popescu (2009) from the European Association of Echocardiography is an example of this. He published recommendations for training, competency and quality improvement in echocardiography. Aimed mostly at the cardiology fellow, but still recognizes the need for a structured programme to address the learning objectives and achieve goals – in both basic and advanced levels (Popescu, 2009).

4.2.1 International Guidelines

The International expert statement of training standards for critical care ultrasonography (Cholley *et al*., 2011) provides a very useful guideline for basic critical care echo training. It states that not only should it be mandatory in the curriculum of intensive care medicine, but that it is the role of each country to support the implementation of such training programmes. The framework document was developed by eleven critical care societies from five continents. Twenty-nine experts were charged with writing standards for ultrasound in the critical care setting. These included how to achieve competency in basic critical care echo, how to deliver teaching and how to organize certification. Among this round table of experts there was agreement on some issues and not on others. For example, it was agreed that the theory of any programme should include lectures and course material. There was no consensus however, on the required number of cases that each fellow should perform to reach a desired level of competency. A general number of 30 was given on a review of the literature from around different centres. There was agreement that training should include a certain number of pathologies and clinical situations, but no consensus was reached as to what this number should be. There was full agreement that initial training should be on normal volunteers, for the fellows to learn about image acquisition, obtaining views and normal anatomy. There was also full agreement that each fellow should maintain a logbook that includes a report of the study he/she performed, and the logbook should be co-signed by the supervisor. This paper concluded by saying that training in basic critical care echo should follow the guidelines defined in the American College of Chest Physicians (ACCP) and La Societe de Reanimation de Langue Francaise (SRLF) statement, but that each centre can tailor and adapt to their own needs. It goes without saying, that there should be one or two designated echo machines in every ICU for performing TTE and TOE but also for training the fellows. (Cholley, 2011)

4.3 Assessment of Competency in Critical Care Ultrasonagraphy

There was a consensus statement issued via a collaboration between ACCP and SRLF on competency in Critical Care ultrasonography in the CHEST Journal. This paper suggests that critical care ultrasonography requires competency in basic and more advanced modules and that each module has definable components. (Mayo *et al*., 2009)

The statement also suggests that the mastery of each module defines competency and it lists specific skills as a guide for achieving competency and certification (Mayo *et al*., 2009). According to the consensus statement, basic echo should be focused, and goal-directed, designed to enable an echo fellow to acquire the basic images such as PLAX, PSAX, apical and subcostal views. In addition, basic echocardiography should teach assessment of LV size and function, RV size and function, valve function, pericardial effusion and tamponade. Basic echocardiography training should ensure that an ICU fellow is able to assess the haemodynamic condition of any critically ill patient. Interestingly, the consensus group also stated that the echo machine used should be of high specification with full 2D and Doppler capabilities and should be available in the ICU on a 24-hour basis (Mayo *et al*., 2009).

This consensus statement is an excellent guide for physicians and trainers undertaking a training course in basic echo in the ICU. It should be used as a foundation for developing training methods and standards when formulating a site specified curriculum.

A group from Denmark, (Nielsen *et al*., 2013), makes the important distinction between validating competency in TTE and traditional measures of assessing TTE skills, such as duration of training and number of examinations performed. They look at the validity of an instrument for structured assessment of echo skills. The instrument has a global rating scale and a procedure specific checklist. Other investigators have made a similar point, that competency in TTE is unrelated to traditional measures such as number of studies, keeping a log book etc., and suggest assessing technical and interpretation skills (Nair *et al*., 2006).

The European Association of Echocardiography offers a validated accreditation process using traditional methods such as number of scans, log books etc. These methods may be unreliable for various reasons such as inconsistencies between observers or quality issues. This can be improved using global rating and checklists for observations. The global rating scale consists of a five-point scale ranging from very poor (1) to very good (5) when rating an overall examination including the number of good images acquired. The checklist was developed using national and international guidelines and recommendations such as standard of 2D and colour Doppler images, optimization of images, and optimization in Doppler and colour modalities such as scale etc. The checklist was graded using very poor; 1 (not suitable for interpretation), up to; 5 (could be fully interpreted), not completed scored 0. The total possible score is 440. This is a very useful tool. However, there is still the need for a more *practical* approach to formulating and assessing a curriculum such as, number of hours with hands-on practice, keeping a logbook, attending courses and lectures and an actual examination in both theory and practice of basic echo. However, the test instrument in the Danish study may prove useful in testing the *validity o*f a curriculum.

There has been other work in developing scoring systems to aid in the validation of a basic echo curriculum. Jozwia *et al*., (2014) studied a score for assessing basic echo skills performed by intensive care doctors treating ventilated patients. Their skills were evaluated after 1 month, 3 months and 6 months, and these skills were compared with those of experts, paying attention to diagnosis and the therapeutic yield of basic echo. They validated their scoring system in three ways: total scores between fellows with and without prior echo experience, secondly, the scores obtained by the beginners improved dramatically over the six months and thirdly the total score obtained was associated with the ability to make a diagnosis and therefore treat the patient appropriately. These findings were consistent with previous evidence, that basic echo training requires only a limited amount of time.

4.4 Certification Process in Basic Critical Care Echocardiography

Mayo (2011) states that certification “defines an important minimum standard”. One of the main obstacles to certification has always been logistics, especially if there are large numbers of fellows coming through the training process. It was noted that each different country or centre would want to formulate their own certification, but for correct and transparent certification to take place, ideally the process should come from an independent body to avoid conflict of interest. Basic echo represents one portion of training for intensive care fellows. Another concern is the time and money that would be required to certify this qualification. However, in France a certification for competency in *advanced* echo has been developed. The programme runs for two years with hands-on experience, lectures and the fellows required to perform large numbers of advanced studies. They are then examined by a board which is independent of the course, and carries a high failure rate. (Veillard-Baron *et al*., 2008). This certification process is a model for other centres to follow as it is a structured pathway. However it is for advanced level, and *not* basic level of echocardiography which may prove more challenging due to the short time frames and perhaps fewer numbers of fellows on basic courses. The consensus statement from CHEST makes it clear that competency is distinguished from certification and that the statement may form a foundation or framework for providing formal certification in the whole area of ultrasound in critical care but not specific to basic echo. It appears evident from the literature that the experts agree that certification is not required for a basic level of training (Cholley *et al*., 2011) however it would be beneficial for those fellows taking part in any training programme to have some sort of certification to carry forward.

The European Society of Intensive Care Medicine (ESICM) now provides certification in advanced echocardiography and a diploma for fellows who have met the requirements of competency in advanced critical care echo.

In Australia and New Zealand no formal examination or certification is provided for *basic* echo in the critical care setting. The Australian Society of Ultrasound in Medicine (ASUM) provides certification for *advanced* echo by extending their well-known diploma in diagnostic ultrasound to advanced CCE (Australian Society of Ultrasound in Medicine, 2015)

The NBE or National Board of Echocardiography in Australia has a policy of certification for physicians who have completed their full fellowship in cardiology and there are also board exams for anaesthetists and intensivists.

4.5 European Recommendations for Training, Competency and Quality Improvement in Echocardiography

The purpose of these European recommendations (Popescu *et al*., 2009) is to provide guidelines for training and competency in modern echocardiography. While these recommendations are intended for specialized cardiology sonographers and doctors, it is quite relevant to anyone undertaking training in echo. It states that for competency in echo at a basic level one requires knowledge of the following: physics of ultrasound, principles of echo, instrumentation, other criteria such as knowledge of anatomy, blood flow, abnormalities and of course indications and contraindications. This committee also broke down the training into basic and advanced levels. Obviously, the case mix is important for the trainee. There was a consensus on the number of examinations to be performed and for basic level cardiology trainees it states that they should perform 350 cases per year in order to achieve and maintain competency. The case mix for cardiology fellows will obviously be far more varied and will include far more ‘cardiac’ cases than the case mix for fellows as already outlined. The trainee will then undertake an accreditation exam which they will be expected to pass. The training programme should take place in an accredited centre and should follow a very structured path which will include practical training and theory. Web based teaching programmes are also recommended.

To prove the competency of the trainee is the key and it must ensure that the trainee has the appropriate knowledge and skills. This may be measured in three ways; 1. Statements from trainers and supervisors, 2. Examinations and 3. Practical assessment and logbook. It is stated that one cannot underestimate the importance of the trainers and supervisors. At the end of the training the supervisor will be asked to testify that the candidate has undergone a training programme and has achieved appropriate competency. It is agreed that proof of competency is obtained by observing a candidate perform an echo – in other words a practical assessment. The other important way of assessing competency, is written examinations with a theory section and video cases. Benchmarking can be performed when marking the exams. Once again, the log book was discussed, and it was agreed that along with a log book, the candidate should also store images on an off line or digital method, to review cases if required. The number of cases for the log book was recommended at 250 for TTE within a 12 month period after passing the exam. This, again, may be more appropriate for the cardiology candidate.

4.6 British Society of Echocardiography and Intensive Care Medicine

Recently a course which is a collaboration between the British Society of Echo (BSE) and Intensive Care Medicine (ICM) has proved very beneficial for fellows seeking accreditation in echo. As with the European association this is a course comprising of certain goals and standards. The syllabus comprises a written exam and video cases, and only when the candidate has passed the written exam do they proceed to keeping a logbook (Echocardiography, 2015). The candidates need to collate 250 cases in their log book with a specific case mix appropriate to intensive care doctors. There is also what is known as FICE – focused intensive care echo. On the FICE training programme the modules are between 6 and 12 months in an appropriate dedicated intensive care unit. The trainees keep a logbook of 50 cases and 10 of these cases should be directly supervised by an accredited member of staff.

These two societies enable intensive care physicians with an interest in echo to pursue accreditation. The aim of the MMUH course is to validate a focused curriculum for the Irish intensive care fellow in basic echo, and to recommend certification, as well as incorporating echocardiography as an important module in intensive care training. It is evident from the literature around the world that most modern intensive care units strive for this validation in ultrasound in general, so the intensive care training is a matter of fine tuning. Once the fellows have achieved basic echo training, they can continue as desired, to advanced levels and pursue accreditation as a natural progression in the whole field of echocardiography.

4.7 Echo in ICU – The Way Forward

As can be seen from the literature there are many training processes in place around the world for echocardiography in the ICU. Much training however seems to concentrate on more advanced ultrasound and echo, with fellowship programmes and accreditation and certification programmes in place as outlined above. Historically these programmes are more for the cardiology fellow or cardiac physiologist but most echo societies are now embracing their ICU colleagues. (BSE, ESE). There are also many focused echocardiography protocols in place, for example FATE (focused assessed transthoracic echocardiography), FAST (focused assessment with sonography in trauma), FEEL (focused echocardiography evaluation in life support), FUSE (focused ultrasound and echocardiography) and HARTscan (haemodynamic echocardiographic assessment in real time). There is training in all the above but as Lau *et al*., point out, they can all become confusing and what fellows need is a clear pathway with a structured curriculum and training programme – even in basic echo. (Lau *et al*., 2011). This does present a challenge as outlined in the literature as to how to achieve competency and has resulted in the lack of any clear guidelines for fellows wishing to use their skill in their clinical practice. Lau correctly states in his editorial that whatever the format, the development of training in critical care ultrasound needs close collaboration with local, national and international groups.

Royse speaks about ultrasound becoming an integral part of critical care medicine as a very exciting development. He says that is likely that medical schools in the future will teach ultrasound as a core part of basic patient assessment. (Royse, 2013). The hope is that *basic* echo will be part of that *basic* assessment too.

The general statements, standards and frameworks of several prominent centres for Echocardiography have been outlined above. A critical examination of these as well as the British and European Echo Societies' accreditation processes for achieving competency leads us to an answer to the questions explained in this review. The consensus suggests that bedside echo in the training of intensive care fellows is vital for the future, but the challenge is achieving competency and therefore certification on a fundamental level. It is therefore the responsibility of each intensive care society to embrace this exciting diagnostic tool and make it part of the curriculum for their intensive care fellows.

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CHAPTER 5

Study Methodology

5.1 Introduction

In August 2012 a sonographer led hands-on basic echo training programme was initiated in the Intensive Care Unit of the MMUH in Dublin. There was a single Intensive Care Consultant and three intensive care doctors who are known as fellows. None of them had any experience in transthoracic echocardiography (TTE) although two of them had some experience in transoesophageal echo (TOE). A sonographer with over 20 years of experience in echocardiography took the 4 fellows for hands-on training in the intensive care unit for two hours a week for 20 weeks. Echos were performed on ventilated and on highly-dependent patients by the fellows, under the supervision and guidance of the sonographer. The 4 fellows kept a logbook which was signed by the supervisor/sonographer for every case they performed (*Appendix 1*). The aim was to collate 30 cases by the end of the 20 weeks. A Consultant Intensivist with many years of experience in TTE and TOE tutored the fellows for a total of 10-hour didactic lectures during this period. These lectures consisted of material that was relevant for these fellows when performing a TTE on critically ill patients which would enable them to make a quick and timely diagnosis and therefore treat the patient effectively and appropriately (Kuriakose *et al*., 2013).

