

Can echocardiography naïve medical personnel obtain adequate standard echocardiographic images in athletes after a single day of training, for the purpose of pre-participation echocardiography?

Dr Victoria Sarah Stephen

A research report submitted to the Faculty of Health Sciences, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of

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DECLARATION

I, Victoria Sarah Stephen, declare that this research report is my own work. It is being submitted for the degree of Master of Medicine (Emergency Medicine) in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.



10/11/2016

DEDICATION

This work is dedicated to Allan Beuthin.

PUBLICATIONS ARISING FROM THIS STUDY

None at present.

ABSTRACT

Objectives: To determine if echocardiography-naïve doctors could obtain images adequate for pre-participation screening after a single day of training.

Design: A Prospective longitudinal study

Setting: Helen Joseph Hospital Emergency Department

Study Population: Doctors with no previous training in echocardiography

Methods: Twenty-six doctors were trained to perform pre-participation screening echocardiography during a one day course. Six weeks later, 21 participants were assessed again to assess skill retention. The images were analysed and given a diagnostic adequacy score. The time taken to perform the images was also evaluated.

Main Results: The top six participants obtained adequate images for screening 93% of the time after the initial training. Considering the group overall, 63.4% of all the images were adequate after training. The video clips were more adequate than the still images, $p < 0.0001$, of which 77.9% were adequate. The proportion of adequate images decreased to 48.4% at follow-up, $p = 0.034$. The median time obtained by the participants for all views after training was 40 seconds and after follow-up was 60 seconds, the difference of which was not significant, $p = 0.12$.

Conclusions: It is feasible to use novice sonographers to perform pre-participation screening echocardiography provided that the skill of candidates is assessed after training and competent individuals are selected. Video images should be used rather than still images. Refresher courses should be provided between sessions as the degree of loss of skill is significant.

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NOMENCLATURE

Abbreviations

A4C – Apical four chamber view

A4C RV – Apical four chamber view optimised for the right ventricle

ARVC – Arrhythmogenic right ventricular cardiomyopathy

Echo – Echocardiogram

ED – Emergency department

eFAST – extended focus assessed sonography in trauma

EM – Emergency medicine

FATE – Focus assessed transthoracic echocardiography

FEEL – Focused echocardiography entry level

FTTE – Focused transthoracic echocardiography

HCM – Hypertrophic cardiomyopathy

ICU – Intensive Care Unit

ITER – In-training evaluation report

OSCE – Objective Structured Clinical Examination

PLAX – Parasternal long axis

PSAX – Parasternal short axis

PSAX AV – Parasternal short axis view at the aortic valve level

PSAX MP – Parasternal short axis view at the mid-papillary level

SCA – Sudden cardiac arrest

SXC – sub-xiphoid four chamber view

TTE – Transthoracic echocardiography

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Chapter 1 INTRODUCTION

Motivation and rationale for this research

The incidence of Sudden Cardiac Arrest (SCA) during sport and athletic activities is increasing worldwide (1). Sport is becoming increasingly competitive with athletes performing competitively at a younger age. Consequently, it has become imperative to improve the detection of potentially lethal cardiac conditions prior to the participation of athletes in major events. Much research has taken place to determine which methods of screening are appropriate to detect such conditions. Recently echocardiography has been recognised as an important tool in screening. However access to echocardiography expertise is limited, particularly in the resource limited setting of South Africa. Attention has therefore been turned to echocardiography training beyond the scope of the traditional cardiology setting to help improve access.

It is unknown whether echocardiography-naïve medical personnel can obtain adequate images on athletes through limited training in basic echocardiography which could then be evaluated and interpreted by a relevant specialist. It is also unknown how long it takes these individuals to acquire the skill of basic echocardiography and to what degree this skill is retained. If it were possible to train individuals to obtain images of sufficient quality, a significant number of athletes could potentially undergo pre-participation screening in the future. The specialist reviewing the images could “red flag” suspected cardiac pathology and

then the athlete could undergo further investigation. Pre-participation echocardiography, performed by non-cardiologists, would be cheaper to perform, allowing only those high-risk athletes detected on pre-participation screening to undergo formal, in-depth echocardiographic evaluation. This limitation of cost and appropriate usage of specialist resources is desirable in a resource limited country such as South Africa, while still allowing athletes to receive pre-participation screening and hence enabling a reduction in the tragic occurrence of untimely death on the sports field. This study was undertaken to investigate whether echocardiography naïve medical personnel could, through a limited training programme, produce adequate imaging for the purposes of pre-participation screening of athletes.

Statement of the problem

It is unknown if echocardiography-naïve individuals can obtain adequate standard echocardiographic images after a single day of training, and whether these images could be of adequate quality to be interpreted by a qualified echo specialist, who could perform further formal investigation on those subjects with features concerning for pathology. The degree of retention of the skill of echocardiography after training is also unclear.

Aim and objectives

Study aim

To establish whether echocardiography naïve medical personnel can obtain adequate standard echocardiographic images after a single day of training, for the purposes of pre-participation echocardiography for athletes.

Study objectives

1. To describe the diagnostic adequacy of images generated and the time taken by echocardiography-naïve medical personnel after completion of a training session.
2. To compare the adequacy of still images to video images obtained during the assessment.
3. To compare the adequacy of the different views to assess if a particular view was more difficult to achieve than others.
4. To compare the degree of knowledge and skill retention of the participants through a follow-up testing session six weeks after the training session.

Chapter 2 LITERATURE REVIEW

Incidence of sudden cardiac arrest (SCA) in athletes

Research from several countries has described the incidence of SCA in athletes. Maron et al (1) examined the US National Registry of Sudden Death in Athletes which recorded 1866 deaths over a period of 27 years, from 1980 to 2006 in the United States of America. They included athletes who were less than 40 years of age, and who had suffered SCA related to participation in sport. Cardiovascular causes were then examined specifically. Of note, the rate of reporting SCA increased by 6% a year with more events being reported in the latter half of the period studied than the earlier half. Sixty-nine percent of the cases occurred between 1994 and 2006, while only 31% of the cases occurred from 1980 to 1993. Whether this increase was due to improved reporting or due to an actual increase in incidence is not known. The increased incidence could be related to the increased number of individuals participating in sport.

Death attributed to cardiovascular causes was sought. One thousand and forty-nine (56%) of the total 1866 were found to be due to a cardiovascular disease. The mortality rate was calculated as 0.61/100 000 person-years. Overall, the majority (89%) of athletes experiencing SCA were male. However, the number of female athletes experiencing a SCA increased over the study period. The highest incidence was reported in the final six years of the study period, from 2000-2006.

Corrado DI et al (2) studied the incidence of SCA amongst athletes in Italy, specifically in the Veneto region. An incidence of 2.1 per 100 000 athletes per year was reported in this study.

Causes of sudden cardiac arrest

There are many causes of sudden cardiac arrest occurring during sport, some of which depend on the age of the athlete and the geographical distribution (3). In athletes younger than 35 years of age, the most common causes of SCA are due to congenital heart disease (CHD), which may not have been previously diagnosed. Congenital heart disease can be either structural or arrhythmogenic in nature, or a combination of the two.

A common cause of structural congenital cardiac disease is hypertrophic cardiomyopathy which is responsible for greater than one-third of SCA in most studies (4). Other causes include congenital coronary artery anomaly, Marfan's syndrome, mitral valve prolapse, arrhythmogenic right ventricular cardiomyopathy and congenital aortic stenosis. Arrhythmogenic abnormalities include ion channelopathies that predispose to fatal dysrhythmias such as Wolff-Parkinson-White syndrome, the Brugada syndrome, and congenital long QT syndrome. Non-congenital causes of SCA in athletes include myocarditis, drug induced dysrhythmias and premature atherosclerotic coronary artery disease (5). The causes of myocarditis are myriad; which include infective causes, drugs, postpartum and auto-immune mediated myocarditis. Drug induced dysrhythmias

can be caused by physician-prescribed medications or by performance enhancing drugs illicitly used by the athlete (6).

In athletes over the age of 35, the most common cause of SCA is atherosclerotic coronary artery disease; very often which has not been clinically suspected or diagnosed (4). Several studies describe the combination of intense, strenuous physical exercise with underlying unrecognised heart disease as being the cause of sudden cardiac arrest on the sports field (4,6).

There is some geographical variation in the causes of SCA. For instance, hypertrophic cardiomyopathy is the commonest cause of SCA amongst athletes in the United States of America followed by congenital anomalous coronary arteries and myocarditis (6). Studies performed in Italy have shown that arrhythmogenic right ventricular cardiomyopathy is the commonest cause of SCA in that country, followed closely by premature atherosclerotic coronary artery disease (2). The geographical variation has been suggested to be due to the different genetic composition of the different populations. Corrado et al (2) have also proposed that the reduced incidence of HCM found amongst Italian athletes in their study may be due to individuals with HCM being excluded from sport due to the pre-participation screening that had already been in place in Italy for many years.

Methods of detection of SCA causes through pre-participation screening

Pre-participation screening involves methods investigating an athlete in an attempt to diagnose conditions causing SCA prior to participation in sport, with the aim of potentially preventing SCA in these individuals. Several methods of pre-

participation screening have been investigated and employed. These include history and physical examination, resting electrocardiogram (ECG) screening, stress ECG testing and echocardiography. A variety of these methods is employed by sports governing bodies depending on the guidelines followed and the financial resources available (6). The American Heart Association (AHA), the International Olympic Committee (IOC), and the European Society of Cardiology (ESC) have published different recommendations for pre-participation screening.

History and physical examination

The AHA screening guidelines, known as the 12-Element AHA Recommendations for pre-participation cardiovascular screening of competitive athletes, comprises of a medical history and physical examination (6). The 12 elements consist of eight questions on personal and family history and four physical exam findings.

Symptoms such as chest pain on exertion, syncope or near syncope on exertion are sought. Pertinent to the family history; whether a close relative has suffered from an unexplained death below the age of 50 and whether any genetic heart disease is known in the family is asked. On physical examination, BP is measured and noted if elevated. Stigmata for Marfan's disease and cardiac murmurs are sought. Radio-femoral delay is sought to detect coarctation of the aorta. Any abnormal factors detected in an athlete using this screening tool would compel the athlete to be subjected to further investigation by a cardiologist to diagnose or exclude cardiac disease.

However, it has been noted that the AHA recommendations are implemented poorly in actual practice. (7) For example, only 26% of college athletic departments employed forms containing at least nine of the 12 elements of the AHA recommendations. There is a lack of standardisation of how the AHA recommendations are implemented; for instance, some departments employed nurse practitioners and athletic trainers to perform the screening, instead of doctors. When doctors performed the pre-participation screening, only five percent had received specific cardiovascular training.

Pre-participation screening incorporating the use of an ECG

The IOC and ESC stipulate that a resting ECG is to be included in the pre-participation process for all athletes, along with the history and examination. These committees included the ECG as part of their screening programs based on data obtained from the Italian pre-participation screening programmes, which demonstrated a reduction in incidence of SCA after the inclusion of the ECG in its screening programme (8). Conditions such as hypertrophic cardiomyopathy, congenital long QT syndrome, Wolf Parkinson White syndrome and others were detected on ECGs performed on Japanese children during a screening programme that including a history, physical exam and ECG (8).

The inclusion of the ECG in pre-participation has been a topic of much debate (8,9). The AHA for instance, has been reluctant to include the ECG in its recommendations for pre-participation screening, citing cost and impracticality as reasons. The ECG does have its disadvantages. For instance, in studies

examining ECGs performed on athletes, many false positives were found, thus increasing the number of athletes undergoing unnecessary formal investigation (8). Examples of false positives included benign early repolarisation, sinus bradycardia, voltage criteria for left ventricular hypertrophy and incomplete right bundle branch block, which reflect the physiological changes induced by strenuous exercise and are not in themselves pathologic, a condition which is known as Athlete's heart.

Findings on ECG that are concerning for underlying cardiac pathology include: complete right or left bundle branch block, right ventricular hypertrophy, right atrial or left atrial hypertrophy, widespread T wave inversions, and pathologic Q waves. In some studies, athletes with abnormal ECG findings turned out to have normal echocardiograms, whereas those with cardiac abnormalities who were at risk of SCA had normal ECGs (8). Certain cardiac anomalies are also not visible on ECG, such as congenital coronary artery anomalies (9).

In an attempt to restrict the rate of false positives in ECG screening, several interpretation criteria have been proposed. Corrado et al published guidelines which differentiate ECG findings as either training-related or training-unrelated; training related being benign findings related to physiological conditioning and training unrelated being pathological findings which could indicate either structural or arrhythmogenic cardiac disease (10).

Pre-participation screening incorporating echocardiography

As it has been recognised that current pre-participation screening methods do not detect all cases of SCA (6); attention has thus been turned to more sophisticated modalities, such as 2-dimensional echocardiography, in order to improve the rate of detection. This has been found to improve diagnosis of various diseases such as hypertrophic cardiomyopathy (11). On 2-D echocardiography, a small left ventricular chamber size, left atrial and left ventricular hypertrophy suggest this diagnosis. Hypertrophic cardiomyopathy can also be detected by measuring the septum to free wall ratio; a ratio greater than 1.4:1 is suggestive of the diagnosis (12).

Aortic stenosis and mitral valve prolapse can be detected by the presence of abnormal valve morphology, colour Doppler and continuous wave Doppler measurements. Marfan's syndrome is characterised by the presence of aortic root dilatation and a bicuspid aortic valve which can be recognised with 2-D echocardiography (11). Left ventricular hypertrophy can also be readily detected and quantified on echocardiography.

Arrhythmogenic right ventricular cardiomyopathy echocardiographic findings include a right ventricular outflow tract of greater than 30 mm in diastole, regional wall motion abnormalities involving the right ventricle, an abnormal trabecular pattern in the right ventricle, a hyper-reflective moderator band and right ventricular dysfunction (13).

Athlete's heart is detected through echocardiography and has the following characteristics: increased left and right ventricular volumes, increased left ventricular wall thickness and muscle mass and increased left atrial size with a normal ejection fraction (14).

Recent studies have investigated the utility of echocardiography in pre-participation screening. The Early Screening for Cardiovascular Abnormalities with Pre-participation Echocardiography (ESCAPE) protocol was developed by a research group in Stanford, California (15). This was a basic echocardiography protocol which was designed to detect the most common diseases associated with SCA in athletes in the US, such as hypertrophic cardiomyopathy, left ventricular dilatation and a dilated aortic root. Only one view, the parasternal long axis (PLAX) view was used in this protocol. This view was used to determine the left ventricular internal diameter, the left ventricular posterior wall thickness, interventricular septal wall thickness and aortic root diameter. It took on average 7 minutes to perform the scan. Sixty-five college athletes were enrolled in the study.

The aim of the study was to determine how many athletes screened positive for potential disease based on the AHA recommendations, the ECG and the echo, and whether the presence of normal echo findings could refute false positive findings found by the ECG or the AHA recommendations. A history and physical examination according to the 12-element AHA recommendations for pre-participation screening was performed on each athlete. An ECG was then carried out, which was interpreted according to the 2010 criteria for screening of Athletes by the European Society of Cardiology. Sports physicians trained in

echocardiography, blinded to the history, physical exam and ECG findings, performed the echo according to the ESCAPE protocol.

The results of the study were as follows: of the 65 athletes who were screened, 59 were negative for potential disease on all three modalities. Three athletes had abnormal ECG findings, two of which had a prolonged QRS interval of greater than 120ms and one had signs of left atrial hypertrophy. Both these ECG findings can suggest the presence of hypertrophic cardiomyopathy. All three athletes with these findings had normal echocardiograms based on the ESCAPE protocol, and also had normal formal echocardiograms performed in a cardiology setting. Another three athletes were found to have positive historical findings; two for exercise related pre-syncope and one for palpitations. All three had normal ECGs and normal screening echocardiograms. Formal echocardiograms done by cardiology were also normal, and all athletes were allowed to continue participating in sport.

Interestingly, the measurements obtained during the six athletes screening echoes were compared with those obtained during the formal echocardiograms, and were found to be statistically similar. This suggests that screening pre-participation echo had good correlation to formal echocardiography in this limited study but based on the small sample size no firm conclusions can be drawn. In addition, only one echo window was used, thus reducing the complexity of learning to acquire multiple views.

A research group based in Madison, Wisconsin developed a five minute screening echocardiography protocol which was used to screen 395 college athletes during their routine sports physical examination (16). The athletes were involved in 14 different sports. The echocardiograms were performed by sonographers and fellows in cardiovascular medicine. The images were interpreted by cardiologists while they were being performed. The screening echocardiograms consisted of the following windows: parasternal long axis, the parasternal short axis view at the aortic and mid-papillary levels, an apical four chamber and apical five chamber view. The aortic root diameter was measured, the aortic and mitral valves were examined for morphology and function, and left ventricular wall thickness and function was assessed. The origin of the coronary arteries were visualised and analysed. The right side of the heart was also examined in depth, whereby the pulmonic valve, tricuspid valve, right ventricular size and function were analysed.

Of the 395 athletes, 333 athletes (84%) had entirely normal echocardiograms. Fifty-five athletes had minor abnormalities such as mild mitral or tricuspid regurgitation, which were considered to be insignificant. Five athletes had abnormalities detected on screening echocardiogram which required a full work-up. These abnormalities were bicuspid aortic valve, pulmonic stenosis, mild cardiomyopathy and one abnormally thickened mitral valve with mitral regurgitation. Importantly, the screening echocardiogram findings were all confirmed by the formal echocardiograms, demonstrating that the screening echo was accurate in detecting pathology. None of the athletes ultimately were prohibited from participating in sport. However, this study used sonographers who were skilled in echocardiography.

In this study, the left coronary artery was visible in 99% of athletes and the right coronary artery was visible in 96% of cases. Despite this being a screening echocardiogram, it was still a technically advanced, in depth study. Each study was performed in approximately 5 minutes, which was time effective. The cost of the screening echocardiogram was \$35 each, which was minimised by not needing to reimburse the sonographers and cardiologists, as this study was part of their usual duties.

A pre-participation screening echocardiography programme was devised in Gabon to investigate the efficacy of such a programme amongst African athletes (17). Two hundred and ten football players were enrolled in the study. A history and physical examination, ECG and screening echocardiography were performed. ECGs were interpreted according to the ESC guidelines. Abnormal findings were either analysed as training related and therefore considered benign, or training unrelated and thus considered as potentially pathologic. The echocardiograms were performed by cardiologists. The echocardiograms included measurements for left ventricular (LV) dimensions and wall thickness in diastole and systole, LV mass, diastolic function measured through pulse wave Doppler of the mitral valve, right ventricular area, LV ejection fraction and area of the left and right atria.

Chest pain was reported by 19 athletes (9%) during the history taking. There was a family history of sudden death in 36 athlete's families (17%). On physical examination, 12 athletes had systolic blood pressures of >140 mm Hg. Training-related ECG abnormalities were found in 150 (71.4%) of athletes. Twenty-six athletes (12.4%) had training unrelated abnormalities for which they were referred

to cardiologists for further investigation. The echocardiograms detected 18 cases of Athlete's heart, where mild LV wall thickening with a dilated LV chamber was found. One case of hypertrophic cardiomyopathy was diagnosed. Two athletes were diagnosed with type II atrial septal defects and one was diagnosed with mitral valve prolapse.

The authors of this study noted that ECG findings unrelated to training were present in a higher proportion than found in studies examining Caucasian athletes, and that further research ought to be done to understand and recognise the different, but normal morphologic patterns in ECGs of black athletes. They surmised that screening echocardiography added little additional benefit for the detection of the causes of SCA in this population, due to the low pick-up rate of serious pathology. Finally they acknowledged the challenge of implementing screening programs in developing countries due to the lack of existing infrastructure.

There are limitations of echocardiography being used as a pre-participation tool. Several diseases are not consistently detected, such as atherosclerotic coronary heart disease and coronary artery anomalies. These may require invasive testing in the form of coronary angiography. Occasionally poor acoustic windows may prevent a thorough echo exam. The added financial cost has also been cited as a limitation (18).

Training in basic echocardiography

Several studies have investigated echocardiography training using limited teaching and hands on training amongst the non-cardiology community in a number of clinical environments. These environments include the Intensive Care Unit, the Emergency Department and Internal Medicine Clinics (19-23). Several studies have demonstrated the ability of doctors and medical students to acquire the skill of echocardiography after limited training. One study by Hellman et al (20) studied the rate of acquisition of echocardiography in emergency medicine residents and demonstrated rapid acquisition of the skill and progressive growth in skill per 10 scans performed.

Jones et al (21) aimed to determine if a six hour echocardiography training programme would improve echocardiography-naïve EM residents' ability to accurately perform goal directed focused echo and to correctly interpret their findings. This was determined by the residents answering a written examination pre and post training. The performance of a trans-thoracic echocardiographic (TTE) examination pre and post training formed the basis of the practical exam. The training greatly impacted on the EM residents' ability to perform TTE, as evidenced by their results in the pre and post training examinations; increasing from an average of 54% to 76% in the written and 56% to 94% in the practical component. However this study did not examine skill retention through a follow up examination at a later date.

Bustam et al (22) used a web-based echocardiography learning program to teach the didactic session to the EM residents enrolled in their study, which was followed by three hours of practical training. The ability of the EM residents to perform and interpret echocardiographic findings was compared to a qualified cardiologist. Agreement between the findings of the cardiologist and EM residents was 93%, suggesting that limited training was sufficient to prepare EM residents in basic echocardiographic performance and interpretation.

In an ICU setting, Vignon et al (23) assessed the ability of residents in obtaining echocardiographic windows on ventilated patients, as well as their ability to detect pathologic findings. A three hour training course followed by a five hour practical session was used for training. The four residents enrolled in the study performed 10-12 examinations each. Their image acquisition, time to complete the examination, number of echocardiographic windows and ability to interpret their findings was compared to a qualified Intensive Care specialist. Their findings were comparable to those of the intensivist, suggesting that residents can be trained in basic echocardiography in an ICU setting using a limited training course.

In an era where the skill of echocardiography is recognised to be desirable across many specialities, the dilemma exists of an insufficient number of people skilled in echocardiography being available to teach. The issue was explored Kuhl et al, (24) whereby they acknowledged this shortage, and investigated whether student tutors, who received a limited amount of training in echocardiography, could teach novices how to perform echo themselves.

The investigators gave six student tutors echocardiography training which comprised of lectures, hands-on training under the guidance of an expert. This was spread out over a number of weeks and consisted of 44 hours of training in total. They then implemented a randomised controlled trial, whereby medical students were either tutored by an expert or by a student tutor. The medical students were blinded to the skill of their particular tutor. The tutors then taught the students in the form of an echocardiography course, comprising of lectures followed by practical training.

The students underwent an objective structured clinical exam (OSCE) before and after the course. They were instructed to demonstrate a PLAX view and an apical five chamber view (A5C), and label the anatomical structures of both. The images were saved, de-identified and assessed for technical quality by two blinded cardiologists. The cardiologists used a checklist, which allowed them to rate the images on a point scale. The checklist assessed the overall quality of the images, the amount of structures correctly labelled, and whether the mitral valve was clearly shown.

Both groups demonstrated a significant improvement after training. However, the group taught by student tutors improved significantly less than the group taught by the expert tutors. The authors concluded that training given by student tutors was inferior to that given by experts. They assumed the difference in outcome was based on the fact that the student tutors probably took longer to acquire good views due to their lack of experience, leading to less time being available for their students to practise.

Echocardiography training for pre-participation screening

Though several studies have examined training in echocardiography within the hospital setting, little has been done on echocardiography being used out of hospital as a screening tool for athletes and the training thereof. Weiner et al (25) designed a pre-participation echocardiography protocol that aimed to detect the major conditions causing sudden cardiac arrest in sport. The protocol consisted of five windows, using a combination of 2D imaging, colour flow Doppler across the valves, continuous wave Doppler of the tricuspid and aortic valves and tissue Doppler of the mitral valve annulus and right ventricular base. The study was performed over a three year period by credentialed sonographers, during which 510 athletes were examined. Outcomes measured included time to setup each echocardiogram and time to acquire images and interpret them. The time decreased significantly over the three year period, suggesting that the echocardiographers became more proficient and efficient with time. Technically adequate images were achieved in 92% of the athletes scanned.

The study by Weiner et al (25) utilised credentialed sonographers in pre-participation screening. No studies exist that examine echocardiography training for novices for the purposes of pre-participation screening.

Echocardiography training and the quality of the images produced

Many studies have examined the ability of novices to perform echo after limited training, and their ability to interpret basic pathology. However, few studies have

been published specifically examining the technical quality of images produced by novices. Frederiksen et.al (26) explored this subject through designing a training course on Focused Assessed Transthoracic Echocardiography (FATE) which is a form of basic echocardiography that can detect gross cardiac pathology in critically ill patients. Twenty-one physicians, inexperienced in FATE, underwent the training course. The images they obtained on two healthy volunteers were recorded after the course. Subsequently, each physician performed ten scans supervised by an expert, where technical image quality was revised and emphasised. The physicians then scanned the two healthy volunteers again, and the image quality of the two separate sessions was compared. The technical image quality was graded according to a scoring system. Various determinants of image quality were scored; such as adequacy of gain, depth, sector width and crispness of the image and the degree to which the image could be interpreted. The scoring system had a maximum of 92 points. The volunteers were also scanned by three experts; their images were compared with those produced by the novice physicians.

After the initial training session, 86% of the images were interpretable. This rose to 93% after receiving further teaching by an expert. Images by the expert sonographers were 100% interpretable. The mean global image score obtained by the physicians after the initial training was 70.2 (72.9-77.0), and after the evaluation session rose to 75.0 (72.9-77.0). The mean global image score for the experts was 89.8 (88.8-90.9). The authors of this study concluded that the technical quality of images produced by novices could be improved by limited hands-on help from an expert, and that the total training time of 5 hours enabled the novices to produce images of sufficient quality 93% of the time.

Nielsen et al (27) highlighted the fact that competence in echocardiography is examined poorly through the use of logbooks, which tend to focus on the number of scans performed and the duration of training. They applied a global rating scale and procedural specific checklist to echocardiograms performed by 45 physicians of varying degrees of experience in echo. The physicians comprised of three groups: interns with four hours of experience in echocardiography, cardiology residents and cardiologists with expertise in echocardiography.

The global rating scale consisted of five points ranging from very poor (score of 1) to very good, score of 5. If images were not suitable for qualitative or quantitative assessment, they were given a score of 1. If images could be used to make qualitative assessments but not quantitative ones, they were given a score of 2. Images with a score of 3 were classified as barely acceptable for quantitative measurement. Images with a score of 4 and 5 were considered to have good and excellent image quality for both qualitative and quantitative assessment respectively.

The procedural checklist demonstrated images of excellent image quality for each view, with instructions on how to manipulate the transducer and how to optimise the image. Image quality was assessed by the following variables: 2D anatomical presentation, use of depth and sector width, quality of the colour Doppler signal, and quality of the pulsed wave and continuous wave Doppler curves. Each variable was graded on the 5 point scale, 1 being very poor and 5 being very good. A total score was calculated out of a maximum score of 440. Performance

efficiency was also measured through measuring the time taken to perform the exam in its entirety. A full standard echocardiogram was performed and the images were saved.

The global rating score attained by the interns was a median score of 1, (range 1-3), residents achieved a median score of 4 (2-4) and the experts achieved a median score of 4 (3-5). The difference in global rating score was statistically significant between all groups, being different between the interns and the residents and also different between the residents and the experts.

The median checklist score attained by the interns was 110, the residents' score was 264 and the experts' score was 310, with all p values demonstrating statistical significance. The global rating score also correlated with the total checklist score.

There was a significant difference in time taken to perform the exam between the three groups, ranging from a median time of 35 minutes amongst the interns, 22 minutes amongst the residents and 17 minutes amongst the experts, with the difference reaching statistical significance.

These instruments were also tested in a pilot study whereby the same global rating scale and checklist score were used to grade echoes performed on patients with varying degrees of image quality and with different pathology. Nine physicians from the same three levels of expertise scanned these patients. There was a strong correlation between level of expertise and image quality as assessed by the global rating scale and checklist score; $r = 0.7$, as previously demonstrated by the

initial study. All three groups produced better images in the patients with better image quality than the one with poor image quality. The authors concluded that the instruments they designed demonstrated validity in clinical practice.

Chapter 3 **MATERIALS AND METHODS**

Ethics

This research was approved by the Human Research Ethics Committee of the Faculty of Health Sciences of the University of the Witwatersrand (protocol approval number M1360610, Appendix 8). The ethical principles of confidentiality were maintained at all times in the study. Permission to conduct the study was obtained from the Management of Helen Joseph Hospital, as well as from the Head of the Helen Joseph Emergency Department. Furthermore, clearance was obtained from the Human Research Ethics Committee for Research of the University of the Witwatersrand.

Enrolment of the participants was done in such a way as to avoid power hierarchy influence. The participants were told that there would be no adverse ramifications by not participating in the study. If they chose to participate in the study, and if they experienced difficulty and did not perform well, this would also not influence the instructors' perceptions towards them, as this study's aim was to determine whether the training was adequate, rather than scrutinising each participant's ability. Furthermore, echocardiography was not a core skill that they as doctors were expected to be proficient in. This fact was stated clearly, and that perceived failure to perform would not result in their reputation being adversely affected. The results of the performances of the individual participants were kept confidential and were not shared with other members of staff that the doctors worked with.

During recruitment of the participants, peer pressure to enrol in the study was avoided by stating that this study was purely voluntary and that they could withdraw from the study at any stage.

Study Design

A prospective longitudinal study.

Study Setting and Population

The study took place in the Helen Joseph Hospital Emergency Department. The study population comprised of echocardiography naïve doctors, who were employed at Helen Joseph Hospital, Chris Hani Baragwanath and Rahima Moosa Hospitals.

Inclusion criteria

1. All echocardiography-naïve doctors who were willing and able to participate in the study.

Exclusion criteria

1. Doctors who would not be available for the six week follow up study.
2. Doctors who have done a course in echocardiography.

Study Protocol

The training took place on two different weekends in order to recruit enough doctors for the study. On Saturday 1 March 2014 and Sunday 2 March 2014 six doctors were trained on each day. A second cohort of doctors were trained on the 21 and 22 June 2014, seven being trained on the Saturday and seven on the Sunday. A total of 26 doctors took part in the training and evaluation.

The day of training comprised of didactic teaching followed by practical training. The didactic teaching revised the anatomy of the heart and the principles of ultrasound. They were taught how to acquire an image, and how to manipulate the settings in order to obtain a good quality image. Six echocardiography views in total were taught, namely the parasternal window, in which the long axis view, (PLAX) and short axis view, (PSAX) were taught. The apical four chamber view (A4C) and the subxiphoid view (SXC) were also taught. Of the parasternal short axis view, the aortic valve level (PSAX AV) and mid papillary level (PSAX MP) were taught. At the apical window, the standard apical four chamber view was taught, as well as the atypical view optimised for the right ventricular apex (A4C RV) was taught. These six views were chosen on the basis of previous echocardiography pre-participation screening protocols in athletes(15, 16). Furthermore, these views are most likely to detect pathology causing SCA, for example HCOM using the A4C and PLAX views, and ARVC is most easily detected on the PSAX AV and A4C RV view.

Mindray TM ultrasound machines (Mindray Medical International Limited, Shenzhen, China) were used for the training, evaluation and follow-up session.

The M5 and M7 models were used. The standard cardiology setting with a cardiac curvilinear probe was used. The Mindray TM M7 was used for all the follow-up sessions with the participants.

On each training day, three instructors experienced in echocardiography provided assistance in the practical training. The participants were trained in a 1:3 instructor to participant ratio, with up to 7 participants being trained in a day. After receiving the didactic lecture on each window, the participants practised the views on models. Three models were present on each day of training. Up to an hour was available for the participants to practise the views on the models. The models were healthy young men. No gross cardiac abnormality was detected in the models incidentally during the course. Each participant was given a checklist, which showed a technically excellent image of each view, as well as a brief summary of how to acquire each view. Troubleshooting tips were also mentioned. See Appendix 3 for the "Echo checklist". The lectures, practice sessions and evaluation sessions lasted 5-6 hours in total per day.

In the afternoon, there was an evaluation session whereby the participants each performed scans on the three models, acquiring the six views they had learnt. Instructions were given prior to the evaluation session. Each participant scanned each of the three models, acquiring six views. Once they were happy with each view, a still image and video image were saved. The video image consisted of three cardiac cycles to ensure that the image could be properly assessed. Each participant was timed by the instructor using a digital stopwatch, to determine the length of time that it took to perform the echocardiography study. Timing started

when the probe touched the model's skin and stopped when the participant notified the instructor when they had acquired the image. The instructors were not allowed to help the participants acquire the view. The instructors save the still images and video clips at the point where the participant thought the view was adequate. The participants were allowed to use the checklists as a reference to remind them of the standard views they needed to acquire and how to acquire them.

Two of the models had surprisingly poor subxiphoid views during the training days. The instructors scanned the models and also could not get acceptable views. Therefore on the second training day, participants were advised not to save the subxiphoid view during the evaluation. Consequently there were fewer subxiphoid views available for analysis compared to the other views.

Each participant answered a questionnaire after the training and evaluation session and the follow-up six week evaluation session to assess their experience and to detect any problems they had.

The participants scanned three models on each training day. For the second training day in August, two of the models from the previous training day were used along with a new model, as the third from the initial training day was unavailable. The models were labelled with a number, 1-4. Each participant saved the image of the model, plus the code assigned to them, e.g. A. To maintain confidentiality, alphabet letters instead of the participants' names were utilised. The names of the doctors participating in the study were held in a password protected computer, and

were only accessible to the researcher and the Emergency Physician reviewing the images.

For example, participant A saved images as A1, A2, A3 etc. as she/he scanned the three models, saving 6 views for each model. The images were therefore saved and captured as A1 PLAX, A1 PSAX AV, A1 PSAX MP for example. In this way, a total of 811 images were captured for assessment.

Six weeks after the initial session a follow up session took place. The doctors were contacted and a time arranged to meet with them that suited them. A total of 21 doctors were available for the follow up session. The remaining five either declined to participate or were unable to participate due to work constraints. The participants for the follow-up session scanned one model. The model in each follow-up session was different to the initial training models. The particular model used for each follow-up session was dependent on who was available to volunteer on each day.

The participants were able to consult their checklist to ensure that they achieved the best possible image. The six views done in the evaluation session were performed. Each view was saved as a still image and video clip for analysis. Time taken to obtain each view was also done with a stopwatch in the same way as the evaluation session. The six week follow up sessions took place in May and August 2014. The follow up session lasted about twenty minutes per participant.

Images from the follow up session were saved as 1-21, thus the identities of the participants were concealed when the images were being analysed. The follow-up scans performed by the participants could not be matched to the scans performed during the initial evaluation, as the alphabet system used in the initial evaluation session was not used in the follow up session. Two hundred and forty-six images were captured for assessment from the follow-up session.

There was no financial compensation for the participants, but the training course was free. The models were paid both for their time during the training and during the follow up sessions.

Data collection

The recorded images were reviewed by the researcher and supervisor. Each still image and video clip for the six views on the three models by all 26 participants were analysed for their technical quality and adequacy for interpretation by an expert using a checklist. (Appendix 7) Since alphabet letters were used for the participants; the researchers were blinded to their identity. There were fewer subxiphoid view images to review due to the poor subxiphoid view that two models had, which was independent of the participants' own skill, as the instructors were also unable to obtain adequate views.

Adequacy of the images was judged by several parameters:

1. The correct use of depth, ensuring that the image filled the screen and was not cut off or too small.
2. The image being on plane, meaning that the image correctly demonstrated all the anatomic features that are standard for that particular view. This reflects the echocardiographer's ability to scan the heart at right angle.
3. For the Apical four chamber view (A4C) the absence of foreshortening was assessed and scored. Foreshortening is an echocardiographic error where the heart is scanned too superficially, resulting in smaller, inaccurate dimensions, particularly of the left ventricle.
4. The correct amount of gain being employed. Gain is the brightness of the structures, and should not be too bright or too dark.
5. Crispness of the endocardial borders was assessed as this helps to determine both structure and function of the heart.
6. The absence of interference or artefact, such as avoiding air from the stomach or the rib shadows.
7. Clarity of the valves was assessed on each view, for example the ability to visualise all three cusps of the aortic valve on the parasternal short axis view at the level of the aortic valve.

Each parameter was scored out of 5. A score of 1 was completely inadequate for pre-participation screen echocardiography, 2 being mostly inadequate and insufficient for screening echocardiography purposes, 3 was adequate for qualitative interpretation, 4 adequate for quantitative interpretation and 5 being excellent quality. An overall score was subjectively determined for each image

based on the fulfilment on the above parameters, decided by the researcher and the supervisor. The overall score was used in the data analysis.

A questionnaire post training, post evaluation and post six week follow up testing was employed to obtain qualitative data pertaining to the participants' opinions regarding their learning and experience.