The course was developed further for subsequent fellows on their six month rotation through the ICU. The aim was to set up a basic echo course which would become mandatory for intensive care doctors to complete as part of their training in intensive care medicine. A faculty was set up which included a Consultant Intensivist, a Consultant Cardiologist and Senior and Chief Physiologists in cardiology. (*Appendix 2*).

5.2 Ethics Submission and Approval

In November 2013 an application for this study was submitted to the MMUH Ethics Committee. The study was approved and the need for informed consent was waivered. (*Appendix 3*).

5.3 Echo Views Specific to Intensive Care Fellow

When performing an echo, the first view acquired is generally the **Parasternal long axis view**. This view is acquired by placing the transducer or probe in the fourth intercostal space on the left side of the sternal border. This view is generally the first view attained if possible, when performing any cardiac echo. It gives important information about the left ventricle (LV), the right ventricle (RV) and two of the four valves of the heart – the aortic valve and the mitral valve. It also enables one to see the left atrium (LA) and the interventricular septum and posterior walls of the LV. In terms of performing an echo, one should be able to assess this view with 2D, colour Doppler and M Mode.

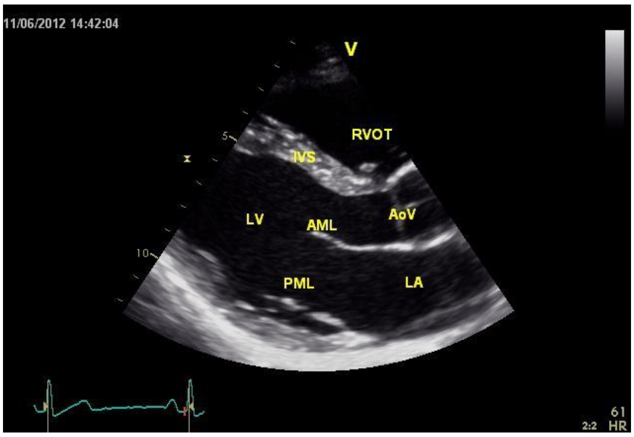

Figure 5.1 Parasternal long axis View (Wikiecho 2017)

The next view obtained when performing an echo is the **Parasternal short axis view**. By rotating the probe 90 degrees from the parasternal long axis view, the image attained is known as the short axis view. This is a view that requires accurate manipulation of the transducer in order to view all of the valves of the heart – the mitral valve, the aortic valve, the tricuspid valve and the pulmonary valve. This view also enables us to see the LV from different angles scanning from the mitral valve past the papillary muscles and down into the LV apex.

Also tilting the probe in a different direction enables viewing of the aortic, tricuspid and pulmonary valves. Again 2D, colour Doppler, M Mode and also pulsed wave and continuous wave Doppler can be applied therefore using all echo modalities for complete assessment in this view.

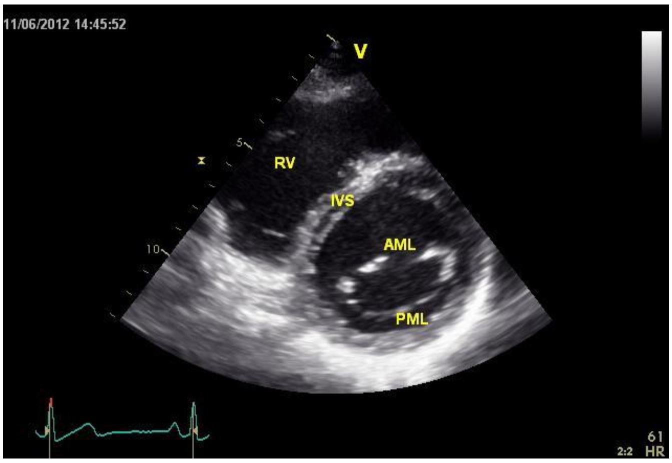

Figure 5.2 Parasternal short axis View (Wikiecho, 2017)

The probe is now moved off the parasternal chest and placed in the apical window to acquire the **Apical 4 chamber view.** The probe is placed at the apex beat of the heart which enables imaging of all four chambers – the two atria and the right and left ventricles. Once again all the modalities of echo can be used in these views – 2D, colour Doppler, pulsed wave and continuous wave Doppler and M mode. This view allows assessment of the two of the valves and all four chambers of the heart.

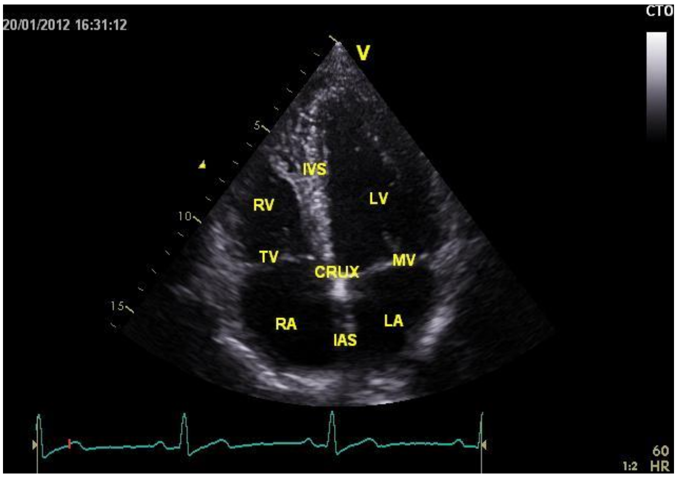

Figure 5.3 Apical 4 chamber view (Wikiecho, 2017)

Apical 5 chamber view – This view is acquired by tilting the probe inferiorly from the apical 4 chamber view, thereby opening up the aortic valve and so creating a 5 chamber view. Here colour Doppler, pulsed wave Doppler and continuous wave Doppler can be applied to assess valve function but more importantly for the intensive care fellow, this view allows the calculation of stroke volume and cardiac output

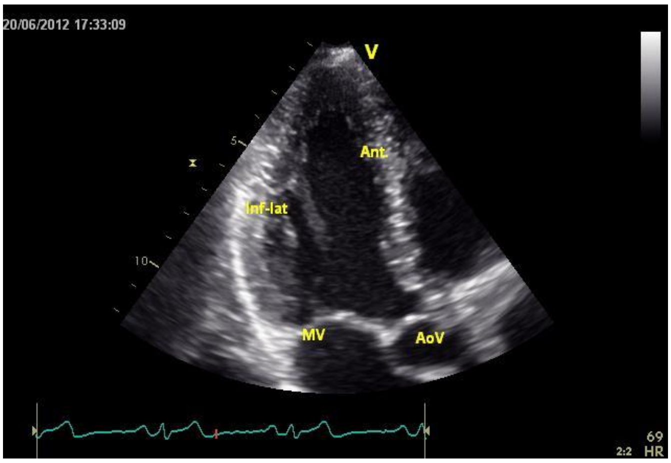

Figure 5.4 Apical 5 chamber view (Wikiecho, 2017)

The probe is now place in the subcostal window to obtain the **<u>Subcostal view</u>.** This view is probably the best view for the intensive care fellow in terms of easy access and also timely and efficient diagnosis in an emergency situation. The probe is placed in the subxiphoid area thus allowing visualization of the whole heart – so all four chambers and all valves, but also the surrounding layer known as the pericardium. If too much fluid builds around the heart it is a life-threatening condition known as tamponade. The subcostal view allows the assessment of this condition but also guides the operator if he needs to drain the fluid out of the pericardial sac in this critical situation. All echo modalities can be applied to this view to improve assessment and gain further information.

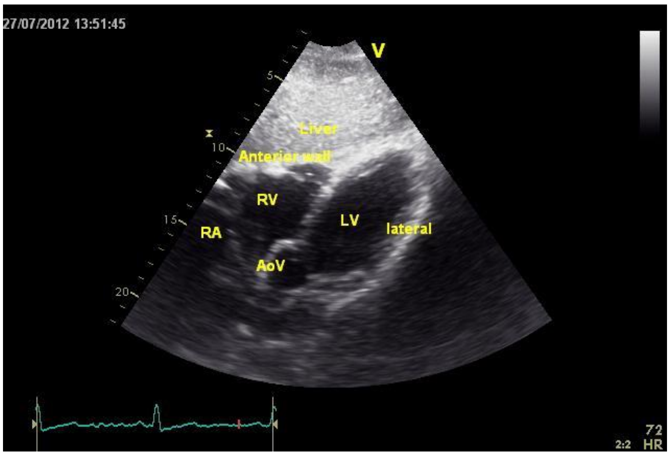

Figure 5.5 Subcostal view (Wikiecho, 2017)

<u>IVC</u> – visualization of the IVC or inferior vena cava, is achieved by rotating the transducer 90 degrees from the subcostal view. The size and distensibility of the IVC gives the intensive care fellow a wealth of information on not only pressures in the heart but also the lungs, and the fluid status of the patient –whether they require more fluids or indeed less fluids.

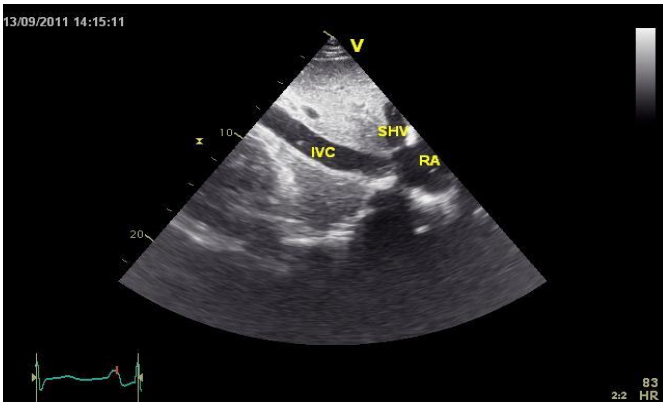

Figure 5.6 Subcostal view – IVC. (Wikiecho,2017)

5.3 Period 1 – January 2014 to June 2014

In January 2014 two candidates enrolled for the six month basic echo programme. These candidates were fellows in Intensive care medicine. The course consisted of 20 weeks of hands-on training – 2 hours per week in the unit. A two-day course replaced the 10-hour lecture series and this course was offered to intensive care doctors from around the country (Fig. 5.7- Period 1). There was also a series of lectures specific to the needs of the intensive care setting. These lectures covered: left ventricle (LV) size and function, right ventricle (RV) size and function, mitral valve regurgitation (MR), aortic valve regurgitation (AR), tricuspid regurgitation (TR) the pericardium and IVC, fluid responsiveness and tamponade. Day 1 of the course starts with lectures on the basic physics of ultrasound and Doppler.

All participants on the course filled in evaluation sheets for both days (*Appendix 4*).

At the end of this 6 month period, the four fellows had completed thirty cases (supervised) in their logbooks and had sat a written exam, an exam of video sample cases and a practical exam. The written exam consisted of 25 multiple choice questions (MCQ's)- each with 5 stems. All questions were true (1 mark) or false answers (0 mark) and all questions had to be answered. There was a 70% pass mark on this paper. The video exam consisted of 5 cases each with 5 true (1 mark) or false (0 mark) answers (Figure 5.7 -Period 1). There was a 70% pass mark. The practical part of the exam was carried out in the intensive care unit. The consultant intensivist carried out the practical exam with the candidates. All sections of the exams had to be passed.

5.4 Period 2 – August 2014 to December 2014

This six month programme was also offered to doctors in the emergency department (ED). There were five candidates. Three were intensive care fellows with little or no experience in TTE and two were ED doctors with very limited experience in TTE. Once again hands-on training was provided for two hours a week for 20 weeks. During this session a second two-day course of lectures was held with the same topics covered as in the first session including hands-on training. Based on the evaluation sheets from the previous course the faculty members were changed and the content of some of the lectures were altered to keep it to a basic level. However, the course structure remained the same, all relevant and specific to intensive care cases. Evaluation sheets were distributed on both days as before. In December all five candidates sat exams, in the exact same format as the previous term and carried the same pass marks. All five fellows also completed 30 cases in their logbooks (Fig 5.7 - Period 2).

5.5 Period 3 – January 2015 to June 2015

There were four candidates on this programme. Two were ED Consultants and two were ICU fellows. None of them had experience in TTE. The same format applied – 40 hours of hands-on training in the ICU. A logbook of 30 cases completed by each candidate. There was a slight change made to the written exams. In June the 4 candidates agreed to sit *two* written exams. The first exam was the same format as described above; 25 MCQ's with 5 true (1 mark) or false (0 mark) stems. The second exam was 10 MCQ's with a single best answer (SBA). They completed a video exam with 5 cases in the same true/false format as on the previous two courses and they completed the practical exam on the unit with the Consultant Intensivist (Fig 5.7 - Period 3).