Outcome Measures

- Time taken to acquire the view (seconds)
- Quality of the still/video image of the view (scale of 1-5: 1=completely inadequate; 5=completely adequate)
- Whether or not the quality of the still/video image of the view was adequate (score of 3 or more) (1=adequate; 0=not adequate)
- Whether or not the quality of the still/video image of the view was adequate (score of 4 or more) (1=adequate; 0=not adequate)
- Qualitative assessment of the participants' responses through a questionnaire

Sample Size

A sample size calculation must be based on the key research question to be answered. This was the comparison of the continuous outcomes (time and adequacy score) between the two events. This would be assessed by a paired t-test for a given view. Since the magnitude of the difference which would be considered meaningful, as well as the variability of the differences, was not known

at the outset, a sample size calculation was based on the 5% significance level, 80% power and small, medium and large effect sizes ($d_z=0.2$, 0.5 and 0.8 respectively). This results in a sample size estimation of 199, 34, and 15 respectively. The study sample size aim of 24 (80% of 30) was thus somewhat small and would allow the detection of medium-large effect sizes (up to $d_z=0.6$). Sample size calculations were carried out in G*Power. (28)

The sample was a convenience sample, being comprised of doctors who were interested in learning the skill of basic echocardiography. Initially, Helen Joseph doctors were invited to participate in the study. Twelve doctors took part in the first weekend of training. The decision was then made to request ethical clearance to recruit doctors at Rahima Moosa and Chris Hani Baragwanath Hospitals, in an attempt to fulfil the sample size. This was granted by the Ethics Committee in April 2014, and recruitment at these hospitals began the following month. Doctors working at Helen Joseph, Rahima Moosa and Chris Hani Baragwanath Hospitals were made aware of the study through email and through direct invitation. A sample of 26 doctors was achieved through these methods.

Data Analysis

All data was captured from the data collection forms and questionnaires and entered onto an electronic spreadsheet (Microsoft Excel, Microsoft Office 2010, Microsoft Corporation). Data analysis was carried out using SAS. (SAS Institute Inc., SAS Software, version 9.3 for Windows, Cary, NC, USA: SAS Institute Inc. (2002-2010))

The following descriptions and analyses were performed:

1. A descriptive analysis of all the variables in the study, overall and categorised by event, view (within event) and image type (within event) was performed. Continuous data were characterised by mean, standard deviation, median, interquartile range, and histogram, while categorical variables were described by frequency tabulation.
2. Time taken to generate the images during the initial evaluation session was analysed by a repeated measures mixed model, with time as the dependent variable, model as a random effect, view as fixed effect, and doctor as a repeated effect. The interaction term between model and view was also included. A log transformation was applied to time, to deal with the effects of the skewed distribution of the data on the violation of the model assumptions. Post-hoc tests using the Tukey-Kramer adjustment for unequal group size was performed to test for differences between views. Follow up data were analysed in the same way.
3. To determine the relationship between time taken to perform the echocardiograms and their adequacy, the Pearson correlation coefficients between logarithmic transformation of time and video image score were determined overall, and for each view, for each event. The logarithmic transformation of time was used to normalise the time data, a requirement for the use of the Pearson correlation coefficient.
4. Comparison of evaluation post training and follow up testing data for time: Since the identity of most of the doctors could not be matched across the two sets of testing, a paired analysis could not be undertaken. Instead the

data had to be treated as coming from two independent groups of doctors.

The data were analysed by a repeated measures mixed model. A log transformation was applied to time as described above.

5. Diagnostic adequacy for the still images and video clips, and all the views performed during the evaluation post training were analysed by a repeated measures mixed model, with quality score as the dependent variable, model as a random effect, view and type as fixed effects, and doctor as a repeated effect. The interaction term between model and view, model and type, and view and type, were also included
6. Adequacy scores from the six week follow up session was analysed in the same way as the evaluation data.
7. To compare the evaluation and follow-up data for diagnostic adequacy of the images a repeated measures mixed model was used, with time as the dependent variable, model as a random effect, event, type and view as fixed effects, and doctor as a repeated effect. The interaction terms between model and view, model and type, type and view, type and event, and view and event, were also included.
8. To determine how many of the still images and video clips were adequate for qualitative assessment for pre-participation screening, a dichotomised score was employed, whereby a score of 1 or 2 was considered inadequate and a score of 3 to 5 was considered adequate. A repeated measures logistic regression was used with the dichotomised score as the dependent variable, model as a random effect, view and type as fixed effects, and doctor as a repeated effect. This was performed on the initial evaluation data, the six week follow up data and to compare the evaluation and follow

up data. The interaction terms between model and view, model and type, type and view, type and event, and view and event, were also included.

9. Due to the poor quality of the still images, the adequacy scores from the video clips were analysed alone. The categorised variable of three or more and four or more was used in the repeated measures logistic regression.
10. The data from the best and least performing participants was analysed by repeated measures logistic regression.
11. The questionnaire was utilised to ascertain the participants' perception of their skills before the training, after the training and after the evaluation.

Significance level

A 5% significance level was used throughout.

Methodological limitations of this study

Source of bias

The Hawthorne effect is a form of observer bias whereby participants being researched perform at a higher level than they normally would perform due to being under scrutiny. For example in this study, the doctors may have produced better images while being assessed than when they were performing on patients without being assessed. The demand effect is similar, whereby participants adjust their behaviour in order to either aid or refute what they perceive the outcome of the research to be. This may have taken place, and was impossible to detect while

analysing the results. Conversely, the participants may have performed poorer due to being under scrutiny. To counteract this effect, the research encouraged the participants to try their best, and that this was not a pass/fail situation, and that their performance would not have any ramifications on how the instructors perceived them.

The participants may have had a higher degree of motivation to acquire skills than other doctors in another setting. Seven doctors (33%) practised echocardiography before the six week evaluation session, which may have improved their performance and thus conveyed bias. This may have been motivated by a desire to perform well in the six week evaluation session, or may have been motivated by an interest to continue practising and learning echocardiography.

Methodological error

The participants' follow-up echoes were saved as numbers 1-21, instead of the original letters that they had been assigned in the initial evaluation, A-Z. Therefore the identity of the participants could not be matched between evaluation and follow-up, thus unpaired statistics had to be used, as each participant no longer acted as his/her control. This increased the standard error of the estimates of the differences between in the initial evaluation and the follow up session, thereby decreasing the power to detect differences.

Chapter 4 RESULTS

Demographics of the participants

Twenty-six doctors volunteered to participate in the course. The doctors ranged from interns and registrars to consultants. The majority of the doctors' stated speciality comprised of Anaesthesia, Internal medicine, Emergency Medicine and Surgery. This is shown in a bar graph below.

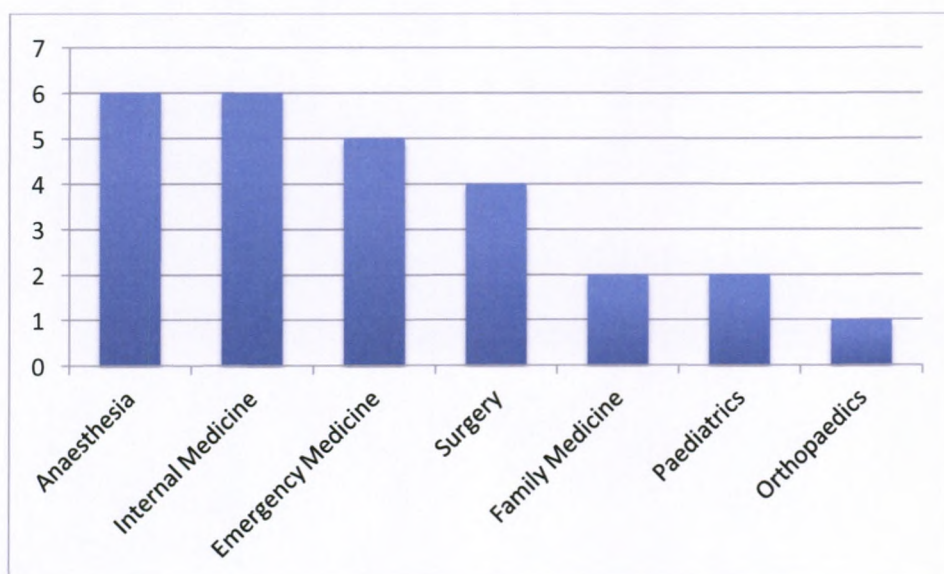


Figure 1: Number of doctors in each speciality who took part in the echocardiography training

The majority of the doctors had little or no experience in basic echocardiography. Eleven of the doctors (42%) stated they had no previous experience in basic echocardiography at all and ten (38%) stated they had little previous exposure to basic echocardiography. No participant had performed a specific course in echocardiography before. Five participants mentioned that they had learnt previously how to perform the subxiphoid view (SXC) as part of the extended

focused assessed sonography in trauma exam (eFAST). No participant felt that they were adequately or very experienced in basic echocardiography.

Time taken to produce the images after training

The time taken to obtain the echo images by the participants was analysed by the means, medians and standard deviations of the data. This is shown in the table below. The data was distributed in a non-Gaussian distribution.

Table 1: The time taken in seconds overall and per view by the participants during the initial evaluation

		N	Mean	Std Dev	Median	25 th Pctl	75 th Pctl
Overall		416	59.9	63.4	40	20	72.5
View	A4C	78	77.3	67.3	59	33	95
	A4C RV	77	57.1	56.2	38	20	75
	PLAX	78	58.3	71	37	21	64
	PSAX AV	77	58.7	68.3	32	20	67
	PSAX						
	MP	78	45.2	48.8	27.5	13	60
	SXC	28	67.3	63.3	48	26	70

The quickest median time was obtained for the PSAX MP view by the participants in 27.5 seconds. The A4C view was obtained in the slowest median time in 59.0 seconds. The mean time for all views was 59.9 seconds and the median time was 40.0 seconds.

The distribution of time that the participants took is shown in the graph on the following page. The results are heavily skewed to the right as most participants were able to obtain the views within 20-60 seconds.

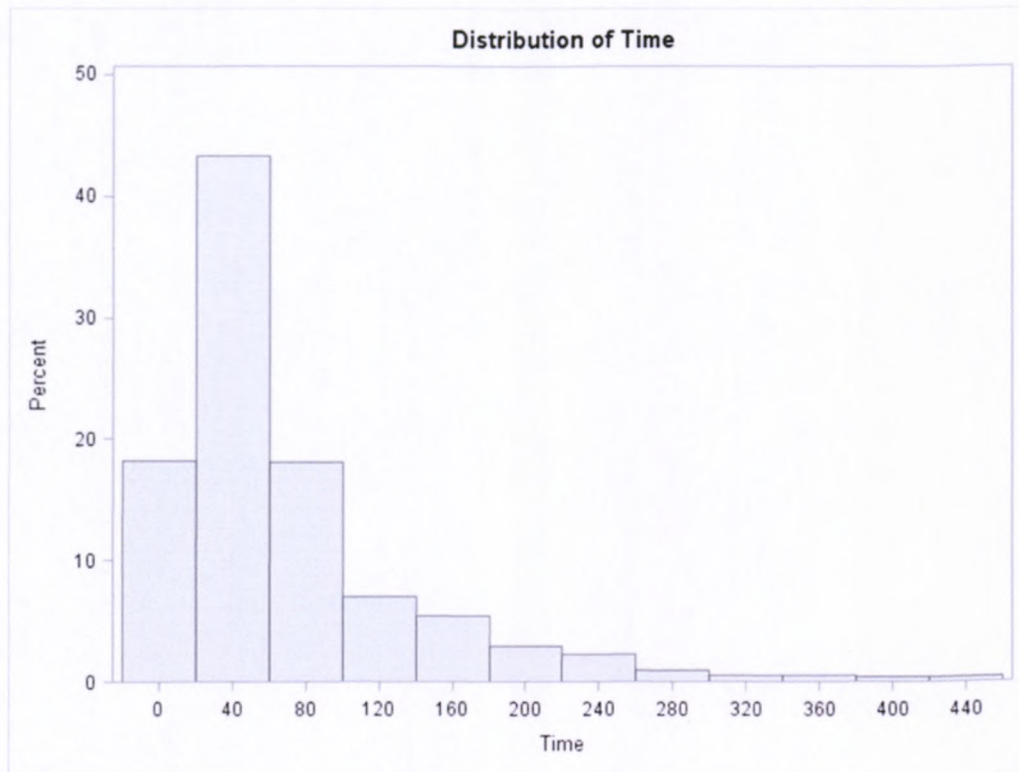


Figure 2: A bar graph demonstrating the distribution of time taken to obtain the echocardiograms after the initial training and the percentage of echocardiograms obtained within each time period

There were significant differences between views ($p=0.028$). Post-hoc tests using the Tukey-Kramer adjustment for unequal group sizes showed that the mean time required to acquire the A4C view was significantly longer than that required to acquire the PSAX MP view.

Time versus Adequacy: is there a correlation?

The relationship between time taken to acquire images and the video image quality score

It was hypothesised that the participants who took longer to perform the echo windows would be more accurate, producing more adequate views and hence getting higher overall scores. The Pearson correlation coefficients between the logarithmic transformation of time and video image score were determined overall, for each view and for each event; being the initial evaluation session of training and the follow-up session six weeks later.

At evaluation:

Overall, there was a significant, negative correlation between the logarithmic transformation of time and quality score ($r = -0.229$, $p < 0.0001$), i.e. as time increased, quality score decreased. The same trend was evident in significant correlations between logarithmic transformation of time and A4C RV and PLAX, but not for the other views. The effect sizes were small (overall, A4C RV) and moderate (PLAX).

Time taken by the top scoring participants versus the bottom scoring participants

The time taken to obtain the views by the top scoring participants was compared to the time taken by the bottom scoring participants. Six participants obtained adequate views 93.3% of the time which was the highest percentage obtained by the group. Seven participants scored the lowest in the group, ranging from 33.3 – 60% adequate.

The SXC view was excluded due to a high number of inadequate views obtained by all participants. A repeated measures mixed model was used with time as the dependent variable, and view and doctor group as the fixed effects. A log transformation was applied to the dependent variable to deal with the effects of the skewed distribution of the data on the violation of the model assumptions.

The effect of doctor group was significant ($p=0.0010$). The mean log times were significantly longer for the Bottom 7 group compared to the Top 6 group. By back-transforming the least-squares estimates of the mean times to seconds from log-seconds we obtain estimates of mean times for the Top 6 of 29s (95% CI: 21-41s) and for the Bottom 7 of 43s (95% CI: 31-62s). As demonstrated in the box-and-whisker plot below in both groups there were instances where much longer times were taken to obtain the views.

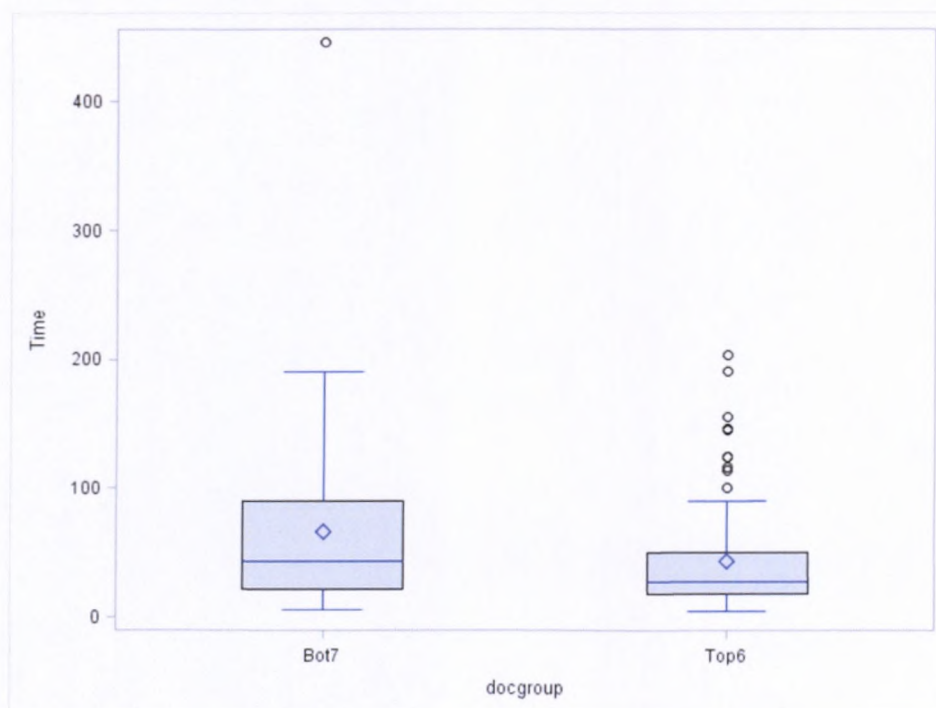


Figure 3: Box-and-whisker plot demonstrating the means, medians and interquartile ranges obtained in time taken to obtain the views by the bottom seven and top six participants

The diagnostic adequacy of the images generated during the evaluation session after training

The overall distribution of score of all the images, both still and video, obtained during the evaluation session immediately after training is shown below. Most of the images scored between 2 and 4.

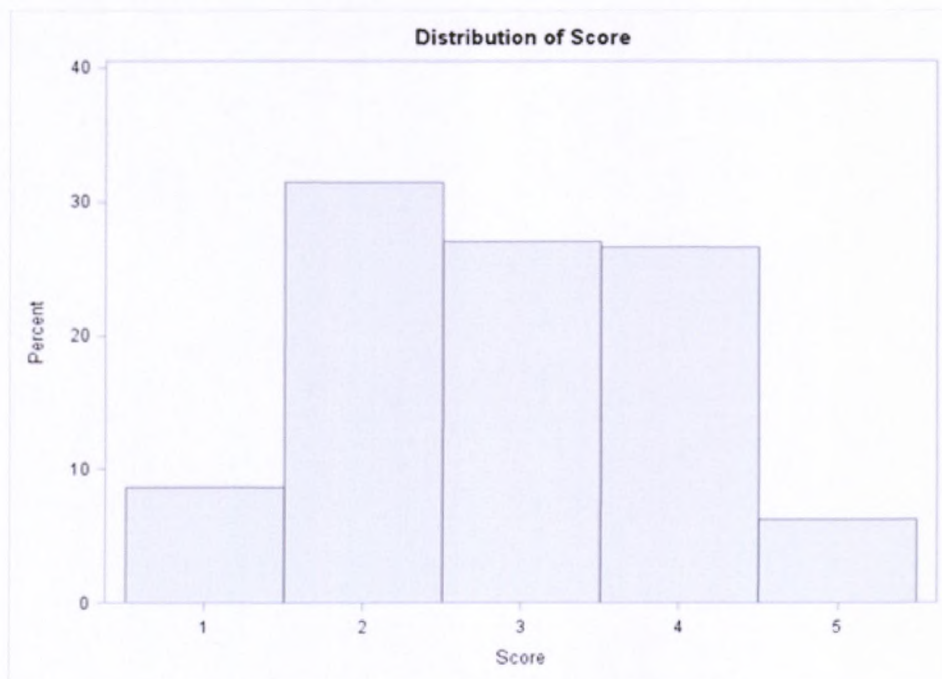


Figure 4: The distribution of adequacy score and the percentage of views obtaining each score during evaluation

At evaluation:

Eight hundred and eleven images were obtained during the evaluation. Of this 417 were still images and 394 were video clips which were obtained from the six different echocardiographic views. They were analysed and given an adequacy

score between 1 and 5, 1 being completely inadequate and 5 being completely adequate as described in the data collection section. The overall mean and median score was 3.0 for all the images obtained. The median score obtained amongst the still images was 2 and for the video clips was 3.

Sub-category		N	Mean	Std Dev	Median	25th Pctl	75th Pctl
Overall		811	3.0	1.1	3	2	4
Type	Still	417	2.6	1.0	2	2	3
	Video	394	3.3	1.0	3	3	4
View	A4C	152	3.0	1.0	3	2	4
	A4C RV	152	3.0	1.1	3	2	4
	PLAX	151	3.0	1.1	3	2	4
	PSAX	149	3.0	1.2	3	2	4
	AV						
	PSAX	151	3.1	1.0	3	2	4
	MP						
	SXC	56	2.5	0.9	2	2	3

Table 2: Number of still images and video clips obtained during evaluation and the adequacy scores obtained

The mean score obtained for most of the views was 3.0, apart from the PSAX MP view which was 3.1 and the SXC which was 2.5. The median score was similar, being 3.0 for all views apart from the SXC which scored 2.0.

Mean adequacy score obtained by the doctors for each view

The mean adequacy scores for each doctor for each view are demonstrated below and on the following page. The error bars denote the maximum and minimum scores attained by each doctor. The doctors were given an alphabet letter from A-Z. The mean scores are placed by alphabet letter on the graphs. Due to the poor subxiphoid views that some of the models had, some of the doctors were instructed not to perform the view.

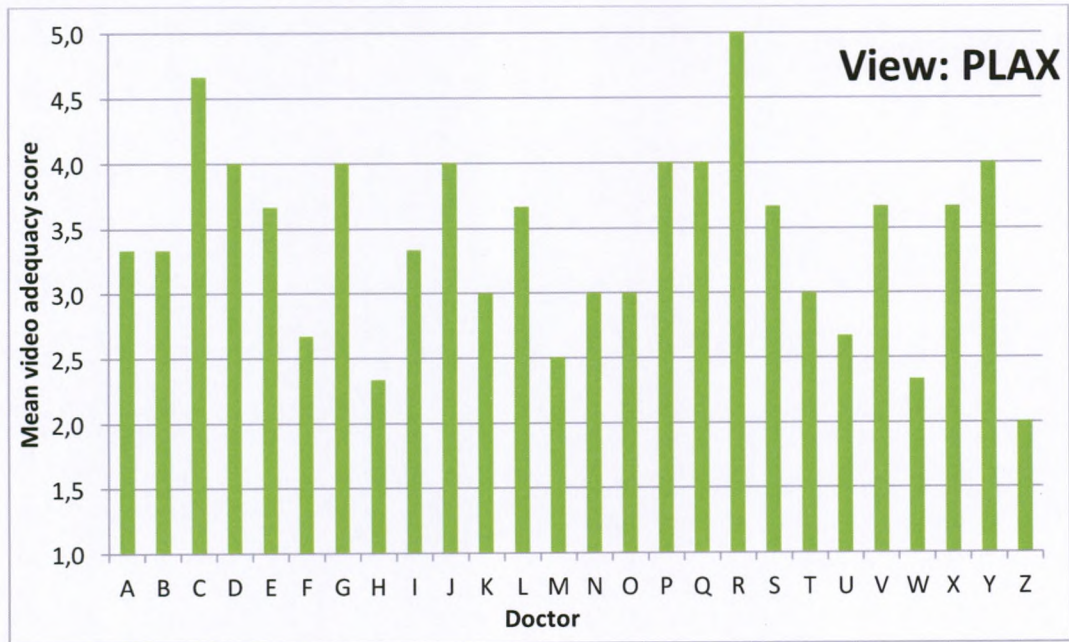


Figure 5: Mean video adequacy score obtained by the doctors in decreasing order of score during evaluation for the PLAX view

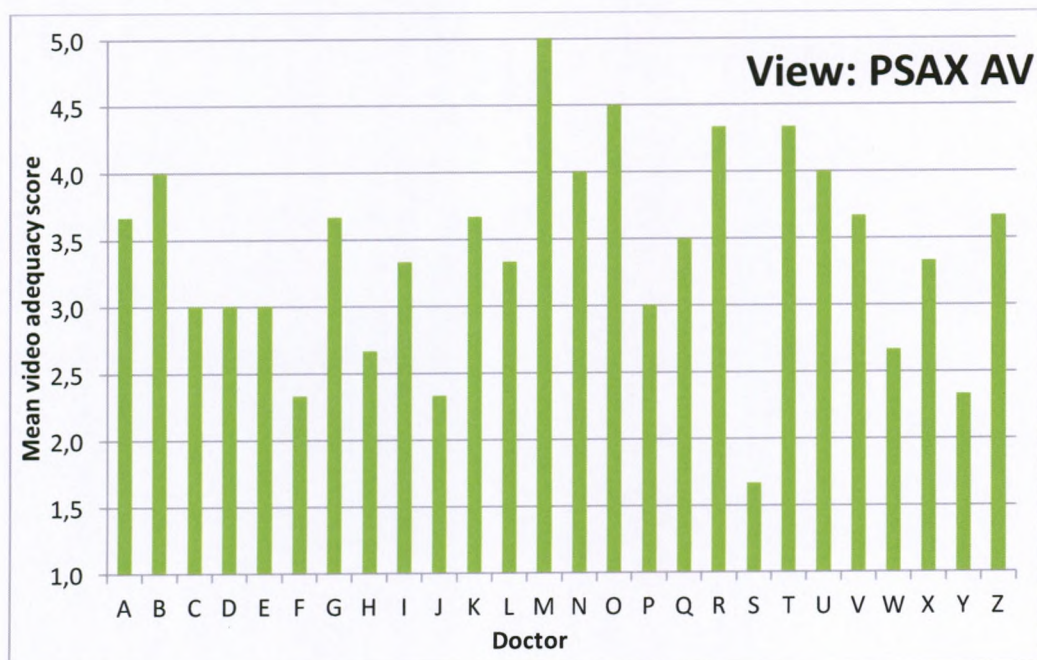


Figure 6 Mean video adequacy score obtained during evaluation for PSAX AV view

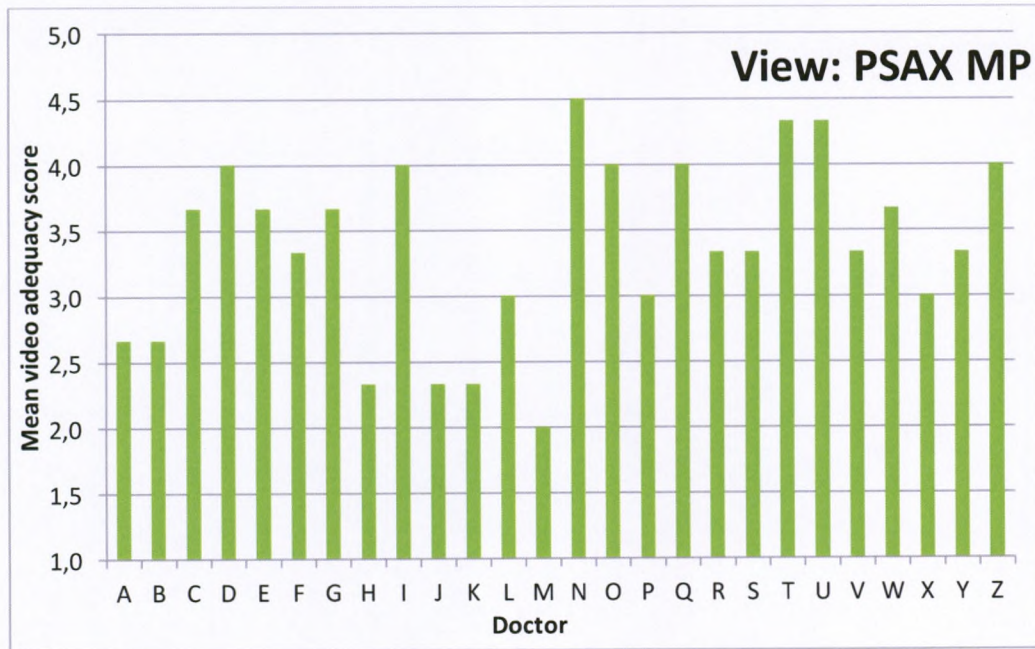


Figure 7: Mean video adequacy score obtained by the doctors during the evaluation for the PSAX MP view

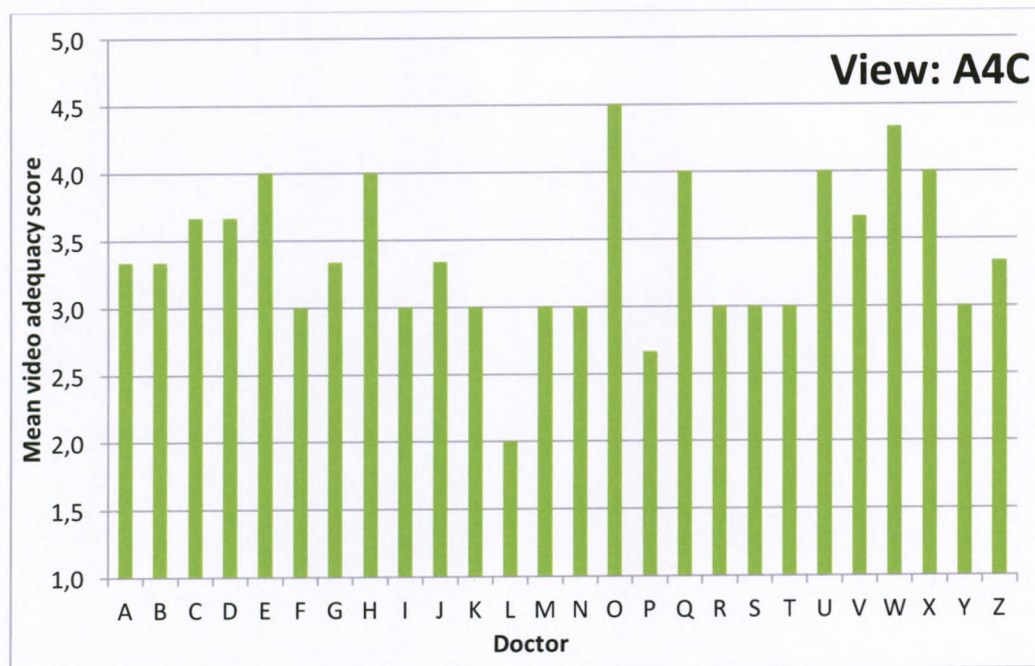


Figure 8: Mean video adequacy during evaluation for the A4C view

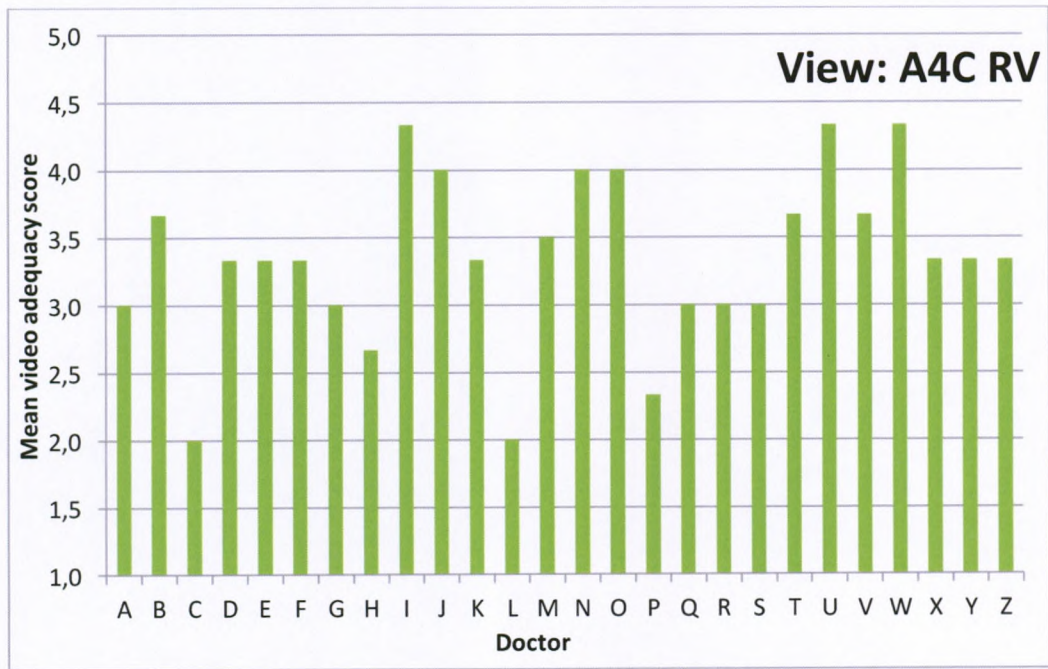


Figure 9: Mean video adequacy score during the evaluation for the A4C RV view

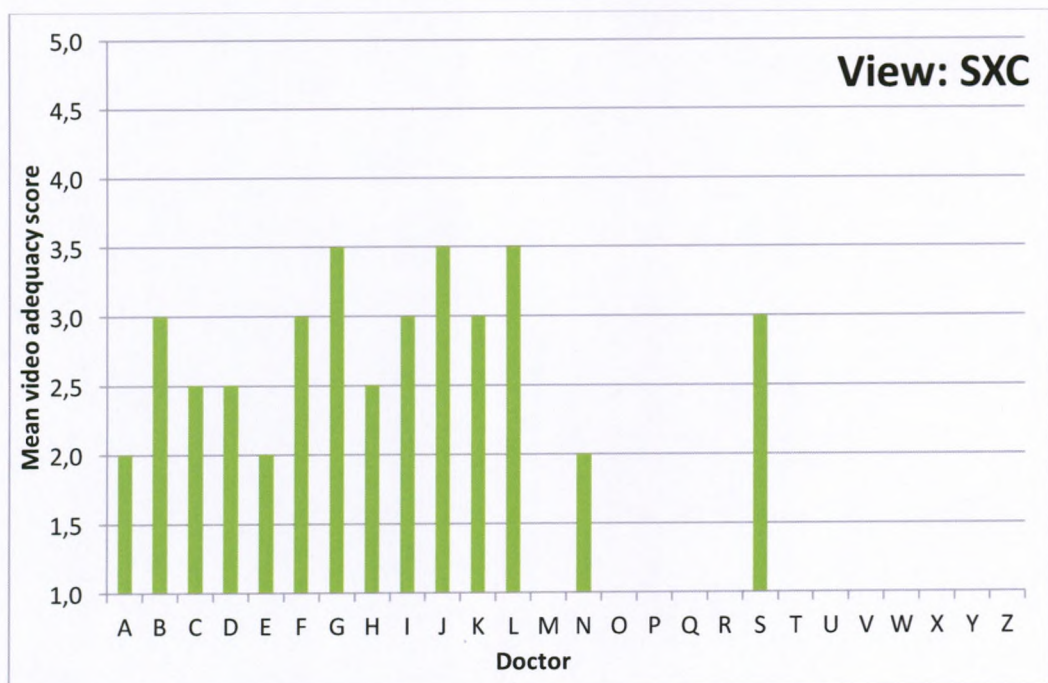


Figure 10: Mean video adequacy score obtained during the evaluation for the SXC view

Comparison of the adequacy of the different views obtained after the initial training

A repeated measures mixed model was used with quality score as the dependent variable and view and type as fixed effects. The interaction term between model and view, model and type, and view and type, were also included. There was no significant differences in adequacy scores between the different views ($p=0.24$).

Comparison of the adequacy of the still images to video clips after the initial training

The video images were significantly more adequate than the still images, as determined by mean score ($p<0.0001$). The mean quality score (over a balanced set of views) was higher for the video images compared to the still images. The mean score for still images was 2.6, and that for the video images was 3.2.

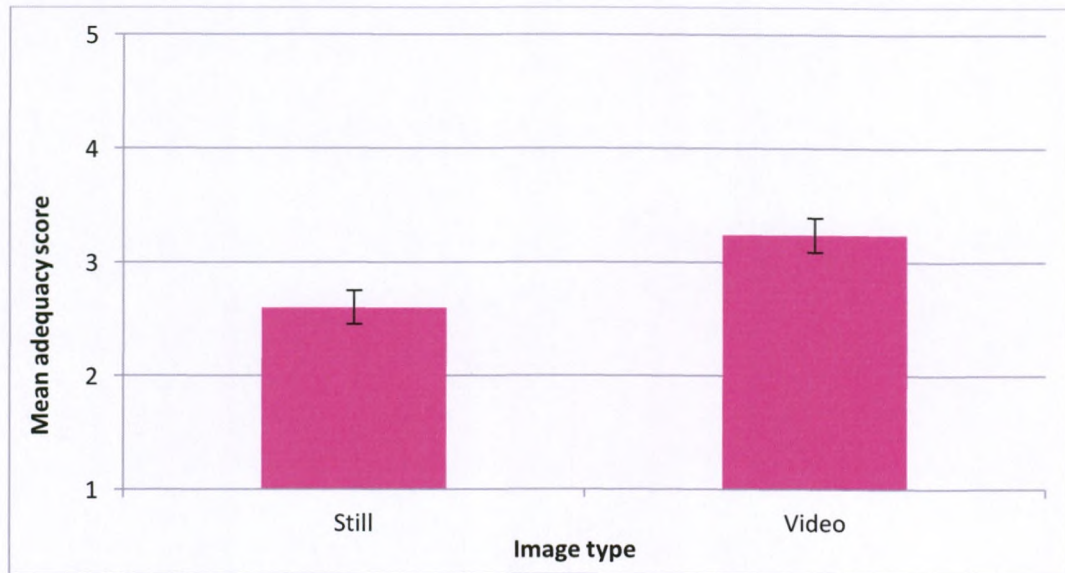


Figure 11: The mean adequacy score obtained for the still images and video clips. Error bars denote the minimum and maximum scores

Diagnostic adequacy: Categorised Score of three or more

The adequacy of the views were further analysed using a categorised score of 3 or more, which was judged to be adequate for the quantitative analysis of echocardiographic images.

Overall, 63.4% of the images, including still images and video clips were adequate when a score of more than or equal to 3 was used. 49.6% of the still images were adequate. More of the video images were adequate during the evaluation session, with 77.9% scoring 3 or more. The number of still and video images and percentage found to be adequate is shown in the table below.

The percentage of adequate images for each view is also shown. The participants were able to obtain a score of 3 or more in over 60% of all the images in all the

views, except for the subxiphoid view where only 48.2% of the images scored 3 or more, although this did not reach statistical significance.

Table 3: The percentage of inadequate and adequate views overall, per image type and per view at evaluation

		Score ≥ 3			
		Inadequate		Adequate	
		N	%	N	%
Overall		297	36.6	514	63.4
Type	Still	210	50.4	207	49.6
	Video	87	22.1	307	77.9
View	A4C	53	34.9	99	65.1
	A4C RV	54	35.5	98	64.5
	PLAX	55	36.4	96	63.6
	PSAX AV	56	37.6	93	62.4
	PSAX MP	50	33.1	101	66.9
	SXC	29	51.8	27	48.2

When looking at the overall adequacy for each view, combining the image type still versus video for each view, the PSAX MP view had the highest percentage of adequate images at 66.9%. The SXC had the least percentage of adequate views at 48.2%.