5.6 Period 4 – August 2015 – December 2015

There were four candidates on this programme. Two ED doctors and two intensive care fellows enrolled for 6 months with the same format applied as all the other sessions. A two-day course was held during this semester and evaluated as before. The written exams at Christmas 2015 consisted of 25 MCQ's T/F and 10 MCQ's SBA (as in Period 3). They completed a video exam with 5 cases in the same true/false format as on the previous two courses and a practical exam was included as usual (Fig 5.7 - Period 4).

5.7 Period 5 – January 2016 - June 2016

There were four candidates on this programme. Two intensive care fellows were enrolled on this session along with a Consultant from the ED department and a Specialist Registrar from the Acute Medical Assessment Unit (AMAU). On this occasion the MCQ included one format only; 25 MCQ's with SBA (Figure 5.7 - Period 5). The pass mark was again 70%. The video cases remained as true/false answers and the practical was carried out in the ICU by the Consultant Intensivist. Results and comparisons on all the above are cited in the discussion Chapter 7.

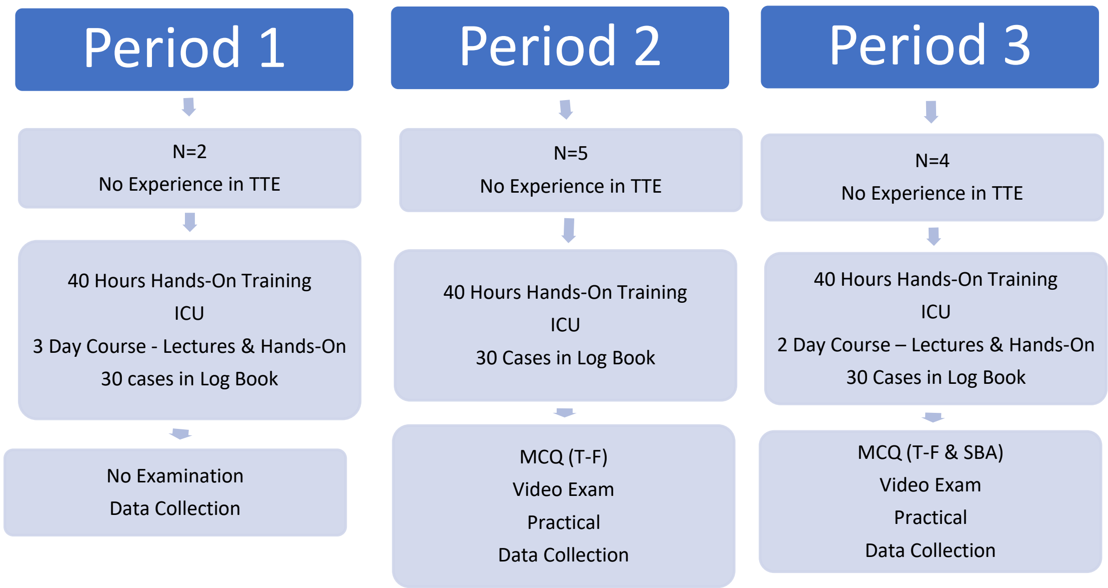

Figure 5.6 Periods 1-3

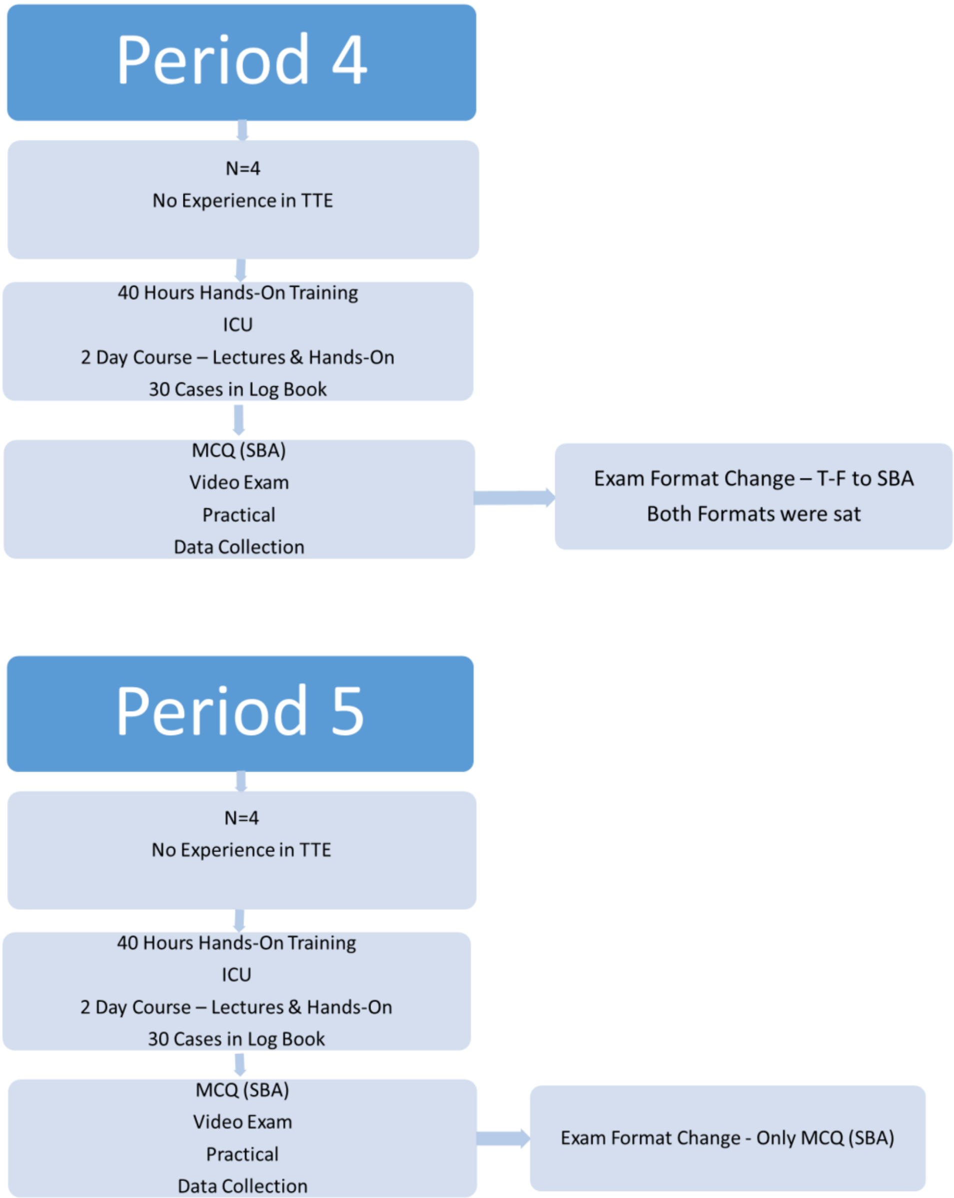

Figure 5.7 Periods 4-5

5.8 Data Collection Sheets

Data collection sheets were devised to allow easy comparison of the echo data performed by the experienced Intensivist and the trainee (*Appendix 5)*. The sheets included patient demographics; presenting complaint, medication, mechanical ventilation and use of vasoactive medications. It contained information on image quality in all views. Ventricular chamber size and function were indicated by ranges and tick-box method. Data included fluid assessment and volume status. Where a change of management of the patient occurred based on the echo findings, this was recorded. Both the intensivist and trainee completed a data sheet for each TTE study, with the former data sheet serving as the "gold standard".

The data collection commenced during the final month of hands-on training and during the practical examination.

5.9 Statistical Analysis

Sensitivity and specificity is a very common method of statistical analysis used in relation to medicine or medical conditions. Sensitivity looks at the true positive rate and specificity looks at the true negative rate, in terms of for example, people correctly identified as *having* a condition to those correctly identified as *not* having a condition. Calculation of sensitivity and specificity includes true positive (TP) false positive (FP) true negative (TN) and false negative (FN) for the statistical calculations. Thus, sensitivity quantifies the avoiding of false negatives just as specificity does for false positives.

A simple formula used in the analysis of this study was:

Sensitivity $\frac{a}{a+b}$ where a = true positive and b = false negative

and

Specificity $\frac{c}{c+d}$ where d = true negative and c = false positive

This study used this method of statistical analysis in looking at the expert as the gold standard against the fellow, under specific headings taken from a data collection sheet. The study used an agree and disagree (yes and no) principle, converting yes and no into 0 and 1 respectively, to enable the use of the binary equation for sensitivity and specificity. Positive and negative predictive values were included as were expected agreement percentages. A 95 % confidence interval was applied in all cases.

5.10 Training Faculty:

The faculty consisted of a

(1) Chief physiologist who was the hands-on trainer (RO'M)

(2) Consultant Intensivist (FC)

(3) Consultant Cardiologist (JO'N)

(4) ICU Senior Fellows (rotation) lecture series

(5) Senior physiologist (KC)

(6) Chief Physiologist and DIT lecturer (GK)

The faculty members gave lectures and provided some additional hands-on training assistance as clinical cases arose on the ward. The faculty evaluated each 2-day course and made changes based on the feedback received.

5.10.1 10 Hour Lecture Series

This include lectures on physics of ultrasound, how to scan and attain images, lectures on the left ventricle, right ventricle, fluid response, valvular function, the pericardium and tamponade. Evaluation sheets were filled in on all days and the course evolved over time with the information obtained from these sheets. An example of a change made was that there was an overwhelming request for more hands-on sessions, so this was addressed and provided on subsequent courses. Some lectures were changed and tweaked to provide more basic information.

5.11 References

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Mayo, P. H. 2011. Training in critical care echocardiography. *Annals of Intensive Care*, 1**,** 36-36.

Mayo, P. H., Beaulieu, Y., *et al*., 2009. American College of Chest Physicians/La Societe de Reanimation de Langue Francaise statement on competency in critical care ultrasonography. *Chest*, 135**,** 1050-60.

Vignon, P., Mucke, F., *et al*., 2011. Basic critical care echocardiography: validation of a curriculum dedicated to noncardiologist residents. *Crit Care Med*, 39**,** 636-42.

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CHAPTER 6

Results

6.1 Introduction

The most important factor in this study was assessing the ability of the fellow to perform an echo and acquire the views specific to their needs in the intensive care setting. These views are parasternal long axis view (PLAX), the parasternal short axis view (PSAX), the apical 4 chamber view (A4C), the apical 5 chamber view (A5C), the subcostal view and being able to visualize the IVC from the subcostal view (*Appendix* 5). It was therefore important they learned how to obtain and recognize the echocardiographic features that would help diagnose the six main causes of hypotension or haemodynamic shock. These clinical domains include: cardiac function –left ventricle and right ventricle (LV and RV), regional wall abnormalities, valve dysfunction – (mainly mitral regurgitation, tricuspid regurgitation and aortic regurgitation). Pericardial disease and tamponade are further causes of hypotension that need to be identified, and haemodynamic shock and finally filling status or fluid responsiveness should be recognised.

6.2 Indications for Echo

Over the course of a 2.5-year period a total of 19 fellows were recruited on the basic echo training programme.

Table 6.1 shows the number of cases per indication recorded. As can be seen, 66 scans were performed in this study first by the expert first and then by the fellow. Data collection sheets were only presented at the practical exam or at the end of the six months (*Appendix 5*) which accounts for the low numbers i.e. 1 murmur and 2 RV function assessments.

Indication	Number of Cases
Assess LV function	44
RWMA	5
Assess murmur	1
Fluid responsiveness - hypovolaemia	5
RV function	2
Endocarditis	5
Presence of pericardial effusion	4

Table 6.1 Clinical indication for echo

Blood pressure and heart rate were recorded on the data sheet taken from the bedside monitors at the time of each study.

Rhythm	SR n = 54 (81%)	A FIB n = 12 (18%)
Apache score	Mean 18 (Max 35 and Min 6)	
Mechanical ventilation	n = 40 (60%)	
Inotrope	n = 8 (12%)	
Vasopressor	n = 23 (35%)	

Table 6.2 Characteristics of patient population

6.3 Results for Acquiring the Views

6.3.1 PLAX

Proportion estimation   Number of obs = 66

(Std. Err. adjusted for 50 clusters in patient no)

plaxv	Proportion	Robust Std. Err.	[95% Conf.	Interval]
True positive	0.909	0.037	0.804	0.961
True negative	0.045	0.026	0.014	0.138
False pos've	0.030	0.021	0.007	0.120
False neg've	0.015	0.015	0.002	0.107

Table 6.3 Results PLAX

In 60 of the studies the expert and fellow both acquired the PLAX thus giving the true positive proportion. On 3 occasions the expert and the fellow agreed there was no PLAX window thus giving a true negative proportion. On 2 occasions the fellow thought they had acquired a PLAX view when in fact the expert did not, and on 1 occasion the fellow could not acquire the PLAX when the expert could.