A repeated measures logistic regression was used to analyse the data with the dichotomised score as the dependent variable and the view and type as fixed effects. The interaction terms between model and view, model and type, and view and type, were also included.

There was no significant difference between the different views in terms of the dichotomised score of 3 or more, $p=0.24$. The type of image modality still image versus video clip remained highly predictive of adequacy, $p<0.0001$.

The interaction between view and image type was significant ($p=0.033$). Overall, the proportion of adequate images was higher for video than for still images, but the difference was greater for A4C in particular than for the other five views.

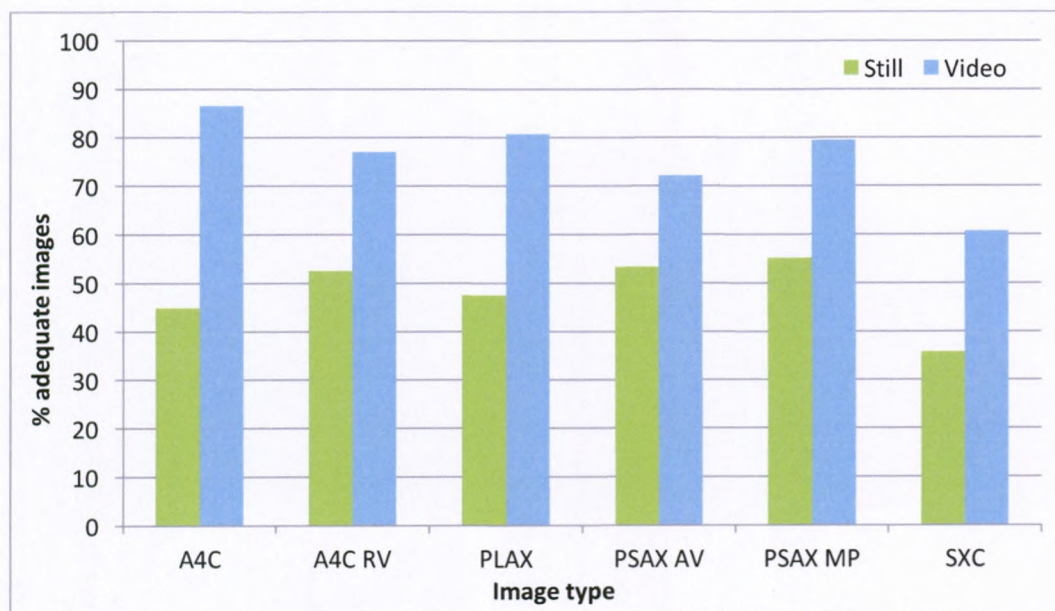


Figure 12: The percentage adequate images obtained per view and per image type

Percentage adequate views obtained by the best performing and worst performing participants

The percentage adequate views obtained by the top 6 participants, excluding the subxiphoid view, was 93%. The bottom 5 participants obtained 33-67% adequate images. The top 12 candidates obtained images 80-93% of the time, while the bottom 10 obtained adequate images 33-60% of the time.

Score of 4 or more

The data were analysed further using a categorised score of 4 or more, to determine what proportion of images were of excellent quality that would allow quantitative assessment by an expert interpreter.

When adequacy was determined by a score of 4 or more, the percentage of adequate views decreased to 35.3%. A total of 48.2% of the video images were adequate while only 23% of the still images were adequate, as shown in the table below.

Table 4: Percentage adequate views based on dichotomised adequacy score of 4 or more overall, per image type and per view

		Score ≥ 4			
		Inadequate		Adequate	
		N	%	N	%
Overall		525	64.7	286	35.3
Type	Still	321	77.0	96	23.0
	Video	204	51.8	190	48.2
View	A4C	105	69.1	47	30.9
	A4C RV	98	64.5	54	35.5
	PLAX	97	64.2	54	35.8
	PSAX AV	87	58.4	62	41.6
	PSAX MP	90	59.6	61	40.4
	SXC	48	85.7	8	14.3

When a score of 4 or more was used to judge adequacy, the number of images obtaining this score all decreased across all the views. The PSAX AV view and MP view had slightly more adequate images and video clips than the other views. Only 14.3% of the SXC images scored 4 or more.

A repeated measures logistic regression was used to analyse the data as described above. However, the SXC view was omitted from the analysis due to the small number of adequate views, which led to problems with model convergence.

The effect of type was significant ($p < 0.0001$). 48.2% of the video images scored 4 or more, compared to only 23.0% of the still images. The type of view was not significant, $p = 0.76$, nor did the type of image modality affect the adequacy of each view, $p = 0.63$.

Adequacy of the video images at evaluation

We surmised that the video images would be significantly more adequate than the still images. We thus analysed the data from the video images on their own to determine if video clips alone would be of sufficient quality for them to be used for pre-participation screening. A dichotomised score of 3 or more was considered adequate for pre-participation screening.

At evaluation:

At evaluation, 77.9% of the video images were adequate, scoring 3 or more. The A4C view had the highest percentage of adequate images; 86.5% scored 3 or more, followed by the PLAX view 80.8% and the PSAX MP view at 79.5%. The SXC had the lowest percentage of adequate views at 60.7%. There was no overall difference in the adequacy between the views, $p = 0.1$.

Table 5: Percentage of adequate views obtained overall and per view for the video clips at evaluation

		Inadequate		Adequate	
		N	%	N	%
Overall		87	22.1	307	77.9
View	A4C	10	13.5	64	86.5
	A4C RV	17	23.0	57	77.0
	PLAX	14	19.2	59	80.8
	PSAX AV	20	27.8	52	72.2
	PSAX MP	15	20.5	58	79.5
	SXC	11	39.3	17	60.7

Data from the six week follow-up session

Time taken to produce the different views during the follow-up session

During the follow-up session the participants took a mean time of 93s to perform the views and a median time of 60s. The overall time in seconds and the time taken per view are shown in the table below.

Table 6: Table of the time taken to obtain the views during the follow-up session

		N	Mean	Std Dev	Median	25th Pctl	75th Pctl	Min	Max
Overall		122	93.0	86.0	60.0	28.0	135.0	6	411
View	A4C	21	106.6	84.7	85.0	31.0	167.0	15	300
	A4C RV	20	78.3	79.6	59.5	25.5	100.0	13	360
	PLAX	20	90.8	80.3	65.0	26.5	142.0	10	270
	PSAX AV	20	87.1	93.1	62.5	35.0	92.5	7	411
	PSAX MP	20	95.0	90.7	55.0	15.0	157.5	6	270
	SXC	21	99.1	94.2	50.0	35.0	140.0	19	346

The data were analysed as described for the data obtained during the initial evaluation. There were no significant differences between views ($p=0.85$).

Time versus Adequacy at Follow-up:

Overall, there was a significant, negative correlation between the logarithmic transformation of time and quality score ($r = -0.333$, $p < 0.0001$), i.e. again, as time increased, quality score decreased. The same trend was evident in significant correlations between logarithmic transformation of time and A4C RV, PLAX and SXC, but not for the other views. The effect sizes were moderate (overall, A4C RV, PLAX) and large (SXC).

The diagnostic adequacy of the images generated at follow-up

Two hundred and forty-six images were obtained in the follow up session. The mean score overall for the images at the six week follow up session was 2.7 and the median score was 2. The highest mean score of 3.1 was obtained for the A4C RV view. The PLAX and PSAX AV both scored 2.4, which was the lowest mean score at follow-up.

Table 7: The adequacy scores overall, per image type and per view during follow-up

Sub-category		N	Mean	Std Dev	Median	25th Pctl	75th Pctl
Overall		246	2.7	1.0	2	2	3
Type	Still	123	2.3	0.8	2	2	3
	Video	123	3.0	1.1	3	2	4
View	A4C	42	2.8	1.1	3	2	4
	A4C RV	42	3.1	1.1	3	2	4
	PLAX	40	2.4	0.9	2	2	3
	PSAX AV	40	2.4	1.1	2	2	3
	PSAX MP	40	2.8	1.1	3	2	4
	SXC	42	2.6	0.9	2.5	2	3

A repeated measures mixed model was used with quality score as the dependent variable and view and type as fixed effects. There were significant differences between views ($p=0.0028$). The mean quality score (over a balanced set of image types) was higher for A4C RV compared to PLAX and PSAX AV. There was no significant interaction between view and image type ($p=0.79$).

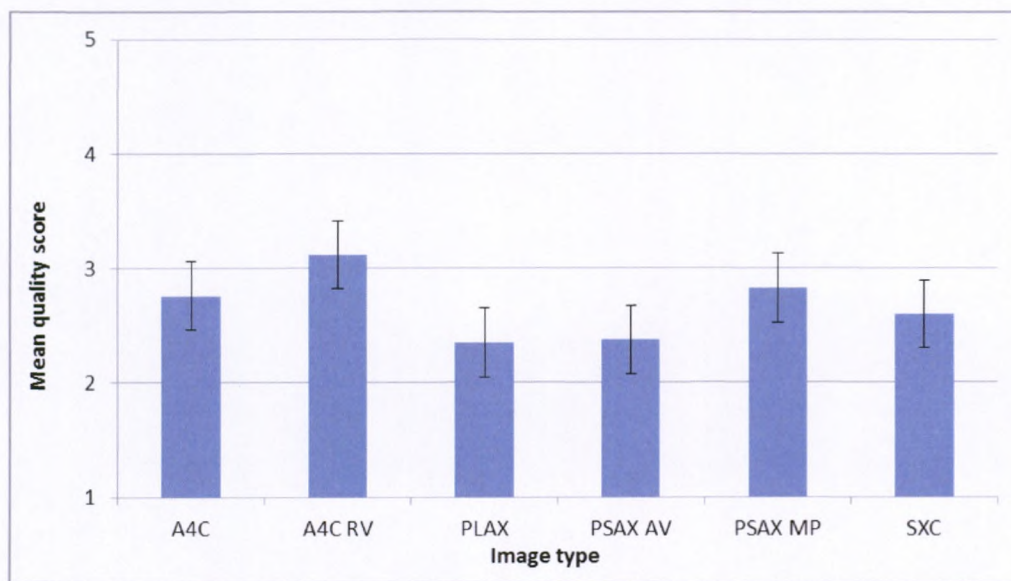


Figure 13: The mean adequacy score obtained per view at follow-up

Effect of image type – still versus video at follow up

There were significant differences between the still images and the video clips ($p<0.0001$). The mean quality score (over a balanced set of views) was higher for the video images compared to the still images.

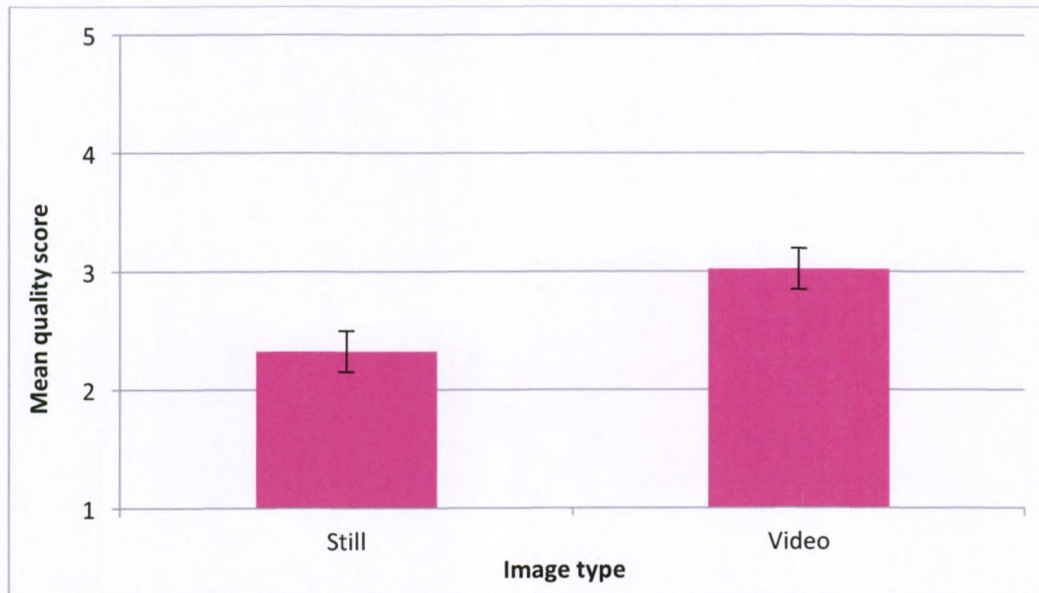


Figure 14: The mean adequacy score obtained per image type at follow-up

Diagnostic adequacy Score 3 or more at follow up

At follow-up 48.4% of all the images were adequate. More video clips were adequate for interpretation than still images, being 60.2 and 36.6 % respectively. The A4C RV view had the highest percentage of adequate images, while the SXC had the least percentage of adequate images.

Table 8: Percentage of inadequate and adequate views based on dichotomised score of 3 overall, per image type and per view at follow-up

		Inadequate		Adequate	
		N	%	N	%
Overall		127	51.6	119	48.4
Type	Still	78	63.4	45	36.6
	Video	49	39.8	74	60.2
View	A4C	20	47.6	22	52.4
	A4C RV	13	31.0	29	69.0
	PLAX	27	67.5	13	32.5
	PSAX AV	29	72.5	11	27.5

PSAX MP	17	42.5	23	57.5
SXC	21	50.0	21	50.0

Diagnostic Adequacy of the various views at follow up using categorised variable 3 or more

The effects of type ($p=0.0003$) and view ($p=0.035$) were significant. The video images were of higher quality: 60.2% of the video images scored 3 or more, compared to only 36.6% of the still images. The effect of view also reflects what we saw earlier: the proportion of adequate images was significantly lower for PSAX AV compared to A4C RV.

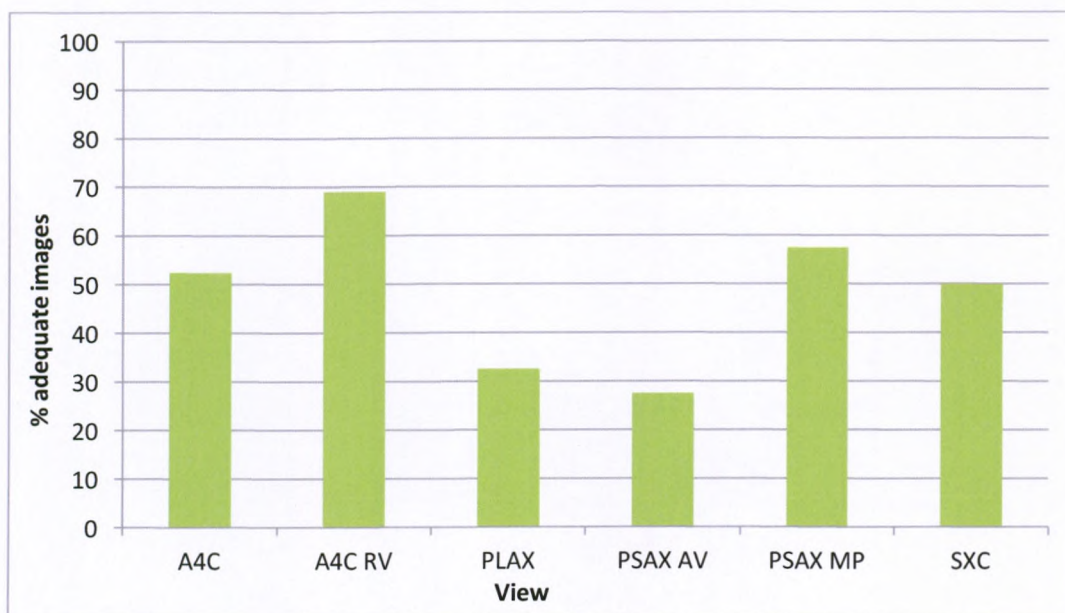


Figure 15: Percentage adequate views per view at follow-up

Diagnostic adequacy score 4 or more

The majority of images were inadequate when a score of 4 or more was used. More still images were inadequate (91.1%) than video images (59.3%).

Table 9: Percentage adequate views based on dichotomised score of 4 at follow-up overall, per image type and view

		Inadequate		Adequate	
		N	%	N	%
Type		185	75.2	61	24.8
	Still	112	91.1	11	8.9
	Video	73	59.3	50	40.7
View	A4C	29	69.0	13	31.0
	A4C RV	25	59.5	17	40.5
	PLAX	34	85.0	6	15.0
	PSAX AV	33	82.5	7	17.5
	PSAX MP	28	70.0	12	30.0
	SXC	36	85.7	6	14.3

Views SXC, PLAX and PSAX AV were omitted from the analysis due to the small number of adequate views, which led to problems with model convergence. The effect of type was significant ($p < 0.0001$). 40.7% of the video images scored 4 or more, compared to only 8.9% of the still images.

Diagnostic adequacy of the video images analysed alone at follow-up:

60.2% of all the views were adequate. The A4C RV view had the highest percentage of adequate images, being 81%, the PSAX AV view was the least adequate with 40% of the images being adequate in quality. There was no statistical difference between the views' adequacy, $p = 0.17$.

Table 10: Percentage of adequate video images at follow up based on dichotomised score of 3 or more

		Inadequate		Adequate	
		N	%	N	%
Overall		49	39.8	74	60.2
View	A4C	7	33.3	14	66.7
	A4C RV	4	19.0	17	81.0
	PLAX	11	55.0	9	45.0
	PSAX AV	12	60.0	8	40.0
	PSAX MP	8	40.0	12	60.0
	SXC	7	33.3	14	66.7

Data to compare performance at evaluation and at follow-up

Comparison of time taken during evaluation and during follow-up

Since the identity of most of the doctors could not be matched across the two sets of testing, a paired analysis could not be undertaken. Instead the data had to be treated as coming from two independent groups of doctors.

Using a repeated measures mixed model, with time as the dependent variable, model as a random effect, event and view as fixed effects, the data were analysed. The interaction terms between model and view, and view and event, were also included. A log transformation was applied to the dependent variable to

deal with the effects of the skewed distribution of the data on the violation of the model assumptions.

There was no statistical difference between the time taken during the initial evaluation and at follow-up, ($p=0.12$). There was less variation in the times taken between the participants during the follow-up. It appears that the quickest participants from the initial evaluation session had slowed down during the follow-up session.

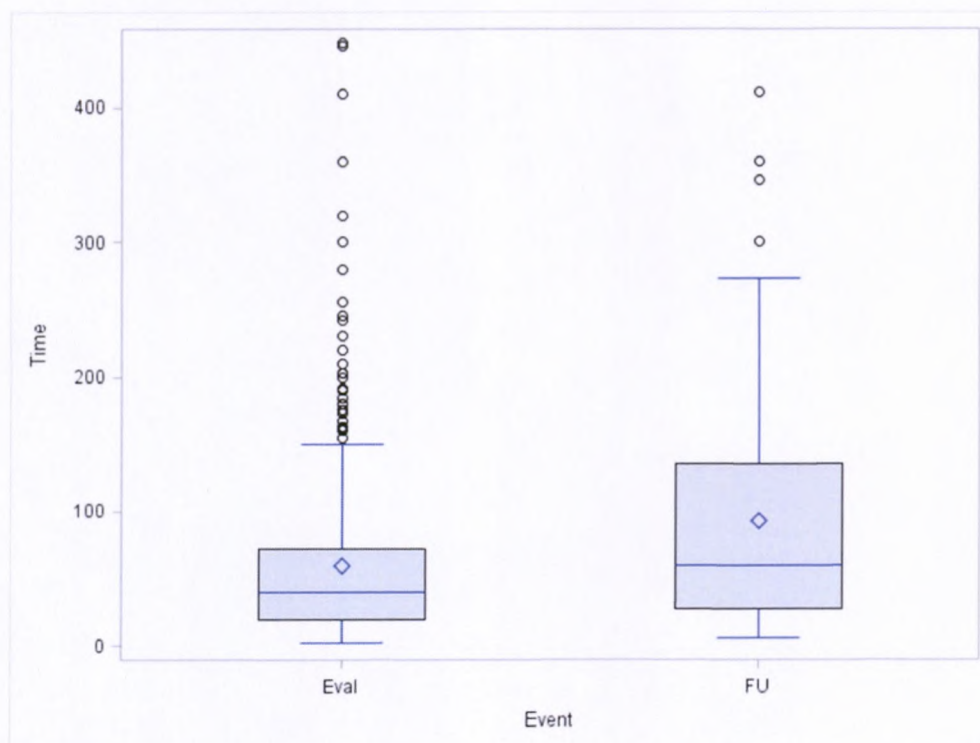


Figure 16: Box-and-whisker plot comparing the times taken by the participants at evaluation and follow-up

Comparison between the diagnostic adequacy of the images at evaluation and at follow –up

Since the identity of most of the doctors could not be matched across the two sets of testing, a paired analysis could not be undertaken. Instead the data had to be treated as coming from two independent groups of doctors.

A repeated measures logistic regression was used with the dichotomised score as the dependent variable, model as a random effect, event, type and view as fixed effects, and doctor as a repeated effect. The interaction terms between model and view, model and type, type and view, type and event, and view and event, were also included.

There was no significant difference in overall quality score between evaluation and follow-up ($p=0.10$). There was no difference between the different views between evaluation and follow up, $p=0.19$. Once again, a significant difference between the type of image modality was demonstrated between evaluation and follow up, $p=0.049$.

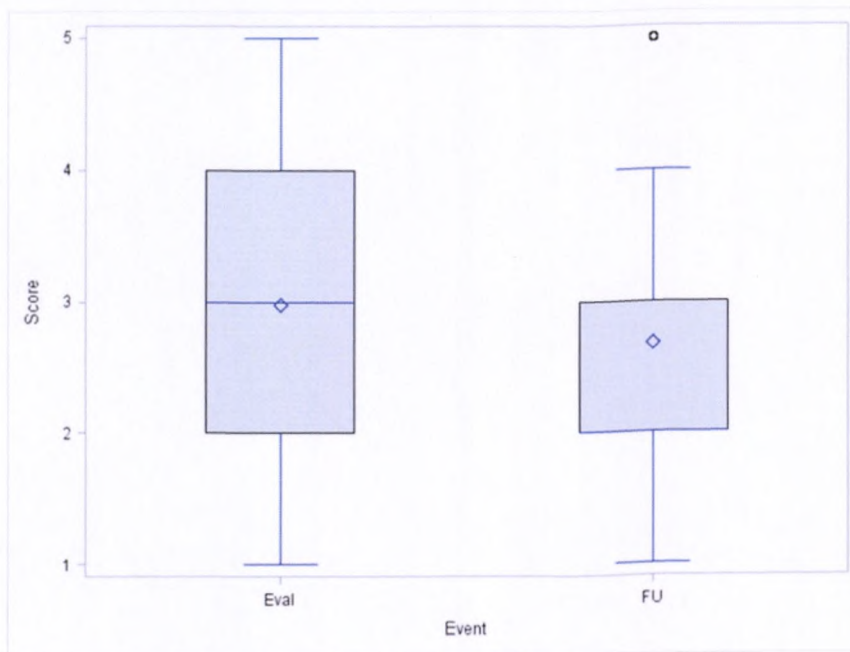


Figure 17: Box-and-whisker plot demonstrating adequacy score obtained at evaluation and follow-up

Dichotomised score 3 or more

The effect of event was significant ($p=0.034$). The proportion of adequate images decreased from 63.4% at evaluation to 48.4% at follow-up. The effect of type of image modality still versus video remained significant as demonstrated earlier.

Dichotomised score 4 or more

View SXC was omitted from the analysis due to the small number of adequate views, which led to problems with model convergence. The effect of event was significant ($p=0.048$). The proportion of adequate images decreased from 35.3% at evaluation to 24.8% at follow-up.

Comparison of the diagnostic adequacy of the video images analysed alone between evaluation and follow up using dichotomised score of 3 or more:

There was a significant difference in adequacy between the video images obtained at evaluation and follow-up, $p= 0.028$. The proportion of adequate images decreased from 77.9% to 60.2% at follow-up.

Results of the questionnaire after the training course

A questionnaire was employed to understand the participants' perception of the training. A five-level Likert scale was used in most of the questions to assess the participants' perceptions and attitudes towards the training.

After the training session, the participants felt that their knowledge of basic echocardiography had improved. Twelve of the participants (46%) stated their knowledge had improved and eight (31%) felt their knowledge was greatly improved after the training course. Twenty-four of the participants felt that the lectures were useful to very useful in aiding their understanding. Twenty-three participants stated that the practical, hands-on training was helpful to very helpful in enabling them to confidently acquire images.

Nineteen participants felt that the hands-on training was the most useful part of the training, while six stated that both the lectures and the hands-on practical session were useful. When asked whether there was enough time devoted to their practical hands-on training, ten participants felt there was an adequate amount of

time, while ten more were neutral in their response. Only five stated that there was plenty of time for them to practise. None stated that there was not enough or not nearly enough time for them to practise prior to them being evaluated.

When asked which of the views was easiest to learn and perform; twelve participants (46%) considered the parasternal long axis view to be the easiest. Two participants answered that the easiest view to acquire depended on the model which they were scanning. Only two participants thought that the SXC view was the easiest view to acquire.

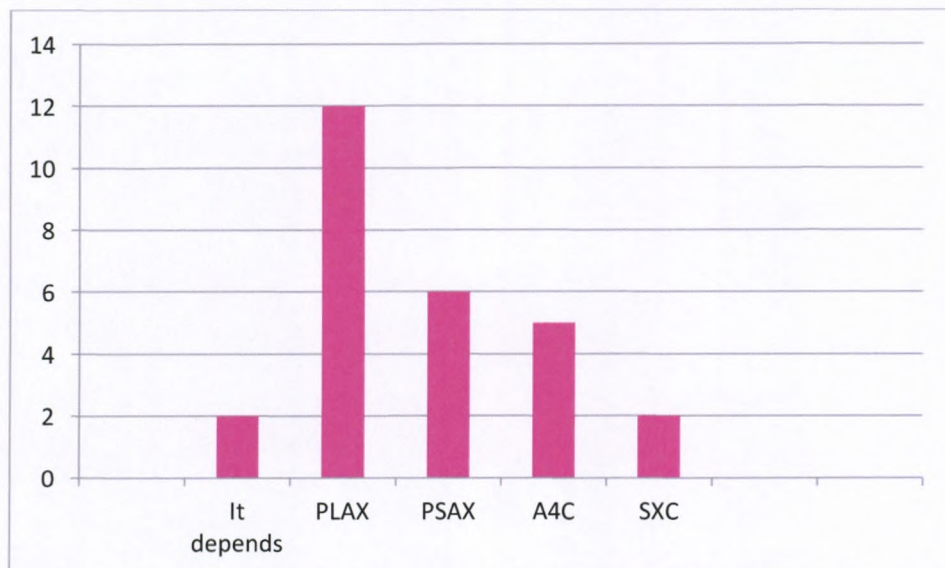


Figure 18: Number of participants and which view they found the easiest

Seventeen of the participants (65%) thought that the SXC view was the hardest to acquire while 2 (8%) thought that the PLAX view was the hardest to achieve.

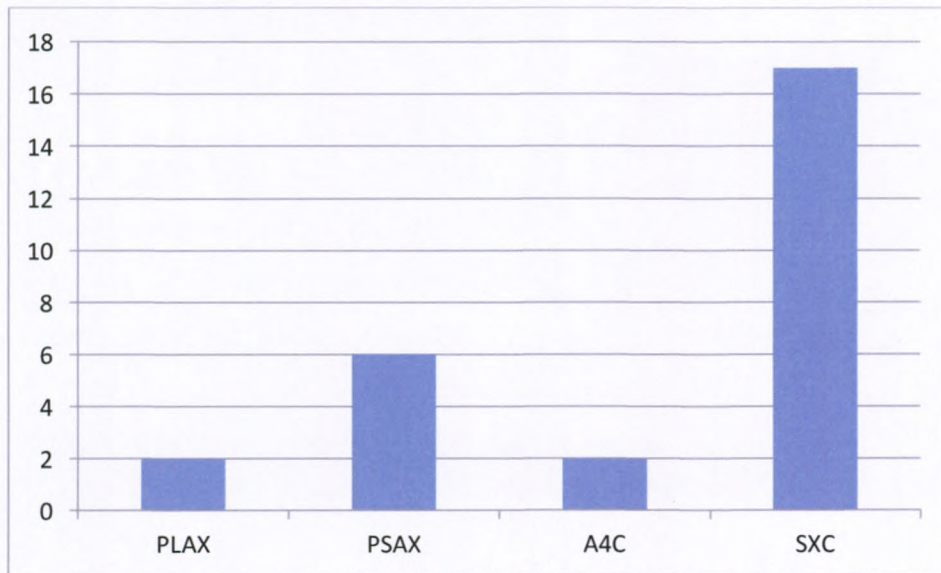


Figure 19: Number of participants and which view they found most difficult

When asked whether they thought that one day was sufficient to learn basic echocardiography for pre-participation screening, the group was evenly divided. Thirteen thought that one day was sufficient while twelve did not. One participant did not answer the question. Those who thought one day was insufficient reasoned that one needed more time to be confident and more time was needed for novices to become efficient and to produce adequate images.

Results of the six week follow up questionnaire

Twenty one doctors were willing to participate in the follow-up testing session and filled out the questionnaire afterwards. When asked whether the checklist which they were allowed to use during the six week follow up session was useful, all participants answered yes. They stated that they would have forgotten how to perform the views without it, and that it served as a useful reminder to adjust the depth of the image and the angle and position of the probe on the model's chest.

When asked if they would have managed without the checklist, 16 participants said no, 1 said only some views would have been manageable without a checklist, another participant stated that the views would have taken much longer without a checklist while 3 felt they could have managed without the checklist.

The participants were asked to rate their degree of skill retention from the course. No participant thought they possessed less than 20% of the skills that they had learnt. The majority thought they had between 41 and 60% skills retained, as shown in the bar graph below.

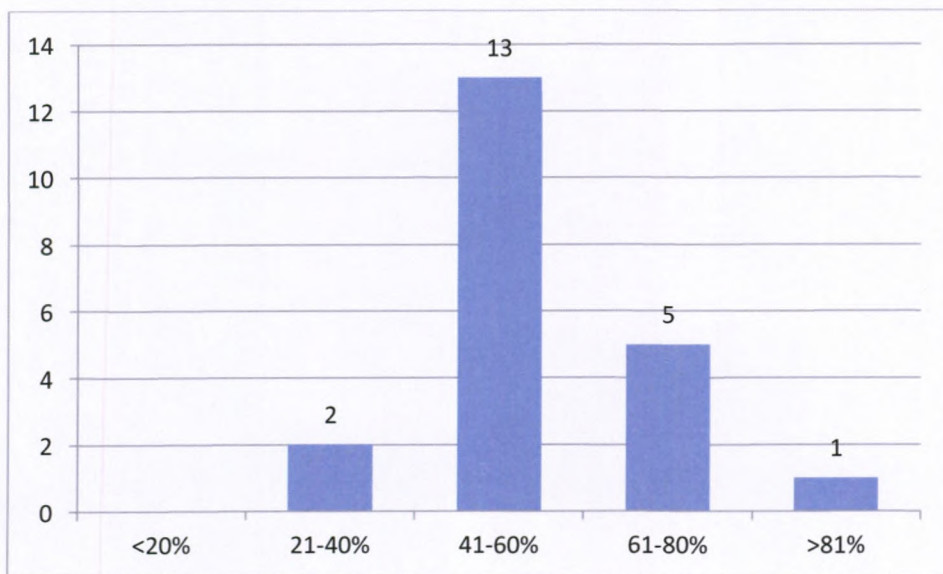


Figure 20: Degree of skill retention as perceived by the participants at follow-up

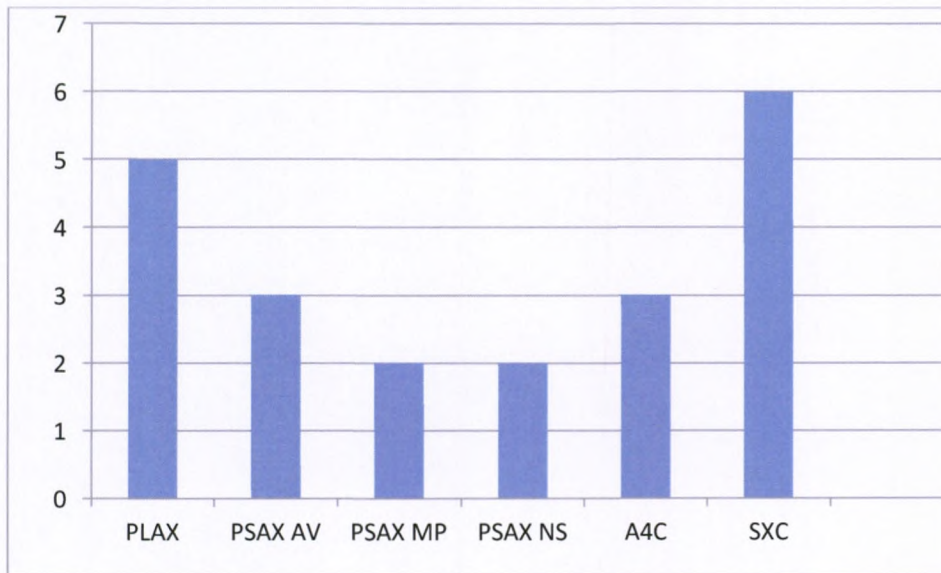


Figure 21: Number of participants and which view they found most difficult during the follow-up session

Six of the participants thought that the SXC view was the most difficult to perform, two participants stated that the parasternal short axis view was the most difficult, but did not specify which level they found most difficult, shown on the bar graph as PSAX NS – level not specified.

The participants were asked which view was easiest to perform during the follow up session. None stated that they found the PSAX AV the easiest, while the largest proportion stated that they found the PLAX view the easiest.

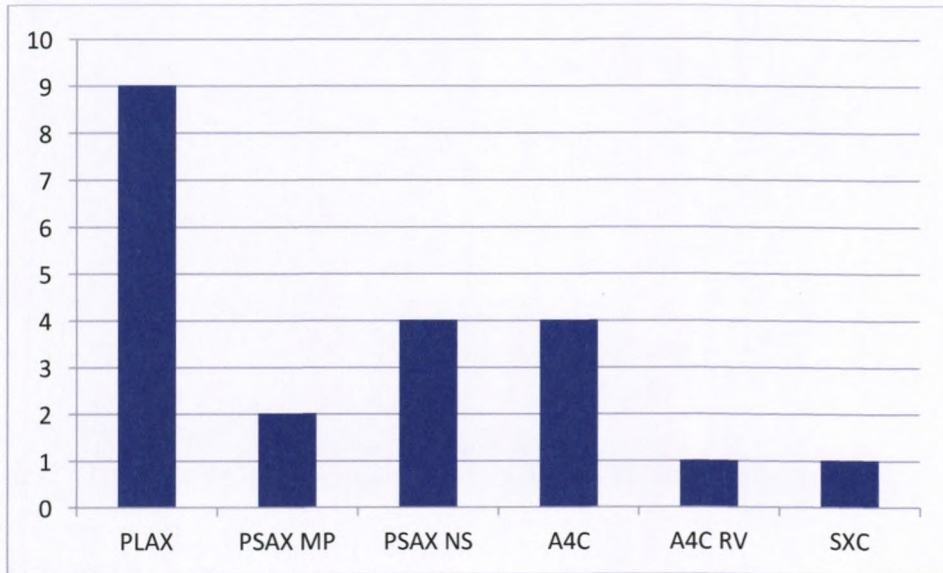


Figure 22: The number of participants and which view they found the easiest at follow-up

Fourteen participants said that they did not practise echocardiography during the six weeks between the training course and follow up. The remaining seven stated that they had practised echo as part of their clinical work. When asked about how confident they felt about the echocardiography skills after follow-up, of those who had practised echo, 3 felt confident, 1 still felt unconfident and 4 felt neither confident nor unconfident.

Chapter 5 **DISCUSSION**

Time taken to acquire the views by the participants during the study

Time taken to acquire the views after training

The participants were able to acquire the views rapidly after training. The median time that the participants took to acquire a view after the initial training was 63.4 seconds. There was a significant difference in time taken to acquire the different views. The median time to acquire the A4C view was significantly longer than to acquire the PSAX MP view. The PSAX MP view is quick to acquire as we teach the novices to tilt the probe caudally from the PSAX AV view to get the MP view. The A4C view is more technically challenging to acquire due to the variability in the position of the A4C on different people's chests. Thin, tall people's A4C view is often more medial than anticipated and requires more angling of the probe upwards to visualise the A4C correctly. This could occur frequently in those athletes who are tall and thin therefore the A4C view may take longer in this population as well. It also often requires more adjusting of the model's position to obtain the A4C view, often with the model in the left lateral position, thus taking longer.

Time taken to acquire the views during the follow-up session

During the follow-up session, there was no difference in time taken to acquire the different views. There was less variation in the times taken between the

participants during the follow-up. It appears that the quickest participants from the initial evaluation session had slowed down during the follow-up session demonstrating some loss of skill from their initial training session.