6.3.2 PSAX

Proportion estimation Number of obs = 66

(Std. Err. adjusted for 50 clusters in patient no)

	Proportion	Robust Std. Err.	[95% Conf.	Interval]
saxv				
True positive	0.803	0.054	0.671	0.891
True negative	0.121	0.046	0.055	0.248
False pos've	0.015	0.015	0.002	0.107
False neg've	0.061	0.030	0.022	0.156

Table 6.4 Results PSAX

In the case of the PSAX on 53 occasions the expert and the fellow acquired the view = true positive. There were 8 cases where the expert and the fellow could not acquire this view giving true negative. There was 1 occasion where the fellow acquired this view when the expert did not, thus giving a false positive proportion and there were 4 occasions where the fellow could not acquire this view and the expert did.

6.3.3 Apical 4 Chamber View

Proportion estimation Number of obs = 66

(Std. Err. adjusted for 50 clusters in patient no)

a4cv	Proportion	Robust Std. Err.	[95% Conf.	Interval]
True positive	0.803	0.053	0.676	0.888
True negative	0.106	0.043	0.046	0.227
False pos've	0.015	0.015	0.002	0.107
False neg've	0.076	0.033	0.031	0.175

Table 6.5 Results Apical 4 chamber view

In the case of the apical 4 chamber view there were 53 occasions where the fellow and the expert acquired this view giving the true positive proportions. There were 7 times where neither the expert or the fellow could acquire this view giving the true negative proportions. There was 1 occasion where the fellow acquired the view and the expert did not = false positive and there were 5 cases where the fellow could not acquire the view when the expert could.

6.3.4 Apical 5 Chamber View

Proportion estimation Number of obs = 66

(Std. Err. adjusted for 50 clusters in patient no)

a5v	Proportion	Robust Std. Err.	[95% Conf.	Interval]
True positive	0.682	0.059	0.553	0.788
True negative	0.167	0.047	0.092	0.284
False pos've	0.030	0.021	0.007	0.117
False neg've	0.121	0.041	0.060	0.229

Table 6.6 Results Apical 5 chamber view

On 45 occasions the expert and the fellow acquired the apical 5 chamber view = true positive proportions. There were 11 occasions where the expert and the fellow could not acquire this view – true negative proportions. On 2 occasions the fellow acquired the view when the expert did not, giving a false positive and on 8 occasions the fellow could not acquire the view when the expert could.

6.3.5 Subcostal View

Proportion estimation Number of obs = 66

(Std. Err. adjusted for 50 clusters in patient no)

subcv	Proportion	Robust Std. Err.	[95% Conf. Interval]	
True positive	0.818	0.056	0.678	0.906
True negative	0.091	0.042	0.035	0.216
False pos've	0.015	0.015	0.002	0.107
False neg've	0.076	0.039	0.026	0.201

Table 6.7 Results subcostal view

There were 54 cases where the expert and the fellow both acquired the subcostal view = true positive. There were 6 occasions where neither the expert or the fellow acquired this view giving the true negative proportions. On 1 occasion a fellow acquired this view when the expert did not and on 5 occasions the fellow could not acquire this view when the expert did.

6.3.6 IVC View

```
Proportion estimation            Number of obs   =         65

             (Std. Err. adjusted for 50 clusters in patient no)
--------------------------------------------------------------
             |               Robust
             | Proportion   Std. Err.     [95% Conf. Interval]
-------------+------------------------------------------------
ivc          |
True positive|      0.677      0.066          0.534       0.793
True negative|      0.200      0.054          0.112       0.331
False pos've |      0.031      0.022          0.007       0.121
False neg've |      0.092      0.042          0.036       0.219
--------------------------------------------------------------
```

Table 6.8 Results IVC view

On 44 occasions the expert and the fellow acquired the IVC view giving the true positive proportions. On 13 occasions the expert and the fellow could not acquire this view = true negative. There were 2 occasions where the fellow acquired the view when the expert did not and 6 occasions where the fellow could not acquire this view when the expert did. There was data omitted from 1 case on this view.

6.4 Results for the Clinical Domains

The next part of the analysis concerned the agreement between fellow and expert in terms of the 7 clinical domains – again with the expert as the gold standard. As mentioned the seven clinical domains are; LV size and function, regional wall abnormality, RV size and function, valvular function, pericardial disease, tamponade and fluid status.

6.4.1 Results for Left Ventricular (LV) Size

LV size	Freq.	Percent	Cum.
True positive	60	92.31	92.31
False positive	3	4.62	96.92
False negative	2	3.08	100.00
Total	65	100.00	

Proportion estimation   Number of obs = 65

_

(Std. Err. adjusted for 17 clusters in fellow_id)

	Proportion	Robust Std. Err.	[95% Conf.	Interval]
lvsize				
_prop_1	0.923	0.034	0.813	0.971
_prop_2	0.046	0.025	0.015	0.137
_prop_3	0.031	0.019	0.008	0.109

Table 6.9 Results LV Size

True Positive: Fellow agreed with expert that LV was normal in size *or* dilated. There were 60 cases with normal LV function, 5 cases where LV size was enlarged.

There was one patient in whom the expert could not assess LV function as views could not be obtained.

False Positive: Fellow called LV mildly dilated (2 cases) and severely dilated (1 case, where only parasternal windows available) when expert called LV size normal.

False Negative: Fellow did not call LV size at all but this was because the fellow did not obtain a reasonable echo window.

6.4.2 Results for Left Ventricular (LV) Function

```
Results for LV fxn
Confidence intervals adjusted for clustering within Fellows
**************************************************

         LV fxn |      Freq.     Percent        Cum.
----------------+-----------------------------------
  True positive |         58       87.88       87.88
  True negative |          2        3.03       90.91
 False positive |          4        6.06       96.97
 False negative |          2        3.03      100.00
----------------+-----------------------------------
          Total |         66      100.00

Proportion estimation             Number of obs    =         66

             (Std. Err. adjusted for 17 clusters in fellow_id)
--------------------------------------------------------------
             |                Robust
             | Proportion   Std. Err.     [95% Conf. Interval]
-------------+------------------------------------------------
lvfxn        |
     _prop_1 |      0.879      0.039         0.769       0.941
     _prop_2 |      0.030      0.020         0.008       0.113
     _prop_3 |      0.061      0.027         0.023       0.151
     _prop_4 |      0.030      0.031         0.003       0.229
--------------------------------------------------------------
```

Table 6.10 Results LV Function

True Positive; fellow agreed with expert on left ventricular function. There were 58 cases where the LV function was normal and 4 cases where it was reduced.

True Negative: On 2 occasions the fellow and expert agreed the LV function was reduced

False positive: fellow called LV function reduced when expert said was normal (in 3 cases called moderately severe reduction and 1 case called severe reduction LV function)

False negative: Fellow missed abnormal LV function (1 case where fellow called LV function normal and expert said moderately reduced. 1 case fellow could not obtain view)

6.4.3 Results for Regional Wall Motion Abnormality (RWMA)

```
Results for RWMA
Confidence intervals adjusted for clustering within Fellows
**************************************************

-> tabulation of rwma

           RWMA |      Freq.     Percent        Cum.
----------------+-----------------------------------
  True positive |          8       12.12       12.12
  True negative |         38       57.58       69.70
 False positive |          3        4.55       74.24
 False negative |         17       25.76      100.00
----------------+-----------------------------------
          Total |         66      100.00

Proportion estimation            Number of obs   =         66

      _
             (Std. Err. adjusted for 17 clusters in fellow_id)
--------------------------------------------------------------
             |                 Robust
             | Proportion   Std. Err.     [95% Conf. Interval]
-------------+------------------------------------------------
rwma         |
     _prop_1 |      0.121      0.047         0.052       0.259
     _prop_2 |      0.576      0.058         0.450       0.693
     _prop_3 |      0.045      0.022         0.016       0.125
     _prop_4 |      0.258      0.051         0.164       0.379
--------------------------------------------------------------
```

Table 6.11 Results RWMA

True Positive: Fellow and expert agree that there are RWMA's present. There were 8 such cases.

True Negative: Fellow and expert agree that there are no RWMA's. There were 38 such cases.

False Positive: Fellow called a RWMA when the expert said there was none; there were 3 cases (in each case the expert felt could not assess adequately)

False Negative: Fellow says no RWMA when expert says there is one or may be one. There were 17 such cases, but in 13 cases the fellow called no RWMA but the expert was unable to rule one out, 2 cases the expert called RWMA but the fellow missed, and 2 cases where the fellow had inadequate views.

6.4.4 Results for Right Ventricle (RV) Size

```
Results for RV size
Confidence intervals adjusted for clustering within Fellows
**************************************************

-> tabulation of rvsize

       RV size |      Freq.     Percent        Cum.
---------------+-----------------------------------
 True positive |         57       87.69       87.69
 True negative |          4        6.15       93.85
False positive |          1        1.54       95.38
False negative |          3        4.62      100.00
---------------+-----------------------------------
         Total |         65      100.00

Proportion estimation            Number of obs   =         65

             (Std. Err. adjusted for 17 clusters in fellow_id)
--------------------------------------------------------------
             |               Robust
             | Proportion   Std. Err.     [95% Conf. Interval]
-------------+------------------------------------------------
rvsize       |
     _prop_1 |      0.877      0.033         0.788       0.932
     _prop_2 |      0.062      0.028         0.023       0.154
     _prop_3 |      0.015      0.015         0.002       0.114
     _prop_4 |      0.046      0.022         0.017       0.120
--------------------------------------------------------------
```

Table 6.12 Results RV Size

True Positive: Fellow and expert agree on RV size. 60 cases where the RV was normal and 4 cases where it was dilated.

True Negative: Fellow and expert agree RV size not normal.

False Positive: 1 fellow called the RV normal when the expert failed to assess.

False Negative: 3 fellows unable to assess when the expert called normal.

6.4.5 Results for Right Ventricular Function (RV fx)

```
Results for RV fxn
Confidence intervals adjusted for clustering within Fellows
**************************************************

-> tabulation of rvfxn

         RV fxn |      Freq.     Percent        Cum.
----------------+-----------------------------------
  True positive |         60       92.31       92.31
  True negative |          1        1.54       93.85
 False negative |          4        6.15      100.00
----------------+-----------------------------------
          Total |         65      100.00

Proportion estimation              Number of obs   =          65


             (Std. Err. adjusted for 17 clusters in fellow_id)
--------------------------------------------------------------
             |               Robust
             | Proportion   Std. Err.     [95% Conf. Interval]
-------------+------------------------------------------------
rvfxn        |
     _prop_1 |      0.923      0.028         0.837       0.965
     _prop_2 |      0.015      0.015         0.002       0.114
     _prop_3 |      0.062      0.029         0.022       0.160
--------------------------------------------------------------
```

Table 6.13 Results RV Function

True Positive: Fellow and expert agree on the RV fx. There were 60 cases of normal RV function

True Negative: 2 cases where the fellow and the expert were unable to assess

False Positive: 1 case where fellow called RV normal when expert unable to assess

False Negative: 3 cases where fellow called the RV function reduced when the expert called it normal.

6.4.6 Results for IVC Size

Proportion estimation Number of obs = 65

_

(Std. Err. adjusted for 49 clusters in patientno)

	Proportion	Robust Std. Err.	[95% Conf.	Interval]
ivcsize				
True positive	0.708	0.061	0.571	0.815
True negative	0.138	0.047	0.068	0.261
False pos've	0.046	0.027	0.014	0.140
False neg've	0.108	0.040	0.050	0.218

Table 6.14 Results IVC Size

True Positive: There were 46 cases where the expert and fellow agreed that the IVC size was normal.

True Negative: On 8 occasions both fellow and expert agreed they could not assess adequately.

False Positive: On 4 occasions the fellow made an assessment on the IVC when the expert was unable to.

False Negative: On 7 occasions the fellow said he could not assess or visualize the IVC when the expert could.

6.4.7 Results for ESCO

```
Results for ESCO
Confidence intervals adjusted for clustering within Fellows
**************************************************

-> tabulation of esco

           ESCO |      Freq.     Percent        Cum.
----------------+-----------------------------------
  True positive |          2        3.08        3.08
  True negative |         59       90.77       93.85
 False positive |          2        3.08       96.92
 False negative |          2        3.08      100.00
----------------+-----------------------------------
          Total |         65      100.00

Proportion estimation              Number of obs   =          65

              (Std. Err. adjusted for 17 clusters in fellow_id)
--------------------------------------------------------------
              |                Robust
              | Proportion   Std. Err.     [95% Conf. Interval]
--------------+-----------------------------------------------
esco          |
      _prop_1 |      0.031      0.031         0.004       0.219
      _prop_2 |      0.908      0.044         0.763       0.968
      _prop_3 |      0.031      0.019         0.008       0.109
      _prop_4 |      0.031      0.019         0.008       0.109
--------------------------------------------------------------
```

Table 6.15 Results ESCO

True Positive: – There were 2 occasions of end systolic cavity obliteration and both fellow and expert agreed.

True Negative: – On 59 occasions the fellow and the expert agreed there was no cavity obliteration.

False Positive: – On 2 occasions the fellow called end systolic cavity obliteration when the expert did not.

False Negative: – On 2 occasions there was no agreement so the fellow did not assess when the expert did.

6.4.8 Results for Pericardial Effusion

```
Results for PE
Confidence intervals adjusted for clustering within Fellows
*********************************************

-> tabulation of pe

             PE |      Freq.     Percent        Cum.
----------------+-----------------------------------
  True positive |          4        6.15        6.15
  True negative |         56       86.15       92.31
 False positive |          2        3.08       95.38
 False negative |          3        4.62      100.00
----------------+-----------------------------------
          Total |         65      100.00

Proportion estimation              Number of obs   =         65


             (Std. Err. adjusted for 17 clusters in fellow_id)
--------------------------------------------------------------
             |               Robust
             | Proportion   Std. Err.     [95% Conf. Interval]
-------------+------------------------------------------------
pe           |
     _prop_1 |      0.062      0.032         0.020       0.173
     _prop_2 |      0.862      0.050         0.718       0.938
     _prop_3 |      0.031      0.018         0.009       0.103
     _prop_4 |      0.046      0.026         0.014       0.142
--------------------------------------------------------------
```

Table 6.16 Results for Pericardial Effusion

True Positive: Fellow and expert agree on the presence or absence of a pericardial effusion. There were just 4 cases of this on the study.

True Negative: Fellow and expert agree that there was no pericardial effusion. This occurred in 56 of the cases.

False Positive: There were 2 cases where a fellow called a pericardial effusion when there was none.

False Negative: There were 2 cases where the expert said there was no effusion but the fellow did not assess.

6.4.9 Results for Tamponade

```
**************************************************
Results for TAMP
Confidence intervals adjusted for clustering within Fellows
**************************************************

-> tabulation of tamp

          TAMP |      Freq.     Percent        Cum.
---------------+-----------------------------------
 True negative |         64       98.46       98.46
False positive |          1        1.54      100.00
---------------+-----------------------------------
         Total |         65      100.00

Proportion estimation            Number of obs   =          65

      _

             (Std. Err. adjusted for 17 clusters in fellow_id)
--------------------------------------------------------------
             |               Robust
             | Proportion   Std. Err.     [95% Conf. Interval]
-------------+------------------------------------------------
tamp         |
     _prop_1 |      0.985      0.015          0.882       0.998
     _prop_2 |      0.015      0.015          0.002       0.118
--------------------------------------------------------------
```

Table 6.17 Results Tamponade

True Negative: Fellow and expert agree there was no tamponade. There were no cases of tamponade at time of study

False Positive: 1 fellow called a tamponade when the expert said there was none.

6.4.10 Results for Tricuspid Regurgitation (TR)

```
**************************************************
Results for TR grade
Confidence intervals adjusted for clustering within Fellows
**************************************************

-> tabulation of trgrade

      TR grade |      Freq.     Percent        Cum.
---------------+-----------------------------------
 True positive |         33       50.77       50.77
 True negative |         23       35.38       86.15
False positive |          3        4.62       90.77
False negative |          6        9.23      100.00
---------------+-----------------------------------
         Total |         65      100.00

Proportion estimation             Number of obs   =          65

      _

             (Std. Err. adjusted for 17 clusters in fellow_id)
--------------------------------------------------------------
             |              Robust
             | Proportion   Std. Err.     [95% Conf. Interval]
-------------+------------------------------------------------
trgrade      |
     _prop_1 |      0.508      0.086         0.332       0.681
     _prop_2 |      0.354      0.095         0.185       0.570
     _prop_3 |      0.046      0.024         0.015       0.131
     _prop_4 |      0.092      0.041         0.035       0.221
--------------------------------------------------------------
```

Table 6.18 Results TR

True Positive: On 33 occasions the expert and fellow agreed on some degree of TR.

True Negative: On 23 occasions the expert and fellow agreed there was no TR

False Positive: There were 3 occasions where the fellow saw TR and the expert did not.

False Negative: There were 6 occasions where – 3 times the expert saw mild but the fellow did not and 2 times the expert saw moderate when the fellow did not. 1 occasion the expert saw mild TR and the fellow did not assess.

6.4.11 Results for Mitral Regurgitation (MR)

```
Results for MR grade
Confidence intervals adjusted for clustering within Fellows
***********************************************

-> tabulation of mrgrade

      MR grade |      Freq.     Percent        Cum.
---------------+-----------------------------------
 True positive |         25       38.46       38.46
 True negative |         32       49.23       87.69
False positive |          4        6.15       93.85
False negative |          4        6.15      100.00
---------------+-----------------------------------
         Total |         65      100.00

Proportion estimation              Number of obs    =         65

      _

             (Std. Err. adjusted for 17 clusters in fellow_id)
--------------------------------------------------------------
             |               Robust
             | Proportion   Std. Err.     [95% Conf. Interval]
-------------+------------------------------------------------
mrgrade      |
     _prop_1 |      0.385      0.080         0.234       0.562
     _prop_2 |      0.492      0.075         0.339       0.647
     _prop_3 |      0.062      0.029         0.022       0.159
     _prop_4 |      0.062      0.024         0.027       0.135
--------------------------------------------------------------
```

Table 6.19 Results MR

True Positive: There were 25 occasions where the expert and fellow agreed on some degree of MR.

True Negative: There were 32 times where the expert and the fellow agreed there was no MR.

False Positive: On 3 occasions the fellow said there as MR when there was none present.

False Negative: There were 4 occasions where the fellow saw no MR when the expert did.

6.4.12 Results for Aortic Regurgitation (AR)

```
**************************************************
Results for AR grade
Confidence intervals adjusted for clustering within Fellows
**************************************************

-> tabulation of argrade

      AR grade |      Freq.     Percent        Cum.
---------------+-----------------------------------
 True positive |          6        9.23        9.23
 True negative |         47       72.31       81.54
False positive |          9       13.85       95.38
False negative |          3        4.62      100.00
---------------+-----------------------------------
         Total |         65      100.00

Proportion estimation             Number of obs   =          65

      _

             (Std. Err. adjusted for 17 clusters in fellow_id)
--------------------------------------------------------------
             |              Robust
             | Proportion   Std. Err.     [95% Conf. Interval]
-------------+------------------------------------------------
argrade      |
     _prop_1 |      0.092      0.040         0.036       0.217
     _prop_2 |      0.723      0.057         0.589       0.826
     _prop_3 |      0.138      0.039         0.074       0.244
     _prop_4 |      0.046      0.029         0.012       0.162
--------------------------------------------------------------
```

Table 6.20 Results AR

True Positive: There were 6 occasions where the expert and the fellow agree on some degree of AR.

True Negative: There were 47 times where the expert and fellow agreed on no AR.

False Positive: There were 9 cases where the fellow called AR when there was none.

False Negative: There were 3 times the expert saw AR but the fellow did not.

6.5 Results of Examinations of Fellows

6.5.1 Results of Written Exams

Candidate – is the fellow who completed the course and sat the exams

Period 1 (July 2014)

	MCQ T/F 25 Qs of 5 T/F Results	**Video Exam** 6 Videos of 5 T/F Results
Candidate 1	109/125 (87%)	23/30 (76%)
Candidate 2	113/125 (90%)	29/30 (96%)

Table 6.21 Results of Written and Video Exams for the July 2014 session.

Percentage results given in parenthesis.

Period 2 (December 2014)

	MCQ T/F 25 Qs of 5 T/F Results	**Video Exam** 6 Videos of 5 T/F Results
Candidate 1	97/125 (77%)	24/30 (80%)
Candidate 2	96/125 (76%)	24/30 (80%)
Candidate 3	92/125 (73%)	26/30 (86%)
Candidate 4	106/125 (84%)	24/30 (80%)
Candidate 5	88/125 (70%)	27/30 (90%)

Table 6.22 Results of Written and Video Exams for the December 2014 session.

Percentage results given in parenthesis.

Period 3 (July 2015)

	MCQ T/F 25 Qs of 5 T/F Results	**MCQ SBA** 10 Qs (result post negative marking)	**Video Exam** 5 Videos of 5 T/F Results
Candidate 1	111/125 (89%)	90% (80%)	22/30 (88%)
Candidate 2	94/125 (75%)	40% (Fail)	19/25 (76%)
Candidate 3	110/125 (88%)	70% (40%)	18/25 (72%)
Candidate 4	1120/125 (88%)	80% (60%)	23/25 (92%)

Table 6.23 Results of Written, MCQ and Video Exams for the July 2015 session.

Percentage results (and negative marking scores given in parenthesis)

Period 4 (December 2015)

	MCQ T/F 25 Qs of 5 T/F Results	**MCQ SBA** 10 Qs (result post negative marking)	**Video Exam** 5 Videos of 5 T/F Results
Candidate 1	99/125 (79%)	60% (Fail)	20/25 (80%)
Candidate 2	95/125 (76%)	80% (70%)	20/25 (80%)
Candidate 3	91/125 (72%)	90% (80%)	22/25 (88%)

Table 6.24 Results of Written, MCQ and Video Exams for the December 2015 session. Percentage results (and negative marking scores given in parenthesis)

.

Period 5 (June 2016)

	MCQ SBA Exam 25 Qs (result post negative marking)			**Video Exam** 5 Videos of 5 T/F Results	
Candidate 1	20/25	80%	(70%)	19/25	(76%)
Candidate 2	18/25	72%	(58%)	23/25	(92%)
Candidate 3	22/25	88%	(82%)	19/25	(76%)
Candidate 4	15/25	60%	(40%)	22/25	(88%)

Table 6.25 Results of MCQ and Video Exams for the June 2016 session.

Percentage results (and negative marking scores given in parenthesis)

6.5.2 Results of Practical Exams

There were 17 of the 19 fellows performed the practical exam.

Period 1 (July) 2014: _ Cases: 1 Fail, 2 Pass

Candidate 1 Vs Expert

Study 1 Fail. Missed RV dilatation in a collapsed patient

Study 2 Pass

Candidate 2 Vs Expert

Study 1 Pass

Study 2 Pass (correctly identified the RV dilatation missed above)

Period 2 (December) 2014: _ Cases: 2 Fail, 3 Pass

Candidate 3 Vs Expert

Study 1 Fail. Diagnosed moderate AR. None seen by expert

Candidate 4 Vs Expert

Study 1 Pass

Candidate 5 Vs Expert

Study 1 Pass

Candidate 6 Vs Expert

Study 1 Fail. Diagnosed moderate AR. None seen by expert. Different patient to the case above.

Candidate 7 Vs Expert

Study 1 Pass

Period 3 (June) 2015: Cases: 1 Fail, 5 Pass

Candidate 8 Vs Expert

Study 1 Pass

Study 2 Pass

Candidate 9 Vs Expert

Study 1 Pass

Study 2 Fail

Candidate 10 Vs Expert

Study 1 Pass

Study 2 Could not use as no "Expert" datasheet to corroborate

Candidate 11Vs Expert

Study 1 Pass

Period 4 (December) 2015: Cases 2 Pass

Candidate 12 Vs Expert

Study 1 Pass

Candidate 13 Vs Expert

Study 1 Pass

Period 5(June) 2016; Cases 1 Fail , 6 Pass

Candidate 14 Vs Expert

Study 1 Fail — Diagnosed severe AR. None seen by expert

Study 2 Pass

Candidate 15 Vs Expert

Study 1 Pass

Study 2 — Excluded from study as patient asked Fellow to stop scanning

Study 2 — Excluded from study as patient asked Fellow to stop scanning

Candidate 16 Vs Expert

Study 1 Pass

Study 2 Pass

Candidate 17 Vs Expert

Study 1 Pass

Study 2 Pass

CHAPTER 7

Discussion

7.1 Introduction

The following were the aims of this thesis which studied teaching basic transthoracic echocardiography (TTE) skills to intensive care doctors known as fellows.

1. **To evaluate a basic echocardiography training course for Irish Intensive Care fellows, using both cognitive and practical assessment.**
2. **To evaluate criteria that course participants need to attain to achieve competency on completion of this course**
3. **To furnish evidence and recommendations to the Joint Faculty of Intensive Care Medicine in Ireland regarding basic level echocardiography training for intensive care fellows**

The results chapter outlines the data generated from January 2014 to July 2016, analysing information from data sheets collated towards the end of each term (20 weeks training).

During the 20 week "hands-on training" period each fellow was given a logbook and from day one they entered data, measurements and a report on the echos they performed. The aim over the 20 weeks was to have 30 cases collated in the logbook (*Appendix 1*).

As the course progressed, so did the logbook. It was evident the fellows were able to fill in the measurement section of the log book accurately and it also demonstrated their ability to write a comprehensive report on their findings – in other words, make a diagnosis. The log book was counter signed by the 'hands-on' tutor who not only tracked the progress and corrected any mistakes, but mainly commented on the technical ability of each fellow for each case. The log book clearly shows progression of the fellows through the weeks and makes a good case for the implementation of a log book as being an essential component of any basic echo course. (Cholley 2011)

7.2 Acquiring Echocardiographic Views

The fundamental requirement for a fellow undertaking a course in critical care transthoracic echocardiography, is acquiring the technical skills that allow the heart to be assessed through the three echocardiographic "windows" on the front of the chest. Assessing competency in the acquiring of these views is a challenging but crucial component of evaluation. (Vignon, 2011)

In the present study we looked at agreement between the intensive care fellow and the expert, the latter being the reference, in acquiring each specific TTE view. In addition, each of the TTE views were graded as excellent, good (which would be considered optimal) and poor (which would be suboptimal). After 20 weeks of "hands-on" training the data indicates a good correlation, between expert and echo fellow, in attaining the standard echocardiographic views available in each "window". The data indicate that fellows did learn to accurately grade image quality, which is a cornerstone in recognising the limitations of TTE in the critical care setting (Salem *et al*., 2008). In some clinical circumstances an alternate diagnostic test (for example Transoesophageal echocardiography or CT scan) may be required.

When the individual standard TTE views acquired were compared (see Chapter 5), the parasternal views (long and short axis), the apical 4 chamber and the subcostal views were most consistently obtained by the fellow.

For the parasternal long axis (PLAX) the expert and the fellow could acquire the view in 90% cases. In only 3 cases did the fellow did agree with the expert. The literature supports that PLAX views is quite easy to acquire on most patients even ventilated patients (Kaddoura, 2016). Once the PLAX view is found there is no need to move the probe in the window. The parasternal short view (PSAX) was acquired by the expert and fellow in 80% of cases. Moving from the PLAX to the PSAX involves rotation and tilting of the TTE probe on the chest wall to obtain three "slices" through this axis of the heart. Therefore, the PSAX view is more difficult for *both* expert and fellow. In five cases the fellow failed to correctly obtain this view. In the critical care environment, finding the parasternal views can be challenging due to surgical chest wall incisions (midline after cardiac surgery), drains, pacing wires and bandages that impede access. The subcostal window becomes an important alternative in this situation. Indeed, it often referred to as the window of first choice in a hypotensive emergency (Arntfield,2011). The subcostal view was found by both fellow and expert 80% of cases. In six cases the fellow could not acquire this view. This has potential important clinical implications, particularly for diagnosing pericardial effusion and cardiac tamponade (Feissel, 2004). The inferior vena cava (IVC) view showed a lower (67%) agreement between expert and fellow. On seven occasions the fellow failed to obtain the IVC view. The reason is similar to the parasternal window as above. The IVC view requires a 90-degree manipulation of the TTE probe which can result in the operator losing the view.   Of note the IVC view is used in the assessment of volume status (Jardin,1997). This diagnosis can also be inferred from the PSAX view (end systolic cavity obliteration ESCO, indicating hypovolaemia). Therefore, there is some redundancy in making the diagnosis of hypovolaemia, in that if the IVC view is not obtained, the diagnosis can still be made if PSAX view shows ESCO. (Repesse *et al*., 2013)

There was 80% agreement in obtaining the apical 4 chamber view, which is reasonable and compares with the subcostal view. In certain critically ill patients, particularly after cardiothoracic surgery (sternal wound, subcostal drains) the apical windows may be the only TTE views available. It is important in the assessment of regurgitant left sided valvular lesions and calculating stroke volume and cardiac output. The latter are a cornerstone in haemodynamic monitoring in critical care. (Bergenzaun *et al*., 2011). It is important to appreciate that proficiency in acquiring this view by the ICU fellow takes a longer time compared to the parasternal and subcostal window; ten – twelve weeks for apical views compared to four – five weeks for the parasternal and subcostal views (*Appendix 1*). The reasons are many and include, the landmark for finding the view is the apex beat which can differ between patients and relates to left ventricular size. Body habitus, including obesity and ironically slim stature (ribs close together) and breast tissue all impact on finding the view (Otto, 2015). The apical five chamber view had a low acquisition rate, only found by expert and fellow in 67% of cases. This view also had the highest failure rate of acquisition (10 cases) by the ICU fellow. Acquiring this view requires tilting the TTE probe, a minor but challenging adjustment that often results in displacement of the probe out of the window.

A period of 40 hours Hands-on training" requires the fellows to achieve competency in obtaining *all* TTE views to ensure flexibility in the difficult critical care environment. On occasions, there may be only one window or view of sufficient diagnostic image quality in a ventilated critically ill patient (Price,2006). In this study, by week 12 of training, this goal was achieved for all candidates. However, it must be recognised that two views (the IVC and the Apical 5 chamber) are particularly challenging in this environment and associated with the highest failure rate with the fellows.

7.3 Discussion on Results of Clinical Domains

The clinical conditions most likely to cause haemodynamic shock in critically ill patients form the basis of the echocardiographic domains that are taught to the ICU fellows. The clinical conditions and their echocardiographic correlates are; left heart failure (poor LV function and dilated LV), myocardial ischaemia (RWMA'S), pulmonary embolism (RV dilatation and function), hypovolaemia (end systolic cavity obliteration and IVC size), cardiac tamponade (pericardial effusion and 2D signs of tamponade) and acute severe left sided valvular dysfunction (severe mitral and aortic regurgitation). (CHEST, 2009).

7.3.1 Left Ventricular Size and Function

Fellows are shown in the "hands-on sessions" during the 20 weeks how to visualize and assess the LV size and function in all echocardiographic views.

In the majority of cases the practical examination had normal LV size and function and results demonstrate this was recognized by the fellows; 60/65 normal LV size and 58/66 normal LV function. Therefore, at the end of six months the fellows achieved competency in assessing *normal* LV size and function. Many cases of abnormal LV function and size were demonstrated to the fellows during the six month programme.

However, at the practical examination, the fellows missed 2 cases of dilated LV and on 3 occasions incorrectly called an LV dilated when it was normal in size. However, the paucity of abnormal cases of LV size limits the assessment of competency in this regard. The numbers of abnormal cases are very small which is a feature of assessing competency in the naturalistic or "real-life" intensive care environment.

There were 6 cases of abnormal LV function of which the fellows correctly identified 2 and missed 4 cases. They also misidentified 2 normal cases as reduced LV function.

Therefore, the fellows did not achieve competency in recognizing abnormal LV function.

One method of mandating an increased exposure to cases of abnormal LV size and function would be to require a defined number of such cases in the echo log book. In the setting of Intensive care practice abnormal LV function is the commonest of haemodynamic shock (Bergenzaun, 2011). Therefore, abnormal function should represent at least 50 % of the echo log book cases. In addition, it is a cause of haemodynamic shock that can be immediately acted on at the bedside if recognized.

7.3.2 RWMA

A RWMA can be difficult to assess, particularly for the untrained eye in the critical care environment, where patients are ventilated. The results show that ICU fellows failed to recognize a RWMA in 17/25 cases where it was present and recognized it in 8 cases. Of the 41 cases where no RWMA was present, the fellows recognized this in 38 cases (3 cases they falsely identified a RWMA).

In general diagnosis of myocardial ischaemia is confounded in the critical care environment, compared with the Acute Medicine (Coronary Care, Medical Ward and Emergency Department settings). For example, the patients are generally sedated and unable to communicate chest pain which is a cornerstone of making the diagnosis. Also, the diagnosis of RWMA required visualization of endocardium, which is difficult in critically ill patients (Bergenzaun,2011). Therefore, diagnosing myocardial ischaemia in this setting never rests on echocardiography alone and electrocardiography and blood tests (cardiac enzymes) are more commonly relied on. Transoesophageal echocardiography allows better visualization in this regard.

The fellow in training must know his/her limitations in relation to RWMA and exercise caution when reporting. They should have a low threshold to call an expert as it is a more advanced area of echocardiography which is evident from these results.

7.3.3 Right Ventricular Size and Function

Right ventricular function can be affected by pulmonary conditions which are common in the intensive care setting. Therefore, it is an important part of a basic echocardiography training programme (Vieillard-Baron, 2002).

The majority of cases in the practical examination had normal RV size and this was recognized by the fellow in 57/65 cases, demonstrating that they achieved adequate competency in this regard. On 7 occasions when the RV was abnormal (that is dilated), this was correctly identified by the fellows on 4 occasions and missed in 3 others. Although this is encouraging, it is not sufficient to achieve competency. The recognition of a dilated RV by TTE, in a critically ill hypotensive patient, might prove lifesaving as it may lead to emergency treatment of a pulmonary embolism or change of ventilation in an ARDS patient with acute cor pulmonale. Therefore, a higher recognition rate is important. However, the incidence of a dilated RV may be low in the critical care environment, even over a six month period. This limits the ability to mandate a fixed number of such cases for an echo log book.

The fellows achieved competency in recognizing normal RV function, correctly identifying 60/64 such normal cases. There was only one case of abnormal RV function, at the time of assessment, which was correctly identified by the fellows. They did incorrectly call RV dysfunction on four occasions. The assessment of RV function is more challenging than LV function as it requires good visualization in three views.

Recognition of RV dilatation, rather than RV dysfunction is clinically the more important part of this domain. Therefore, the echo programme must specifically emphasize this to the ICU fellow. An additional way to achieve competency in recognizing RV dilatation would be to collect and report on all such suggestions/recommendations for programme improvement.

7.3.4 Pericardial Effusion and Tamponade

There were 7 cases of pericardial effusion of which the ICU fellows recognized 4 and failed to recognize 3. On 3 occasions the fellow called a small pericardial effusion when none was present. This was most likely related to the presence of a fat pad, which can be a normal finding at the apex of the heart. There were no cases of cardiac tamponade in the practical examination or indeed during the six months training programme. This scarcity of echocardiographic tamponade among all the echocardiographic domains presents unique challenges to fellows and trainers with relation to achieving competency. The fellows agreed with the expert on 56/58 occasions when there was *no* pericardial effusion. It can be very important to rule out cardiac tamponade in critically ill hypotensive patients.

7.3.5 Tricuspid Regurgitation (TR)

Recognition and interrogation of the tricuspid regurgitation (TR) is a cornerstone of haemodynamic monitoring with echocardiography in critically ill patients. The TR signal is used to estimate pulmonary artery systolic pressure which is frequently elevated in critically ill ventilated patients. The fellows performed very well in this echocardiographic domain; on 33/39 occasions the fellows correctly identified the presence of TR and on 23/26 occasions they identified the absence of a regurgitant signal. Their ease with diagnosing this lesion maybe related to its frequent occurrence;

it was the most common pathology encountered during the 20-week course and in the clinical examination. Tricuspid regurgitation occurs in 70% of the normal population. (Otto, 2015). In addition, the regurgitant jet is travelling into a low pressure chamber (the right atrium) meaning that the extent of the jet, when present, is very apparent to the eye in the images.

7.3.6 Mitral Regurgitation (MR):

Mitral regurgitation (MR), when it occurs acutely, can be one of the causes of a catastrophic haemodynamic collapse, presenting with hypotension and acute pulmonary oedema. In this setting, it is crucial to identify MR, as the treatment requires surgical intervention and the mortality is very high if it is missed. The results demonstrate that fellows did become proficient in identifying MR and did so on 25/29 occasions that it was present in the clinical examination. Likewise, the fellows correctly ruled out MR in 32/36 cases when it was not present. The ability to recognise MR allows the intensive care fellow to “raise the alarm” to the presence of a life threatening and correctable cardiac lesion. Again, the regurgitant jet travels into a low pressure chamber, (the left atrium) where there is no other turbulence, which makes it easy for the eye to identify in the images. In addition, MR can be visualized in *all* transthoracic views taught on this basic course, which further increases the “pick up” rate.

7.3.7 Aortic Regurgitation (AR):

Acute aortic regurgitation (AR) can also cause a sudden catastrophic haemodynamic collapse, although it is not as common as acute MR (Nahush, 2011). In addition, it is often secondary to pathology, for example, aortic dissection or endocarditis. The data in relation to AR were very striking. The fellows correctly identified 6 of the 9 cases where AR was present, and correctly out ruled 47 of the 56 cases where AR was absent, in the clinical examination. However, AR was the clinical domain with highest incidence of false positive findings in the clinical examination by the fellows. On 9 occasions they identified AR when none was present. They were incorrect in identifying the presence of AR more often than they were correct. There are a number of reasons why this may be the case. Firstly, the AR jet is travelling into the left ventricular outflow tract, which is a "busy place" with much turbulent flow. This makes it difficult, using colour flow Doppler, to distinguish different jets and direction of flow through the aortic valve. In addition, AR is a diastolic jet and the duration of the jet will vary with heart rate (diastole decreased as the heart rate increases). Critically ill patients are frequently tachycardic resulting in a shorter duration AR jet compared to an outpatient setting. This is in contrast to systolic regurgitant lesions, which have a consistent duration, regardless of heart rate (systole does not decrease as heart rate increases). Furthermore, as discussed above, acquiring the apical 5 chamber view, which is central for the detection and quantification of AR, is a very arduous process for basic echo fellows.

7.4 Discussion on Results of Exams: Cognitive and Practical

7.4.1 Multiple Choice Questions

Seven fellows answered the 25 MCQ results for Period 1 and Period 2 and all fellows scored the required 70% pass mark. (One echo fellow did not sit the examination, due to work commitments). During Period 3 and 4 when 7 candidates were offered 25 MCQ (T/F) and 10 MCQ (SBA) a difference in results began to emerge as for the first time 2 candidates sat the SBA type of MCQ. When a negative marking system was applied to the 10 MCQ (SBA) during Period 3 and 4, 4 out of the 7 fellows failed. During period 5 when the number of MCQ (SBA) questions increased to 25, of the 4 fellows who took the MCQ exam, 1 failed. When negative marking was applied 2 fellows failed.

The MCQ (T/F) type questions open up an element of blind guesswork in answering the question, therefore not demonstrating true knowledge by the fellow in training. There is a 50% chance of the fellow answering correctly simply by guessing the answer. Traditional MCQ (T/F) questions are useful when testing recall of learned especially numeric type knowledge, for example, the physics of medical ultrasound. However, this style of question does not allow facts to be placed in context or testing the application of knowledge and problem solving that is so essential to critical care medicine.

The question arose during the study whether to continue true or false questions or go forward with MCQ with a single best answer. MCQ can focus on a broad representation of the material covered and so increases the validity of the assessment. The key however is the construction of good questions. Writing an MCQ is time consuming and therefore MCQs may be written without sufficient context. In this study, the questions were set by the course Cardiac Physiologist/ hands-on tutor and validated by the Intensivist who has 20 years' experience in echocardiography and critical care medicine.

Single best answer type MCQ's may be more discriminatory than the T/F format; they allow the candidate to demonstrate that they 'know how' rather than simply 'know a number', and this is a fundamental principle of the assessment of clinical skill. (Tan and McAleer, 2008). Therefore, the SBA format questions are considered more reliable than the previous MCQ (T/F) in determining the knowledgeable candidates.

An excellent discussion, by Holsgrove (2001), discusses some of the problems associated with negative marking. In fact, negative marking is in a way a test of the candidate's personality; that is it tests their confidence in venturing an answer that they are less than 100 % sure about. It can be argued in the clinical environment that the fellow should be in a position to trust their knowledge enough to commit to an "answer" or clinical course of action. Otherwise they do not functionally possess the knowledge. However, there is a possibility that students may possess the knowledge and be able to demonstrate it in the critical care environment but are so nervous about the prospect of losing marks in an exam that they adopt a cautious strategy. Another study (Hammond, 1998) discuss how negative marking is used to discourage guessing but they found that this concept is perhaps not clearly understood by candidates and once again the decision whether to attempt a question, even when negative marking applies, varies between individuals.

The National Board of Medical Examiners in the USA and the Joint Committee of Intercollegiate Examinations for Surgery in the UK recommend SBA format in their exams, which have been shown to be superior to other formats such as true and false. They also note that negative marking does not improve validity or reliability (Case, 2001, Chandratilake *et al*., 2011). For example, in the present study, when negative marking was applied during periods 3 – 5, more than 50% (6/11) of the candidates failed the MCQ section of the examination, but only one failed the entire examination process. The failure rate with negative marking was clearly disproportionate to overall results for the fellows.

RCSI exit exams use MCQ but no negative marking is applied. Negative marking is not used in the MCQ for the FCAI exams for Anaesthetists.

7.4.2 Video Cases

The video cases section of the written exam had a 100% (18/18 fellows) pass rate through periods 1-**5.** The individual scores were almost always higher than for the MCQ section. The video section exam comprised of showing the candidates a video with a particular pathology and case history and they were then given 5 true or false questions on each video. The question arises whether the 100% pass rate obtained is due to knowledge element of guess work arising once again. The higher individual mark achieved by each candidate (13/18 candidates score > 80% vs 7/18 candidates for the MCQ section no negative marking), suggests that video type examination is easier for candidates.

There is a paucity of literature with regard to this type of examination. However, all Accreditation Bodies; British Society of Echocardiography (BSE), the European Society of Echocardiography (ESE), the American Society of Echocardiography all have a mandatory video section both in their examinations. In addition, they use the single best answer, no negative marking, for the video case section of the exam which suggests this is a more discriminatory way of examining. This may be a recommendation for the current training programme in the future.

7.4.3 Practical Examinations

A practical exam is a fundamental component of any basic echo training course, as it is the only way of truly assessing the technical ability of the fellow. The exams were carried out on critically ill patients by the Consultant Intensivist (reference) and each echo fellow. In addition to testing technical skills, this part of the examination created the new issue of missing an important clinical diagnosis, which could have serious clinical implications and thereby incurring a “fail” mark for the echo fellow.

For example, during Period 1, an echo fellow missed a diagnosis of a dilated RV in a collapsed patient which means an important diagnosis such as pulmonary embolism or acute cor pulmonale could potentially be overlooked (Beaulieu, 2014). During Period 2 - 5, all 4/16 fellows failed the practical exam. All failed on the same pathology – they diagnosed AR when it was not there – on different patients. Aortic regurgitation (AR) can be very challenging to diagnose and indeed assess on echo. It requires good visualization of the aortic valve in all views but to fully assess using colour and continuous wave doppler, the apical 5 chamber view is probably the best. As we can see from the results of acquiring the views, the fellows found the apical 5 chamber view challenging. In the apical 5 chamber view we also see the left ventricular outflow tract (LVOT), which, when colour doppler is applied, can appear 'noisy' and can cause changes on the colour doppler signal similar to that from aortic regurgitation. Aortic regurgitation is one of the lectures included on the training programme but full assessment of AR requires more advanced measurements such as vena contracta, pressure half time, jet width geometry and regurgitant orifice areas (Otto,2009) - measurements which are beyond the scope of a basic echo course. It is clear they picked up flow from colour and doppler assessment that was not actually from the valve but instead turbulent flow in the outflow tract, and this can be common to the less experienced sonographer. This has not been reported on before in the echocardiography literature, although diagnosing AR is considered a competency in Basic Critical Care Echocardiography. (Chest.2009)

Some centres have used echo simulators to assess technical skills. (Beraud *et al*., 2013), when implementing a curriculum for focused echo in the critical care setting, used a simulator in the practical element of the exams. In addition to assessing the fellow's performance in clinical scenarios; they also recorded the time taken to make a diagnosis and the accuracy of the diagnosis. The evaluation on 'real' cases in their study was taken from the last three recorded routine echos (log book cases) the fellows performed on critically ill patients. These were reviewed and considered satisfactory if they were able to visualize the LV and RV, the pericardial space and the IVC and assess them satisfactorily. The present study would support this approach. The individual echo fellows log book in the weekly training clearly demonstrated each fellow's *technical* ability which was shown to improve week to week.

While the international statement on training standards for critical care ultrasound (Cholley, 2011) or indeed the CHEST consensus statement (Mayo,2009) promote training programmes and how to achieve competency in echocardiography, a stand-alone practical exam does not seem to play a big role in their assessment but instead they are assessed on an ongoing basis. Practical assessment is however, a crucial part of the whole accreditation process in the British Echo and European echo societies.

7.5 Study Limitations

A limitation to this study was the number of fellows and of patients. There were 19 fellows over a 2.5 year period and 66 patients were scanned. However, each fellow also performed and reported on a further 30 cases in the logbooks so that the numbers add up to 570 cases performed.

Another limitation of this course was when analysing data, it was difficult to assess fully on valvular function which is graded by mild, moderate and severe. However, to allow binary statistics, it was only possible to see if the expert and fellow agreed on the presence or absence of *any* degree of valvular regurgitation. Similarly, it proved difficult to assess fully an agreement of whether the chamber size was mildly dilated, moderately dilated or severely dilated or whether chamber function was mildly impaired, moderately impaired or severely impaired. Again, the fellows would need to be able to grade these conditions correctly and this was perhaps not shown fully on this study. It should be noted at this point that grading of a leaky valve or grading of the function of the right and left ventricle does improve with experience but also may require the doctor continuing to a more advanced level of echocardiography in order for them to learn how to assess these conditions in more detail.

It was unusual in an intensive care setting not to have more cases of pericardial effusions or tamponade – both important pathologies which any doctor should recognize when performing an echo. It simply comes down to the fact that for the two hours a week in the hands-on training programme there were no patients who had these conditions. This was another limitation of the data collection. Therefore, it is recommended that the log book not only contain 30 cases in general, but instead break down the log book into various pathologies required for the intensive care doctor. So, for example, the logbook should contain a certain number of normal studies, a certain number of patients with a pericardial effusion, a certain number with tamponade and other specific pathologies outlined in the course. As mentioned previously, the logbook is an extremely useful tool in the assessment of these doctors in training and so should be optimized and developed fully for any basic echo course.

7.6 References

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CHAPTER 8

Conclusion

8.1 Conclusions

It is concluded that;

- Forty hours of hands-on training, 10 hours of lectures, 30 log book cases and written and practical examinations are the minimum training components that echo naive critical care doctors require to learn BCCE.
- The study has evolved over the various periods and has improved based on feedback and evaluation. For example, more hands-on training, shorter but more focused lectures and revision material.
- The programme as it now stands is on a par with international best practice in this area of Intensive Care training. (Referenced throughout thesis - Australian and New Zealand Intensive Care Societies, European Association of Echocardiography and International Statement of Training Standards).
- The study has shown that the use of MCQ SBA is a more appropriate assessment tool when examining fellows at the written exams rather than MCQ True/False mode.
- The study has identified Aortic Regurgitation as a specific pathology that is difficult to learn.

8.2 Recommendations

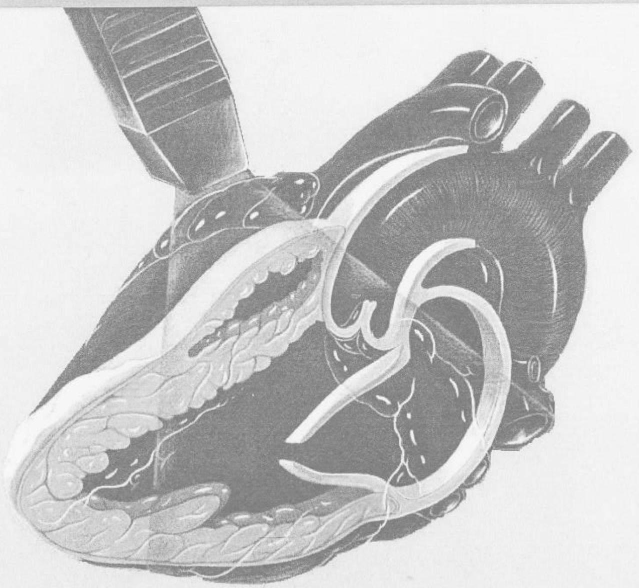
It is recommended:

- Some uncommon pathologies such as cardiac tamponade will require additional video case examples or simulator training to ensure competency in their diagnosis.
- Due to the difficulty in assessing AR, this needs to be highlighted at all parts of training and again mandate a series of 10 examples of AR required viewing for all echo fellows.
- That every 6 months the doctors would be reassessed – perhaps in the form of a practical exam, to re-evaluate their skills, e.g. ACLS etc.
- That a national certification for this basic echo course for intensive care fellows be implemented.
- That a panel of examiners be formed rather than just a single examiner as in this study.
- That submission be made to the Joint Faculty of Intensive Care Medicine in Ireland that a basic echo course such as the one carried out in the MMUH be accepted and validated as part of the curriculum for an intensive care fellow in training in Ireland.
- Those who fail the assessments should only conduct scans under supervision until such time as they successfully pass all aspects of the assessment.

APPENDIX 1

LOGBOOK

Mater Misericordiae
University Hospital



Critical Care Echocardiography
Basic Level

Mater Misericordiae
University Hospital

SE STUDY 9 Date of Study ___/___/______

ent Initials C.L. MRN: [ ] Date of Birth: ___/___/___

cation: POST CARDIAC ARREST

ɔcactive medications: ...

liac history: ...

:hm: ___ BP: ___ CVP: ___ PAP ___ Demographic data: ___

dows: PLAX [ ] PSAX [ ] APICAL 4-C [ ] SUBCOSTAL [ ]

ʌMBERS:

Ventricle:

ɔd ______ mm IVS ______ mm PW ______ mm

... Function: ...

ional Shortening: ... Ejection Fraction % ...

motion abnormalities: ...

' Diameter ___ mm LVOT VTI ___ cm² Stroke Volume ___ ml

: Ventricle:

... Function: ...

motion abnormalities: ...

ʌtrium Size: ... **Right Atrium Size:** ...

'ES:

: Valve: ...

I Valve: ...

pid Valve: ...

ɔnary Valve: ...

:ARDIUM: Fluid/Clot: ...

ME STATUS:

ameter: ...

:T SUMMARY: ...

me/Management: ...

Quality [ ] *Optimal = 1, Suboptimal = 2, Inadequate = 3*

ə Signature: ______ Supervisor Signature: ______

Calculations:

Grossly reduced LV function

Antero-septal Akinesia

EF ~ 20%

Mild mitral regurg. c/w valve intact

No pericardial effusion

Comments

Excellent PLAX / SAX views identified extensive pump

Good apical & subcostal views

Visually assessed EF.

APPENDIX 2

FACULTY

Faculty Basic Critical Care Echocardiography Course 2017

1. Professor Frances Colreavy;

   Consultant Intensivist

   Mater Misericordiae University Hospital

2. Ms Róisín O'Mahony

   Chief Cardiac Physiologist

   Connolly Hospital

3. Professor Jim O'Neill

   Consultant Cardiologist

   Connolly, Mater Misericordiae University Hospital

4. Mr Gerard King

   Chief Cardiac Physiologist & DIT Lecturer

5. Ms Karen Cunningham

   Senior Cardiac Physiologist

   Mater Misericordiae University Hospital

APPENDIX 3

ETHICS

Mater Misericordiae University Hospital
Sisters of Mercy
Eccles Street, Dublin 7, Ireland

Ospidéal Ollscoile Mater Misericordiae
Siúracha na Trócaire
Sráid Eccles, Baile Átha Cliath 7, Éire

Tel: +353 1 8032000 Fax: +353 1 8032404 Email: mmh@mater.ie Web: www.mater.ie

Not for prescription purposes

Dr Frances Colreavy
Consultant in Intensive Care Medicine
Mater Misericordiae University Hospital
Eccles Street
Dublin 7

21st November 2013

Our Ref: 1/378/1596

RE: Validation of a focused transthoracic echocardiography training programme for Irish Critical Care Doctors
Research Protocol

Dear Dr Colreavy

The Mater Misericordiae University Hospital and Mater Private Hospital Research Ethics Committee (REC) at its meeting of Thursday 21st November 2013 discussed the above research study to be carried out the Mater Misericordiae University Hospital (MMUH).

This research study was approved to proceed at the MMUH; this approval is valid until 21st November 2015. The REC agreed that obtaining informed consent for this research study is not necessary; as such a waiver of consent is granted.

It is your responsibility to adhere to the approved study protocol and ensure that all investigators involved with the research only use the approved documents without deviation (unless they have been approved by the REC), to submit annual reports setting out the progress of the research and to notify the REC when the research is concluded.

The Mater Misericordiae University Hospital and Mater Private Hospital Research Ethics Committee would like to remind all investigators involved in research of their legal obligations under the law on Data Protection.

Yours sincerely

Mr Malcolm Kell
Chairman
Research Ethics Committee

c.c. Ms Roisin O'Mahony, Chief Cardiac Physiologist, Department of Intensive Care Medicine, Mater Misericordiae University Hospital

'Commitment to Excellence'

APPENDIX 4

EVALUATION SHEET

Joint Faculty of
Intensive Care Medicine of Ireland

Basic Critical Care Echocardiography Evaluation Form

May 14th 2015 - Day 1

	Excellent	Average	Poor
Standard views – how to acquire / scan *Ms Roisin O'Mahony*	☑	☐	☐
Knobs & Knobology: Live demonstration *Dr Gerard King*	☑	☐	☐
Echocardiography in the haemodynamically shocked patient *Dr Frances Colreavy*	☑	☐	☐
Assessing fluid responsiveness using *Echocardiography* *Dr Rajiv Rooplalsingh*	☐	☑	☐
'Hands-on Training' – How to scan *Dr Colreavy, Ms O'Mahony, Dr King, Ms Cunningham,*	☑	☐	☐

Have you previously attended an echocardiography course in Ireland or outside of Ireland? Please give details no

How much experience do you have with TTE?

some

Additional comments:

v good

Thank you.

APPENDIX 5

DATA COLLECTION SHEET

DATA COLLECTION SHEET

Validation of a Focused Transthoracic Echocardiography Training Programme for Irish Critical Care Doctors.

Study No.

Principal Investigator : Roisin O'Mahony

Please return to Ms Margaret Kellet, Dept of Intensive Care Medicine, Mater Misercordiae Hospital, ph 8032763.

Date - **Fellow -**	**Duration of scan –** **Intensivist -**

Heart Rate	**Rhythm**	**BP**	**Weight**
bpm		**/**	**(kgs)**
APACHE II Score			
Indication for TTE -			
Admission diagnosis			
Mechanical Ventilation	**Yes / No**	**Tidal Volume**	**PEEP**
Inotrope		**Dose**	
Vasopressor		**Dose**	

Acoustic windows obtained : ***(please tick)***

Parasternal Long Axis View	**Yes**	**No**
Parasternal Short Axis View	**Yes**	**No**
Apical 4 chamber View **Apical 5 chamber View**	**Yes** **Yes**	**No** **No**
Subcostal View **IVC**	**Yes** **Yes**	**No** **No**

Image Quality (*please tick*)

Poor ( ) (< 50% identification of LV endocardial borders)

Good ( ) (>50% identification of LV endocardial borders)

Excellent ( ) (identification of full endocardial borders)

Clinical question answered Yes No

Change in management resulting from TTE Yes No

LV size (*please tick)*

Normal – (4.2cm – 5.9cm)	
Mildly dilated – (6.0cm – 6.3cm)	
Severely dilated – (>6.9cm)	

LV function (*please tick)*

Normal – Ejection Fraction >55%	
Moderately reduced – EF 30 – 50%	
Severely reduced – EF <30%	

RWMA Yes No

If yes, please specify which wall/walls -------------------------------------

--

RV Size Diastole (*please tick)*

Normal	
Dilated – (A4C mid RV >3.5cm)	**cm**

RV function

Normal	
Reduced	

IVC Size ***(please tick)***

Normal **Dilated (end expiratory diameter > 2.3cm)** **IVC respiratory variation – (IVC distensibility >12%)**	**Yes No** **Yes No** **Yes No**

Please circle the following

LV end systolic cavity obliteration + hyperdynamic motion YES NO

Pericardial Effusion -	**Yes No**
If 'yes' please state size of effusion -	**Mild Moderate Large cm**
Tamponade -	**Yes No**

VALVE FUNCTION – ***(please circle)***

Mitral regurgitation Mild Moderate Severe

Tricuspid regurgitation Mild Moderate Severe

RVSP plus CVP mmHG

Aortic regurgitation Mild Moderate Severe

(Visual assessment of regurgitant jet width and length).

COMMENTS

APPENDIX 6

RECOMMENDATIONS TO JFICMI

JFICMI Basic Critical Care Echocardiography (BCCE)

2017

Introduction

The "International expert statement on training standards for critical care ultrasonography" position paper published in Intensive Care Medicine 2011 set a standard that *"basic critical care echocardiography [basic CCE] should be mandatory in the curriculum of intensive care unit (ICU) physicians. It is the role of each critical care society to support the implementation of training in GCCUS and basic CCE in its own country".*

There are certain challenges around this, including the limited numbers of potential mentors and limited ICM modular training time. Over recent years there has been considerable expansion of TransThoracic ECHO performed by Intensivists in Ireland with an expansion therefore in the potential mentor base. In parallel with this there has been an expansion in availability of suitable Echo machines. Other jurisdictions have been presented with similar challenges and the FOCUSED INTENSIVE CARE ECHOCARDIOGRAPHY (FICE) addresses some of these. In particular, this JFICMI Education and Training Committee proposal has adopted the mentor solution of the FICE programme (see below). The level of competency to be achieved is derived from the CoBatrice Coba Echo domains.

The JFICMI shall provide for recognition of Basic CCE at defined training sites. Certification at such sites shall support the ability of a candidate to progress to advanced CCE training and accreditation, including the new ESICM EDEC accreditation process which has an entry requirement of certification in basic CCE, and hence an imperative the JFICMI develops such a programme.

Candidates:

- Candidates are registered JFICMI trainees
- Consultants with an Interest in Intensive Care Medicine
  Consultants in Intensive Care Medicine.

Course:

All candidates must attend a recognized Basic Echocardiography course within 12 months of first logbook entry. The JFICMI is happy to review and approve national and international basic CCE. This is usually a 2 day course with a combination of didactic lectures (approx. 10 hrs), clinical examples and hands-on training with volunteers.

Hands-On Training:

Although sites may vary, hands-on training is likely to be modelled on a 6-months 2 hours/week "Hands-on" formal instruction (approx. 40hrs) and mentored personal experience over the same period.

Mentors and Supervisors:

Each approved basic CCE training site shall be able to provide Mentors for the candidates and Supervisors for both mentor and candidate.

(a) Mentor

- Shall have suitable experience and regular practice in Critical Care Echo.
- Where he/she does not hold a recognized certificate in cardiac echocardiography, shall have access to a supervisor for overview of the training provided and for review of difficult cases.

(b) Supervisor

- Shall have a recognized national or international accreditation in echocardiography.
- Shall have suitable experience and regular practice in critical care echo.
- Shall provide oversight, support and on-going training to both mentor and candidate (e.g. Peer review sessions).

Logbook

- Candidate must detail their basic CCE exams in a logbook (model format attached) and submit 30 cases for review by their Mentor.
- The logbook must be representative of the Image Acquisition and Interpretation > Knowledge domains as per Coba Echo (see below).
- The logbook should reflect some cases of RWMA, Valvular abnormality, pleural effusion, hypovolaemia etc, some of which may require a training relationship with other aspects of the hospital outside ICU depending on case-mix – e.g. Cardiac Echo Department / technicians, cardiology, cardiac theatres etc.

Exam

All candidates must complete a short exam to be devised by the JFICMI comprising MCQs and video-loops. This aspect of the training process shall be managed by the JFICMI to ensure consistency of training across sites. The fee shall be kept notional.

Basic Echocardiography Training Programme

Instrumentation

Knowledge

- Lecture 'How to optimize the standard Echo image' or 'Knobology' should incorporate enough physics to use any Echo machine.
- Infection control precautions
- Care of the ultrasound machine including cleaning (transducer head special cleaning agent etc.)

Skills

- Select appropriate ultrasound transducer
- Use conductive gel to aid transmission of ultrasound wave
- Correctly adjusts depth, gain and focus position
- Identifies common artifacts

Functional approach to Echocardiography training incorporating cognitive & technical training.

For example: Mater Misericordiae University Hospital (MMUH) Basic Echo Training over six months

Months 1-2:

- Reliably acquire standard views
- Recognise whether image is adequate or not
- Identify normal and abnormal findings
- Interprets Echo findings with respect to cardio-respiratory support at time of imaging (e.g. level of vasoactive medication, IABP)

Months 3-6:

Recognise the echocardiographic features of the following syndromes:

- LV global dysfunction including cardiomyopathies
- RV dilatation and dysfunction including including acute Cor Pulmonale (Pulmonary Embolism, ARDS)
- Regional Wall Motion Abnormalities (hypokinesis, akinesis)
- Hypovolaemia (IVC diameter and relationship with respiratory cycle spontaneous breathing and ventilator support. LV end-systolic cavitary obliteration)
- Pericardial Effusion including cardiac tamponade (RA & RV collapse)
- Recognise how to differentiate pericardial from pleural fluid Severe mitral regurgitation and severe aortic regurgitation

Additionally recognize:

- Severe calcification of the Aortic Valve
- Aortic dilatation or dissection flap in the ascending aorta

Incorporate findings with clinical picture and communicate findings:

- Start treatment, organize subsequent investigations and reassess impact of initial treatment
- Special situation: Relationship between conduct of peri-arrest Echo and the Advanced Life Support (ALS) Algorithm

Understand the indications for and limitations of Basic Echocardiography training and Transthoracic Echocardiography in general

- Some conditions better visualized using Transoesophageal Echocardiography e.g. Mitral Regurgitation due to Papillary muscle rupture, Aortic Pathology, poor image quality
- Indications for immediate expert assistance, subsequent comprehensive Echo accredited practitioner or need for alternative investigation
- Echocardiographic findings in PE usually indirect
- Finding of left sided Valvular Regurgitation, possible AS requires advanced TTE assessment

Patient Safety & Governance

Format of standard Echo report

- Importance of entering patient information, capturing images and uploading study to appropriate archiving system
- Need to quality assure Echo reports
- Relevance of Date Protection Act to image storage

References:

1. International expert statement on training standards for critical care ultrasonography. Expert Round Table on Ultrasound in ICU. Intensive Care Med (2011) 37:1077-1083

2. Focused Intensive Care Echocardiography (FICE) http://www.ics.ac.uk/ICS/fice.aspx

3. ESICM CoBatrice: http://www.esicm.org/education/cobatrice.