Time taken during evaluation and follow-up – the effect of the checklist

There was also no statistical difference between the time taken during the initial evaluation and at follow-up. The participants were allowed to use a checklist to remind them of how to perform the views correctly during the follow-up session. The reason for this is that in a real-life setting, novice echocardiographers would be encouraged to refer to a checklist to ensure that their views would be adequate for an expert to refer to and screen. Since the participants had a checklist to remind them of how to perform each view, they were able to perform the views more rapidly than if they had to rely on their memory of what they had been taught six weeks prior. Therefore the checklist is likely to be responsible for the fact that there was no significant difference in time taken between the initial evaluation and follow-up. However, if a paired analysis on the data could have been performed a significant difference may have been shown. Also, if half of the participants were given a checklist and the other half were not in the follow-up session, the effect of the checklist would have been more clearly shown. However, this was not done due to the small number of participants that were recruited into the study.

The correlation between time versus adequacy

There was a significant negative correlation between time taken to acquire the view and overall adequacy score at evaluation, although the effect size was small,

$r = -0.229$. This effect was also seen at follow up, and was moderate, $r = -0.333$.

There was again a negative correlation between time and adequacy for particular views at follow up, the effect size being moderate to large. This indicates that the slower the participant was, the poorer the adequacy score of the view would be and more time taken to acquire the view was unlikely to improve the adequacy of the view. This correlation also suggests that a certain number of the participants were not only efficient at acquiring the views, but the quality of their views was good as well.

The top six participants' times were significantly shorter than the poorest performing seven's times. The mean time in seconds obtained by the top six was 29 seconds and the bottom seven's mean time was 43 seconds. This suggests that the participants who obtained excellent views were also quick in doing so. It would be of benefit to select these particular individuals after the training program through an evaluation session and use them to perform the pre-participation screening. However, it is unknown whether the difference between the participants' times would translate into a clinical benefit in a screening echo program.

The diagnostic adequacy of the images obtained during the study

The diagnostic adequacy of the images obtained after the initial training

After the 5 hour training session, the participants achieved an overall mean and median score of 3.0 for all the images obtained. The mean score obtained

amongst the still images was 2.6 and for the video clips was 3.3. During the initial evaluation after training, the novice echocardiographers were able to achieve adequate images for qualitative assessment and screening 63.4% of the time when the score of the still and video images were combined. The video images had a better overall quality, being adequate for pre-participation screening 77.9% of the time. When a score of 4 or more was considered, which would be what would be required for quantitative analysis, the diagnostic adequacy decreased to 35.3% when the images were combined and 48.2% of video clips when the video clips were analysed alone.

A score of 3 or more and 4 or more was used to determine how many images would be suitable for qualitative and quantitative measurement. The number of images suitable for quantitative analysis was low, even when the video clips were analysed alone. However, since pre-participation screening involves getting a qualitative assessment of the heart to screen for abnormalities, we consider the need to obtain a score of 4 or more to be less important. Abnormalities or concerns seen on the screening qualitative echo would then be red flagged for a formal echocardiogram to be performed by an expert echocardiographer.

The top six participants in the study all obtained adequate video clips 93.3% of the time during the initial evaluation after training. In contrast, the bottom seven participants obtained a percentage of adequate images between 33 and 60%. This indicates that amongst novices to echocardiography, there exist a number of individuals who can produce adequate images for pre-participation screening echo after being trained in a one day course. These individuals can be detected through

an evaluation session after the training, and can be selected to perform the pre-participation screening. For example, they could perform the screening echoes several days after the training.

The percentage of adequate views obtained by novices after a one day training course in peri-resuscitation echocardiography (FEEL) was also studied by Price et al (29). Forty-five participants were evaluated after the course, whereby they were required to demonstrate the six views they had learnt on one model. Video clips were assessed in real time, still images were not used. They were able to acquire adequate views more than 90% of the time on all the views except for the parasternal short axis view and the apical two chamber view. In this study the participants were able to obtain 100% adequate subcostal views. The fact that the participants only had to scan one model could be the reason why the percentage of adequate views was so high.

The diagnostic adequacy of the still images versus the video clips

This study demonstrated that the video images were superior in quality to the still images. This effect was evident during the evaluation and follow-up sessions. This is most likely due to when the participants chose to freeze and save the still image, the still image tended to lack clarity, making it more difficult to assess the various structures. The instructors were not allowed to help the participants with deciding when to freeze the image and would save the image when the participants instructed them to.

The video clips, which recorded 3 heartbeats, allowed those analysing the images to see if the image was on plane, to assess the endocardial borders and to view the various anatomic structures, which led to a higher score. Therefore only video clips would be recommended for pre-participation screening due to them being significantly more adequate. An expert viewing the video clip can simply freeze the clip and obtain still images when required, being able to scroll through the clip and freeze the image at the right moment. In hindsight, more emphasis on how to freeze then scroll through to save the best still image should have been taught. This could have led to better still images in this study.

The relationship between adequacy of view based on image type

The adequacy of a particular view was dependent on which type of imaging modality was used; being either still image or video clip when the data was dichotomised as 3 or more. This effect was seen also at follow-up. The adequacy of the image improved when a video clip was performed. This was most significant for the A4C view, where the difference in adequacy increased more than the other five views. The overall adequacy for the A4C view for the still images was 44.9% which increased to 86.5% for the video clips. This difference in adequacy can be explained by the timing of the freezing of the still image which led to inferior quality of the still images. The video clips also allowed a better assessment of certain features which are critical for the A4C view such as the absence of foreshortening and visualisation of the endocardial borders which helps to determine the size of the cardiac chambers and the visual assessment of the ejection fraction. It is easier to determine these features on a moving image than a still image for this

view, as the still image might be frozen during diastole or systole by a novice, leading to significantly different LV volumes. In other views, such as the PSAX MP view, it is easier to get a good overall impression on a still image.

The diagnostic adequacy of the different views

There was no statistical difference in adequacy between the different views obtained immediately after training. All the images from the views apart from the SXC were more than 60% adequate and 77.9% adequate when the video images were analysed alone. This is likely due to equal emphasis placed on each view during the training and equal amounts of time spent on each view.

When asked which of the views was easiest to learn and perform after training, the majority (69%) found the parasternal windows easiest to perform; of these twelve participants (46%) stating the parasternal long axis view to be the easiest and six stating the parasternal short axis view to be easiest. During follow-up nine participants (43%) still found the parasternal long axis the easiest to acquire.

A review of the literature revealed that the parasternal view was the easiest to learn by novices (30, 31). In Mozzini et al.'s study which examined a short training course in focused echocardiography for Internal Medical residents the parasternal view was the easiest to achieve (30). The parasternal view was also easiest to obtain in the study by Chisholm et al (31). In this study, the A4C view was more difficult to acquire and took longer, whereby only 57% of the participants obtained the view within the 2 minute time limit. The A4C view was most difficult to acquire

along with the subxiphoid view in Mozzini et al.'s study. This same trend was demonstrated in our study whereby the A4C view took longer to acquire than the PSAX MP view.

The participants had more difficulty with the SXC view in this study, as they achieved adequate images only 48.2% of the time. This was also the view they found subjectively to be the hardest to acquire, both following training and at the follow-up session. The SXC is traditionally the first view that is taught, especially in emergency medicine and critical care, as it is thought to be the one frequently accessible in supine patients (32). However, studies have shown only limited success in attaining this view (31, 32). Furthermore, in Chrisholm et al.'s study, the A4C view was shown to be obtainable with better quality and significantly more often than the SXC view, even amongst ventilated patients. Mark et al performed 70 echocardiographic exams on 70 patients and found the parasternal long axis view achievable in 98% while the SXC view was only possible in 35% of patients (33). These studies are in contrast to Price et al, where the SXC view was obtained 100% of the time, however only one model was used (29).

It is likely that the participants struggled to obtain good subxiphoid views in this study as the models used were healthy young men with strong abdominal muscles. Adequate subxiphoid views were still not obtained most of the time even though the routine methods to improve the view were taught during the training, for example, bending the knees to relax the abdominal muscles. Based on these findings and that of the other studies mentioned it is apparent that the subxiphoid view is more difficult to obtain than previously taught and less emphasis should be

placed on teaching this view to novices. More attention should be placed on teaching the parasternal windows, which novices are able to acquire after training. The subxiphoid view also has a limited application in comparison to the apical 4 chamber view in detecting most pathology, except in the analysis of septal defects and the visualisation of small pericardial effusions.

The diagnostic adequacy of the images at follow-up

One day courses for echo training are the norm e.g. FATE, (26, 29) FEEL, (34) and Focused transthoracic echocardiography (FTTE) (31) to name a few. All demonstrate that proficiency can be quickly gained as demonstrated by high proficiency scores immediately examined after the training. However few have examined the degree of skill retention.

The mean overall score was 2.7 at follow-up and the median score was 2.0. The still images scoring 2.3 and the video images scoring 3.0. There were significant differences between views at follow-up. The mean quality score was higher for A4C RV compared to PLAX and PSAX AV. This is likely due to the fact that the A4C RV view is easier to acquire for novices as visualisation of the RV apex and tricuspid valve are the only major prerequisites to a good view. The PSAX AV view has more chambers and valves that ought to be visualised by getting a more precise alignment of the probe which is difficult to perform all at once for a novice. Likewise, the PLAX view requires that both the mitral and aortic valves are seen and that the image is on plane so that false assumptions on the LV cavity dimensions and functions are not made.

Using the categorised variable of 3 or more as adequate, 48.4% of all the images were adequate at follow-up. The video images when considered alone still only were adequate 60.2% of the time. This degree of adequacy would certainly be insufficient for pre-participation screening, whereby more than 90% adequacy would be acceptable. This demonstrates that novices would not retain enough skill to perform screening echo of a sufficient quality if they are not practising the skill regularly. Certainly a period of six weeks would be too long between sessions.

The majority of images were once again inadequate when a score of 4 or more was used. More still images were inadequate (91.1%) than video images (59.3%). The participants were unable to retain enough skill after six weeks to obtain images of sufficient quality for quantitative measurements.

Skill retention: Comparison between initial training and follow up

In this study no significant difference in overall quality score between evaluation and follow-up was shown. There was also no difference between the different views between evaluation and follow up. This is likely due to the participants being able to consult the echo checklist in order to check that their views were correct. With no checklist present, these novice echocardiographers would not be able to achieve similar scores six weeks later. However this could not be definitively ascertained due to a paired analysis of the data not being possible, leading to the study being underpowered to detect a difference between evaluation and follow-up. A future study where half the participants have access to a checklist and the

other half not could further delineate the effect of the checklist on the participants' scores.

When the participants were asked if they found the checklist useful, they unanimously agreed. Reasons given included that they would have forgotten how to acquire the views after the six weeks or that they would have taken much longer without it. The data agrees with the participants responses in that the adequacy scores and time taken to acquire the views were similar.

Categorised score of 3 or more between evaluation and follow-up

Significant differences were detected between evaluation and follow-up when a dichotomised score of 3 or more was used. More of the images (still images and video clips combined) obtained after initial training obtained a score of 3 or more than at follow-up. This is also demonstrated with the video clips analysed alone. Adequate video clips decreased from 77.9% to 60.2% at follow-up. The dichotomised score suggests that there is a loss of adequacy over a six week period from the time of training, despite the use of a checklist. It would be unwise to solely rely on a checklist to enable future echocardiographers to obtain adequate images without regular practice to retain the skill.

There was a significant difference in adequacy between the video images obtained at evaluation and follow-up. The proportion of adequate images decreased from 77.9% to 60.2% at follow-up. This demonstrates that the skill retention of echocardiography over a six week period is low even if a checklist is present to

remind the novice. Echocardiography is a skill that needs constant reinforcement through exposure and practice for it to be retained.

A portion of novices who are able to get more than 90% adequate views after training could be selected to perform the pre-participation screening the following day on the athletes. A short time period between the training and the actual screening would help reduce the risk of loss of skill retention that inevitably occurs when the skill is not constantly reinforced through practice. If a longer duration of time between the training and screening occurs, a refresher course should be provided.

Frederickson et al (26) demonstrated that the technical quality of echoes performed by novices can be improved by limited a mentorship based intervention. Novices in echocardiography were trained in the FATE exam, following which 86% of the images were adequate for interpretation. On a separate day the novices performed additional FATE studies under the supervision of an expert who guided them in improving the quality of their images. Following this intervention the number of diagnostically adequate images rose to 93%. A similar intervention like this can be done with the novices after the training and before the actual pre-participation screening. This would help to maintain the diagnostic adequacy of the novice's scans and enable the pre-participation screening to be economically feasible, reducing the need for referral for formal echo.

Skill retention as perceived by the participants

Half of the participants felt that they had retained 40-60% of what they had learnt six weeks prior. Five (19%) thought they had retained 61-80% of what they had learnt. Again, it would have been interesting to see how the participants viewed their skill retention if they had not had access to a checklist during the follow-up.

Practising echo between evaluation and follow-up

Fourteen participants said that they did not practise echocardiography during the six weeks between the training course and follow up. The remaining seven stated that they had practised echo as part of their clinical work, all of which was limited to less than an hour of practice each. When asked about how confident they felt about the echocardiography skills after follow-up, of those who had practised echo, 3 felt confident, 1 still felt unconfident and 4 felt neither confident nor unconfident. It is difficult to deduce from such small numbers if those who practised echo had boosted the adequacy scores acquired by the group during follow-up.

The learning curve of echo in other studies

The need for frequent practice in echocardiography for skill retention and development has been demonstrated in the literature. Chrisholm et al (31) also examined the learning curve after initial training in echo. The participants of the study were staff Emergency Physicians who were trained to use echo through a

one day course. They had access to echo in their department, and were encouraged to practise as much as possible. Their skills were evaluated five months after the initial training. This study showed that the quality of the A4C and SXC views improved as the participants performed more scans.

Mozzini et al (30) studied the knowledge and skill acquisition of basic echo amongst internal medicine physicians. Two groups were trained, one group was given nine hours of training and the other 18. Technical ability to acquire the different views was compared against the tutor as the gold standard. The parasternal views showed substantial agreement with the tutor's in the 18 hour group but not the nine hour group. Neither group was able to obtain adequate apical and subxiphoid views when compared to their tutor. They concluded that an 18 hour course was sufficient to acquire adequate parasternal views but not the apical and subcostal views.

A minimum of 30 scans per year was considered to be sufficient to maintain skill retention following the Focused echocardiography entry level (FEEL) course once the novice has obtained at least 50 scans (34).

The usefulness of an OSCE to test competence after training

Duration of training has been shown to be weakly correlated with competence in scanning ability (35). Nair et al compared the scores obtained by cardiology fellows in their in-training evaluation report (ITER); which is a non-structured subjective assessment of a fellow's scanning and interpretive skills, to the

performance of the fellows in an objective structured clinical examination (OSCE). The OSCE was scored based on a procedural checklist which factored the technical aspects of the image and the measurements obtained. A Global rating score was used to determine if the images overall were inadequate to adequate using a scale from 1-5. The OSCE scores were compared to the scores obtained by expert sonographers scanning the same patients. Traditional methods of assessing proficiency; namely the number of echoes performed and interpreted and the number of years of training were also assessed and compared to the OSCE scores.

All fellows had passed or exceeded requirements in their ITER, however the OSCE scanning scores revealed that the overall image quality obtained by all Fellows were considered barely adequate as per the Global Rating Scale, compared with the expert sonographer. There was also a weak correlation between the number of months of training to the scanning ($r = 0.39$) and interpretation ($r = 0.42$) scores in the OSCE. The OSCE proved to be a better tool to assess the fellows' actual scanning proficiency.

A checklist to rate the diagnostic adequacy of the images by an expert

An objective structured clinical examination (OSCE) has been shown to be a more reliable way to determine competence particularly if a procedural checklist is used (27, 35). A procedural checklist that notes the technical aspects of an image such as depth, gain, clarity of valves and borders and the image being on plane can ensure that these vital factors that ensure quality are not missed. An overall Global

rating scale is obtained based on how many aspects of the checklist are achieved or missed. Using this procedure was shown to have good intra-rater and inter-rater reliability. Based on these studies, the "Data collection checklist" (Appendix 6) in this study was developed, which rated the technical aspects of the image, and an overall score was given. This instrument could be used to select novices who can obtain excellent images after training for the pre-participation screening. The validity of the checklist in the pre-participation screening setting could be a subject of further study.

Deficits encountered in training and recommendations for future training

A combination of lectures with hand-on time to practise echo appears to be an effective method in teaching echocardiography to novices and enables the majority of them to produce adequate images. It is essential that enough time is given to the participants to practise acquiring the views on different models.

Different instructors use different words to explain a concept to the novices, which can cause confusion. For example, it was noted that one instructor said " point the head of the probe upwards" while another said " point the tail of the probe downwards " to explain how to angle the probe more cranially. For future courses, one should ensure that all instructors use the same words when teaching the novices.

An expert to scan all the models to serve as a comparison to the novices' images was not performed. It could be beneficial to have expert images to compare to when determining the adequacy scores of the participants.

Limitations of this study

Selection bias may have been present as the doctors volunteered to participate in the study to learn echo. Therefore they were motivated to learn and this may have resulted in higher scores. However, if novices were trained to learn screening echo and were aware that the best five would be selected to do the actual screening and be paid for it; the financial incentive may also cause them to perform better.

The data from evaluation could not be matched to the follow-up data so the groups had to be treated as unpaired. Had it been possible to pair the data, the effect of skill retention at follow-up could have been clearer. The unpaired data resulted in the study being underpowered which increased the potential for type 2 error.

The analysis of the images was done using an adequacy checklist and the overall score was given based on the researchers' overall impression of the adequacy. A more objective analysis could have been done where the different parameters are given different weights to each based on their relative contribution to the overall adequacy of the image from which an overall score can be calculated.

Five participants (19%) were lost to follow up. It is possible that the overall outcome of follow-up may have been affected, particularly since unpaired statistics was used.

A third of the follow-up doctors practised echo between training and follow-up. Since echocardiography has been shown to improve patient care it was considered to be unethical to discourage them from practising or using echo if they had access to it in their clinical practice. It is not possible to identify from the data who practised and who did not so its effect on the follow-up data is not known. However, the effect of the few who practised may have been minimal as less than an hour of practise was reported by them. Those who practised also did not demonstrate higher confidence levels than those who did not practise.

The effect of the checklist could have been further studied at follow-up whereby half the participants are given a checklist to refresh their memory and check their views are correct and the other half not.

Strengths of this study

This is the first study known to examine the ability of novices to perform pre-participation screening echo after limited training. It is also one of few that have looked at the degree of skill retention after an echocardiography course. This is very important as novices may use echo in their clinical practise to make important decisions on management and to make a diagnosis which could have adverse consequences if performed incorrectly.

Healthy athletic models were chosen for the study to simulate performing screening on athletes. Whereas several studies have only used one model for the novices to scan to evaluate their learning, three models were used in this study.

This enabled the participants to get more experience with scanning and is a more realistic scenario.

The instructor to novice ratio was small, which allowed the participants to have individualised teaching.

The researchers were blinded on analysis of the images performed by the participants, which reduced the possibility of bias. An OSCE type of evaluation was used, which has been shown to be effective in detecting ability to perform echo in other studies.

Chapter 6 **CONCLUSIONS**

It is feasible to use novice sonographers to perform pre-participation screening echocardiography under the following circumstances:

- The skill of candidates is assessed after training and competent individuals are selected
- A checklist is used to assist with image acquisition
- Video images should be used rather than still images for screening purposes.
- A refresher course should be provided if it is longer than a week from the last course

This will enable a lower cost access to screening echo in pre-participation screening programs.

There was no significant difference overall between the diagnostic adequacy score between views although some views take longer to perform than others, for instance the A4C view took significantly longer than the PSAX MP view to acquire. The majority of novice echocardiographers can obtain images within 60 seconds.

There is growing evidence in the literature and in this study that the subcostal view is difficult to acquire by novices, and perhaps emphasis on this view as the first view to be taught to novices may be misguided.

There is a loss of skill retention in echo over six weeks although the use of a checklist attenuated this. Skill retention should be reinforced through regular practice.

Recommendations

There are some novices who are adept at learning echo quickly and can obtain images rapidly. These novices can be identified through an OSCE type of assessment and can be selected to perform pre-participation screening. Further research is required to determine the gradient of loss of skill in echocardiography and to determine after how long a refresher course should be done in order to maintain adequate images performed by novices. If less than six weeks has lapsed since the training course, limited training to refresh skills may all be required, but should be further researched.

The pre-participation screening protocol taught to the novices in this study is considered sufficient to screen for the causes of Sudden Cardiac Arrest in the South African population. Future screening protocols may have to be adjusted based on demographics of the population being screened. For example, ARVC is more common in Italy so a screening program in that population may require more advanced interrogation of the right ventricle.

The novices in this study unanimously found the checklist to be useful during the follow-up session. Further research is recommended to determine how a checklist can be used to improve the quality of novices' echo studies.

Finally, a wide range of doctors took part in this study. This reflects that many doctors are interested in learning this skill to use in their respective fields. Future training should recognise this need and aim to provide good quality teaching that can be tailored to their respective fields.

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Chapter 8 Appendices

Appendix 1

Can echocardiography naïve medical personnel obtain adequate standard echocardiographic images after a single day of training, for the purposes of pre-participation screening echocardiography?

INFORMATION SHEET

June 2014

Dear Colleague

Good day, my name is Victoria Stephen, and I am an Emergency Medicine Registrar at the University of the Witwatersrand. I am doing research for my MMed degree in Emergency Medicine.

Pre-participation screening is the process whereby an athlete is screened for conditions that may predispose an individual to Sudden Cardiac Arrest, thus allowing the individual to undergo further investigation in order to prevent untimely death on the sports field. There are several ways of screening an athlete. Current methods include a focused history, family history and physical examination with or without an ECG. Attention has turned to the incorporation of echocardiography in pre-participation screening.

In order for more athletes to be able to access echocardiography, medical personnel ought to be adequately trained in echocardiography for the purposes of pre-participation screening; being able to produce good quality images that will be interpretable by a Cardiologist or Emergency Physician. The aim of my

research project is to determine whether echocardiography naive medical personnel can be trained to perform echocardiography for pre-participation screening through a single day of training.

I would like to invite you to be a part of this scientific study. Participation would involve the following:

1. To attend a training course in the basics of echocardiography: how to perform echo, how to produce good quality images, and a practical session allowing you to practise what you have learnt on patients. This will run from 8 am to 1 pm.
2. The training will be followed by a session whereby you will perform a pre-participation echo examination on several volunteer models. This will run from 2pm-4 pm.
3. You will be asked to fill out three short questionnaires during the course, how much you learnt and how confident you felt about performing pre-participation echo after a day of training.
4. There will be a follow-up session 6 weeks after the initial course. This will take approximately 30 minutes.

This research has been approved by the Human Research Ethics committee of the University of the Witwatersrand. Confidentiality will be maintained at all times. You are free to withdraw from participation at any stage with no adverse consequence to yourself; no questions will be asked. Please read the "informed consent" form for more information.

There is no financial compensation for participating in the study. You will however benefit professionally as you will have the opportunity to learn the skill of echocardiography. There will be refreshments in the form of lunch provided during the day.

The information that we gain from the study will be very helpful in understanding how much time is required to train medical personnel to perform

pre-participation echo. The hope is to be able to train medical personnel in an effective and efficient way to be able to provide more athletes access to this valuable resource. It is also an opportunity to learn the skill of basic echocardiography which you can begin using in your daily practice and one that you can continue to develop and learn in the future.

If you are willing to participate in this study, please sign the consent form attached.

Many thanks

Victoria Stephen

Phone 082 851 0752

Email victoriastephen@icloud.com

Appendix 2

Can echocardiography naïve medical personnel obtain adequate standard echocardiographic images after a single day of training, for the purposes of pre-participation screening echocardiography?

CONSENT FORM

Dear Colleague

Thank you for reading the attached information sheet. If you are willing to participate in the study, please sign the consent form below.

Dr Victoria Stephen

MBChB (UCT), Dip PEC (SA)

Emergency Medicine Registrar, University of the Witwatersrand

082 851 0752

victoriastephen@icloud.com

I hereby consent to participate in this research project. I have been informed that there are no risks attending to the participation of this study. I understand that I am free to withdraw my consent at any stage, without needing to provide a reason. I also understand that my confidentiality will be preserved at all times.

This research has been approved by the Human Research Ethics Committee of the University of the Witwatersrand – if you have any queries you may

contact Anisa Keshav, Wits Research office, 10th floor Senate House, East
Campus/ Room 101/105 10th floor Faculty of the Health Sciences, at 011 717
1234 Fax: 011 717 1265 Email anisa.keshav@wits.co.za

Name: _____

Signature: _____

Date: _____

Witness' name: _____

Witness' signature: _____

Date: _____

Appendix 3

Echo Checklist

Parasternal Long axis view

Position:

Left Parasternal border, 3rd-4th ICS

Marker dot towards right shoulder

Go lateral along ICS if sternum blocking view

Quality Checklist:

Adjust depth to include the descending aorta

☐

Ensure crisp endocardial border, adjust gain

☐

LV apex should not be seen

☐

Septum should be horizontal with the maximal diameter of the LV visible

☐

The view should cut both the mitral and aortic valves

☐

Action: Freeze and save still image

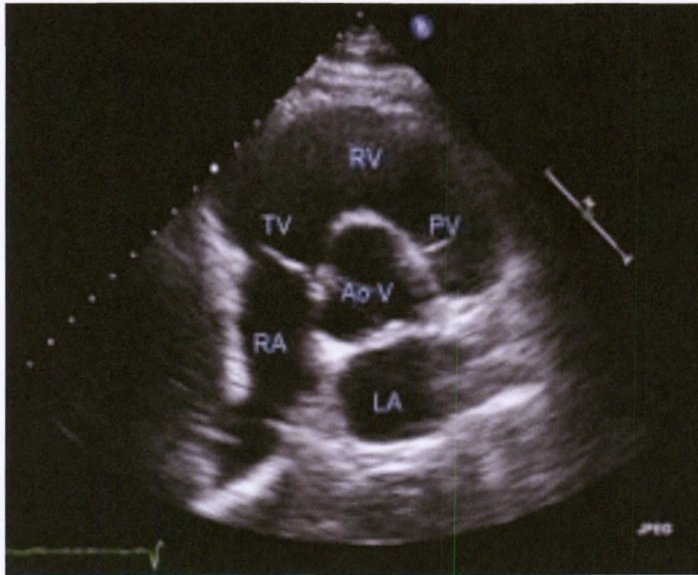
Unfreeze, record 3 heart beats, freeze, press "save cine" to save video



Parasternal short axis view

Aortic Valve level

Position:



Left parasternal border 3rd or 4th intercostal space
Rotate the probe 90 degrees towards the left shoulder
Tilt probe cranially to view the aortic valve
Position model on their left side to improve view
Sliding away from sternum may help

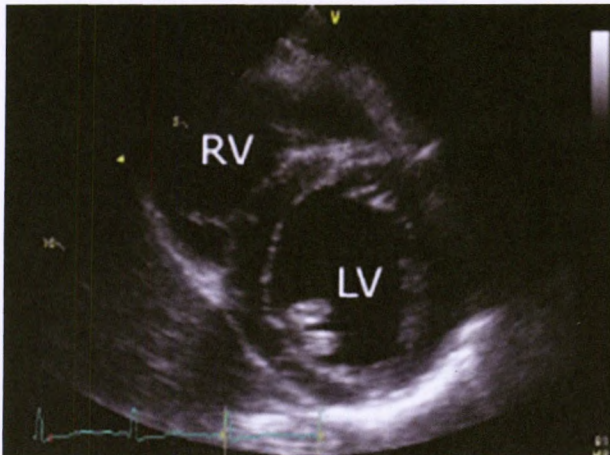
Image from: www.stanford.edu

Quality checklist:

- Ensure RV is well seen
☐
- AV in centre of screen
☐
- Attempt to include PV, if not possible, save additional view with PV
☐
- Save still image, unfreeze, record 3 heartbeats, save video
☐

Mid-papillary level

Tilt caudally from AV level to get mid-papillary level



- LV – centre of the screen ☐
- RV crescent shaped ☐
- LV round ☐
- Papillary muscles in view – not the MV ☐

Apical 4 chamber view

Position:

Palpate the apex beat, position the probe there

Normally located along the nipple line

Marker dot faces to the left of the model, between left axilla and left side of bed

Position model on their left side to improve view

Quality checklist:

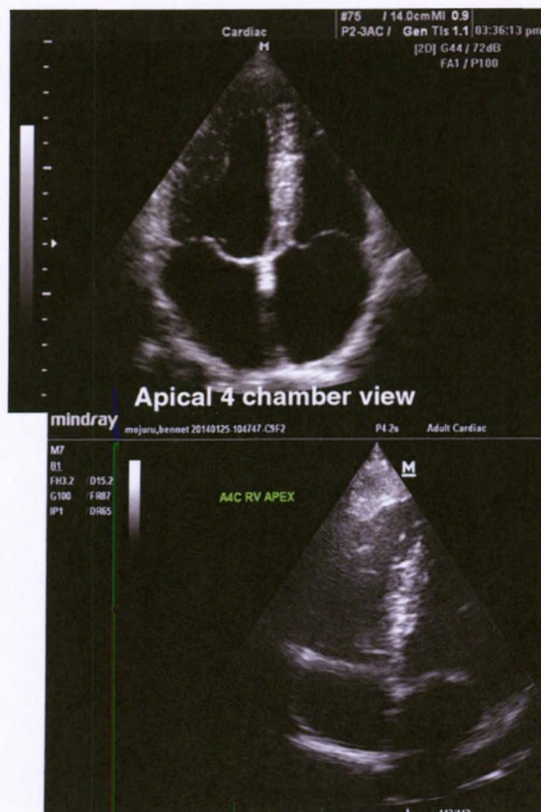
- Make sure that the IVS is perpendicular to the screen.
☐
- The apex is in the centre of the screen at the top
☐
- LV to look bullet shaped
☐
- Atria to be as large as possible
☐
- AV to be absent from image
☐

Action:

Freeze, save image, unfreeze, capture 3 heartbeats, press save cine to save video.

Image RV apex by sliding probe medially, save image

Save video



From: www.medison.ru

A4C RV view

Subxiphoid view

Position:

Position below the xiphoid cartilage

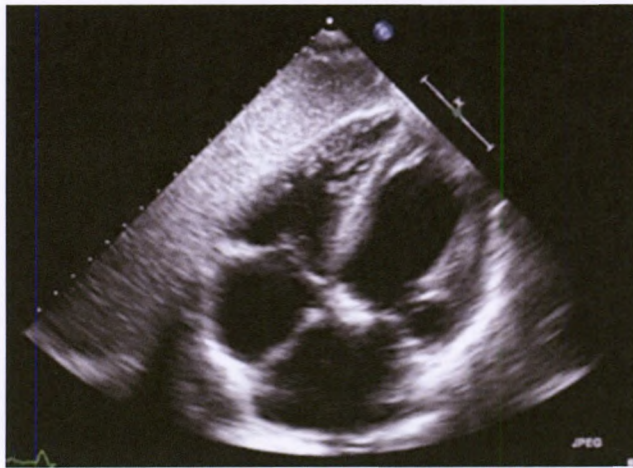
Marker dot points to the left of the patient

Increase the depth to visualise the whole heart

Tilt the probe towards the liver if stomach gas blocks your view

Push probe as flat as possible against model's skin to get under the xiphoid

Allow model to bend knees to relax the abdominal muscles



From: www.stanford.edu

Quality checklist:

- Liver on left of screen ☐
- All 4 chambers to be visualised ☐
- Apex of heart to be seen ☐
- Posterior pericardium to be seen ☐
- TV and MV to be seen ☐

Action:

Freeze and save still image

Unfreeze, record 3 heart beats, freeze, press "save cine" to save video

Appendix 4

Can echocardiography naïve medical personnel obtain adequate standard echocardiographic images after a single day of training, for the purposes of pre-participation screening echocardiography?

TIME SHEET

Model 1:

Time taken to obtain view:

1. PLAX:
2. PSAX AV:
3. PSAX MP:
4. A4CV:
5. AVCV RV:
6. SXC:

Model 2:

Time taken to obtain view:

1. PLAX:
2. PSAX AV:
3. PSAX MP:
4. A4CV:
5. AVCV RV:
6. SXC:

Model 3:

Time taken to obtain view:

1. PLAX:
2. PSAX AV:
3. PSAX MP:
4. A4CV:
5. AVCV RV:
6. SXC:

Appendix 5

Can echocardiography naïve medical personnel obtain adequate standard echocardiographic images after a single day of training, for the purposes of pre-participation screening echocardiography?

POST TRAINING QUESTIONNAIRE

1. What area of medicine do you currently practise in?

2. How would you rate your knowledge of basic echocardiography before the course? (1 being no knowledge, 5 being very knowledgeable)

1 2 3 4 5

3. Has your knowledge of basic echocardiography improved? (1 being no improvement, 5 being greatly improved)

1 2 3 4 5

4. Were the lectures useful in developing your understanding of echocardiography? (1 being not useful at all, 5 being very useful)

1 2 3 4 5

5. Did the practical session help you to get confident at acquiring images? (1 being very unhelpful, 5 being very useful)

1 2 3 4 5

6. Which view did you find the easiest?

7. Which view did you find the hardest?

8. What part of the training did you find the most useful?

POST EVALUATION QUESTIONNAIRE

1. Did you have enough hands-on practical time before the evaluation session? (1 being not nearly enough time, 5 being plenty of time)

1 2 3 4 5

2. How confident did you feel during the evaluations on the adequacy of your images? (1 being very unconfident, 5 being very confident)

1 2 3 4 5

3. How efficient did you feel you were in obtaining the images? (1 being very inefficient, 5 being very efficient)

1 2 3 4 5

4. Which view did you find the hardest in this session?

5. Did you need to reposition the model for any of the views? If so, which views?

6. Do you think basic echocardiography is a useful skill for you to retain and use in your practice of medicine? Please motivate your answer.

7. Do you think a single day of training is adequate to learn basic echocardiography that is required for pre-participation screening? Please motivate your answer.

8. Do you think you would like to learn how to interpret the images? Please explain your answer.

9. What have you learnt or read about point of care echo before this course?

Appendix 6

Can echocardiography medical personnel obtain adequate standard echocardiographic images after a single day of training, for the purposes of pre-participation screening echocardiography?

Six week follow up session questionnaire

1. Did you find the checklist useful? Please motivate your answer.

2. Would you have managed to obtain all the views correctly without using a checklist? Please explain your answer.

3. How would you rate your skill retention of basic echo six weeks after training? Please circle the percentage.

<20% 21-40% 41-60% 61-80% >81%

4. Which view did you find the hardest?

5. Which view did you find the easiest?

6. Did you practise echo after the training session in the last six weeks?

7. How confident did you feel during the evaluations on the adequacy of your images? (1 being very unconfident, 5 being very confident)

1 2 3 4 5

8. How efficient did you feel you were in obtaining the images? (1 being very inefficient, 5 being very efficient)

1 2 3 4 5

Appendix 7

Data Collection Checklist to grade adequacy of the still images and video clips

Score: Very poor = 1

Poor = 2

Adequate = 3

Good = 4

Very good = 5

PLAX:

Very Poor Poor Adequate Good Very good

Image on plane

Correct use of depth

Correct use of gain

Clarity of MV and AV

Crisp endocardial border

Avoidance of artefact eg lung/bone

Overall adequacy:

PSAX: AV level

Very Poor Poor Adequate Good Very good

Image on plane

Correct use of depth

Correct use of gain

Clarity of AV cusps

Crisp endocardial border

Avoidance of artefact

Overall adequacy

PSAX mid-papillary level

Very Poor Poor Adequate Good Very good

Image on plane
 Correct use of depth
 Correct use of gain
 Clarity of papillary muscles
 Avoidance of artefact
 Overall adequacy

Apical 4 chamber view

Very Poor Poor Adequate Good Very good

Image on plane
 Avoidance of foreshortening
 Correct use of depth
 Correct use of gain
 Crispness of endocardial border
 MV and TV seen
 AV not seen
 Avoidance of artefact
 Overall adequacy

Apical 4 Chamber view optimised for RV

Very Poor Poor Adequate Good Very good

Image on plane
 Correct use of depth
 Correct use of gain
 Apex of RV well seen
 Avoidance of artefact

Subxiphoid view

Very Poor Poor Adequate Good Very good

Image on plane

Correct use of depth

Avoidance of artefact

MV and TV seen

Avoidance of artefact

Overall adequacy

Appendix 8

Human Research Ethics Committee clearance


M130610M130610

R14/49 Dr Victoria Sarah Stephen

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
CLEARANCE CERTIFICATE NO. M130610

NAME: Dr Victoria Sarah Stephen
(Principal Investigator)

DEPARTMENT: Emergency Medicine
Helen Joseph Hospital

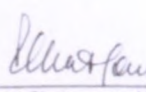
PROJECT TITLE: Can Echocardiography Naive Medical Personnel
obtain adequate Standard Echocardiographic
Images after a Single Day of Training, for the
Purposes of Pre-Participation
Echocardiography

DATE CONSIDERED: 28/06/2013

DECISION: Approved unconditionally

CONDITIONS:

SUPERVISOR: Prof Mike Wells

APPROVED BY: 
Professor PE Cleaton-Jones, Chairperson, HREC (Medical)

DATE OF APPROVAL: 07/08/2013

This clearance certificate is valid for 5 years from date of approval. Extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Secretary in Room 10004, 10th floor, Senate House, University.

I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated, from the research protocol as approved, I/we undertake to resubmit the application to the Committee **I agree to submit a yearly progress report**

Principal Investigator Signature _____ M130610Date _____

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES