THE CARDIOVASCULAR ASSESSMENT SKILLS GAP IN SMALL ANIMAL GENERAL VETERINARY PRACTITIONERS AND IDENTIFICATION OF METHODS TO REDUCE THIS.

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Abstract

Administration of pimobendan to dogs with preclinical myxomatous mitral valve disease (MMVD) with cardiomegaly (stage B2 mitral valve disease, Atkins et al., 2009) has been shown to extend the asymptomatic period by an average of 15 months, and dogs receiving the drug live significantly longer than those receiving a placebo (Boswood *et al.*, 2016).

The identification in general veterinary practice of patients with MMVD who could benefit from this medication relies heavily on the accurate identification of a heart murmur on a physical examination and identification of cardiomegaly, including left atriomegaly, on thoracic radiographs.

Little is known about the ability of general practitioners to identify these patients accurately. To investigate this in more detail, practitioner record keeping in relation to cardiovascular parameters, practitioner accuracy in interpretation of cardiac murmurs (Chapter 1) and practitioner accuracy in identification of cardiomegaly and left atriomegaly on thoracic radiographs (Chapter 2) was assessed. To identify methods that might aid the detection of cardiovascular disease in general practice, the value of focused echocardiography was assessed.

Record keeping by general veterinary practitioners for important cardiovascular parameters was markedly limited in standard. General practitioners, compared with a referral clinician consensus opinion, agreed substantially on murmur grade (K = 0.7), agreed perfectly on murmur timing (K = 1.0) and moderately on the site of maximum intensity of murmurs (K = 0.5).

These findings would suggest that practitioners are able to accurately grade a heart murmur and therefore could potentially correctly select patients who would benefit from further investigation, confirming the cause of the murmur as MMVD and therefore potentially benefit from medication. However due to poor record keeping, the loss of information may prevent the identification of patients in early stages of heart disease or patients who might benefit from further cardiovascular investigation.

When assessing thoracic radiographs for changes associated with MMVD (Chapter II), general practitioners were found to have a high level of accuracy in the detection of patients with marked generalised cardiomegaly (median number of images correctly identified was 100%) and patients with no left atrial enlargement (median number of images correctly identified was 80%) using subjective methods of assessment. However, their accuracy was lower in detection of those with mild changes (median number of images correctly identified with mild cardiomegaly and mild left atrial enlargement was 66.67%). Whilst practitioners were accurate in their ability to measure a vertebral heart score (VHS), the lack of a clear upper limit for VHS meant that VHS added no significant value in aiding correct diagnosis.

Patients in stage B2 MMVD (Atkins et al., 2009) have mild changes on thoracic radiographs, therefore this research suggests that in general practice patients in the early stages of cardiac remodelling, and those who might benefit greatly from medication, may go undiagnosed. This highlights that radiographic examination may not be sufficiently reliable in the evaluation of mild cardiomegaly and emphasizes the need for echocardiography to assist in the detection of patients with B2 MMVD.

The introduction of the novel tool of focused echocardiography (Chapter 3) significantly improved general practitioner's ability to correctly identify cardiac anatomy on echocardiography, detect left atrial enlargement, detect reduced systolic function and detect pericardial effusion ($p<0.0001$), practically obtain the views required to make these assessments, and improved their confidence in both image interpretation and practical acquisition.

In relation to detection of MMVD, following the training course in focussed echocardiography, the mean accuracy of identification of normal left atrial size, a mildly enlarged left atrium and severely enlarged left atrium was 88%. Post training, 95% of practitioners were able to correctly identify a severely enlarged left atrium.

These results suggest that the addition of the focused echocardiogram to general practice could aid earlier detection of patients in stage B2 MMVD or greater by detection of left atrial enlargement. These patients could then benefit from an echocardiogram and potentially benefit from the positive effects of pimobendan.

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Author's declaration

"I declare that, except where explicit reference is made to the contribution of others, that this dissertation is the results of my own work and has not been submitted for any other degree at the University of Glasgow or any other institution."

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Abbreviations

2D	Two-dimensional
ACVIM	American College of Veterinary Internal Medicine
AFAST	Abdominal Focused Assessment using Sonography for Trauma
AFAST3	Abdominal Focused Assessment using Sonography for Trauma, Triage and Tracking
AFS	Abdominal Fluid Scoring
AV	Atrioventricular
BLUE	Bedside Lung Ultrasound Examination
Bpm	Beats Per Minute
Brpm	Breaths Per Minute
CC	Cysto-Colic
CI	Confidence Interval
CPD	Continued Professional Development
crll	Cranial Lung Lobe
CRT	Capillary Refill Time
CT	Computerised Tomography
cTnI	Cardiac Troponin I
CTS	Chest Tube Site
CVD	Chronic Valve Disease
DH	Diaphragmatico-hepatic
DMVD	Degenerative Mitral Valve Disease
Echo	Echocardiography
EPIC	Evaluation of Pimobendan in dogs with Cardiomegaly
FAST	Focused Assessment using Sonography for Trauma
FS	Fractional shortening
GFAST3	Global Focused Assessment using Sonography for Trauma, Triage and Tracking
HR	Heart Rate
HRe	Hepato-renal
ISACHC	International Small Animal Cardiac Health Council
LAE	Left Atrial Enlargement
LVIDDN	Left ventricular dilatation, defined as and body weight normalized left ventricular internal diameter in diastole
mdll	Middle Lung Lobe
MM	Mucous Membrane
MMVD	Myxomatous Mitral Valve Disease
MVD	Myxomatous Valve Disease
NAD	No Abnormalities Detected
NPA	Not Possible to Assess
NT-proBNP	pro B-type Natriuretic Peptide

NYHA	New York Heart Association
PEA	Pulseless Electrical Activity
PCS	Pericardial site
phll	Perihilar Lung Lobe
RPSSA 4C	Right Parasternal Short Axis 4 Chamber View
RPSSA LV	Right Parasternal Short Axis Left Ventricle
RPSSA LA: AO	Right Parasternal Short Axis view of the Left Atrium and Aorta
RR	Respiratory Rate
SD	Standard Deviation
SF	Systolic function
SR	Spleno-renal
TFAST	Thoracic Focused Assessment using Sonography for Trauma
TFAST3	Focused Assessment using Sonography for Trauma, Triage, and Tracking
URLs	Ultrasound Lung Rockets
v	Thoracic vertebral bodies as a measurement system
Vet BLUE	Veterinary Bedside Lung Ultrasound Examination
VHS	Vertebral Heart Score

Publications and presentations

Some of the work contained in this thesis has been accepted for the following publication or presentations:

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Ethical approval

The whole study was reviewed and approved by the University of Glasgow's ethical committee reference: 17a17.

INTRODUCTION

Approximately 10% of dogs presented to general veterinary practices have heart disease (Atkins et al., 2009). An estimation of the mortality rate caused by cardiac disease in the general canine population indicates approximately 7% of all dogs die or are euthanised because of heart failure before 10 years of age (Bonnett et al., 1997).

The most commonly acquired cardiac disease of small breed dogs is chronic valvular heart disease (CVHD, also known as endocardiosis) (Buchanan, 1977; Häggström, Pedersen and Kvart, 2004; Ljungvall *et al.*, 2014). It is thought to account for 75% of cardiac disease seen in general practice.

The cause of CVHD is unknown, however, there is an inherited component in some breeds such as the Cavalier King Charles Spaniel (Swenson et al., 1996) and Dachshund (Olsen, Fredholm and Pedersen, 1999).

CVHD is characterised by changes in the cellular and intercellular matrix of the valve and the chordae tendineae. Early lesions consist of small nodules on the valves, however, with time, these become larger and distort the valve shape and the valve and chordae tendineae become weaker and thickened. This change in valve structure prevents proper coaptation, which results in regurgitation of blood into the left atrium (Buchanan, 1992; Ware, 2003a). The histological changes have been described as myxomatous degeneration and another common name given to this condition is myxomatous valve disease (MVD). CVHD most commonly affects the mitral valve, therefore it is also called degenerative mitral valve disease (DMVD) or myxomatous mitral valve disease (MMVD). It can be detected in any of the four heart valves (62% incidence of mitral valve alone, 32.5% incidence of mitral and tricuspid valves, and 1.3% incidence of tricuspid valve alone) (Buchanan, 1977).

When the valves become incompetent there is volume overload on the side of the heart affected. This can develop slowly and the mean atrial pressure remains low, however as the disease progresses more blood moves back and forth between the ventricle and atrium, reducing the blood flow to the systemic circulation. Initially the body adopts compensatory responses to meet the circulatory needs. The ventricle and atrium dilate to accept the volume of regurgitant blood and eccentric hypertrophy develops to normalise the wall stress. These changes allow the dog to remain asymptomatic for a long period of time. Eventually the ability of the compensatory mechanisms to cope fails, the pressure in the atrium increases and signs of left or right sided failure occur (Ware, 2003a).

There are many classification systems for MMVD, but the most commonly used are the modified New York Heart Association (NYHA), the International Small Animal Cardiac Health Council (ISACHC) and the American College of Veterinary Internal Medicine (ACVIM) consensus statement (Atkins et al., 2009).

The author will use the Atkins classification throughout.

- Stage A: Identifies patients at high risk of developing heart disease but that currently have no identifiable structural disorder of the heart.

- Stage B: Identifies patients with structural heart disease, but that have never developed clinical signs caused by heart failure.

  Stage B1 refers to asymptomatic patients that have no radiographic or echocardiographic evidence of cardiac remodeling in response to CVD.

  Stage B2 refers to asymptomatic patients that have haemodynamically significant valve regurgitation, as evidenced by radiographic or echocardiographic findings of left-sided heart enlargement.

- Stage C denotes patients with past or current clinical signs of heart failure associated with structural heart disease.

- Stage D refers to patients with end-stage disease with clinical signs of heart failure caused by MMVD that are refractory to ‘‘standard therapy’’.

MMVD disease is characterised by a long pre-clinical phase. Until recently, no medical therapies were proven to prolong this period before the onset of congestive heart failure and treatment at this stage was considered controversial. Treatment was only initiated when signs of congestive heart failure developed.

In 2016, research was published from the 'EPIC' study 'Evaluation of pimobendan in dogs with cardiomegaly caused by preclinical degenerative mitral valve disease'(Boswood *et al.*, 2016). The aim of this study was to determine whether the administration of pimobendan to dogs with preclinical mitral valve disease or stage B2 mitral valve disease (Atkins et al., 2009) with a heart murmur grade 3 out of 6 or above and some evidence of cardiac enlargement, but no clinical manifestations of heart failure would delay the onset of clinical signs.

The participants were 360 client owned, small to medium sized dogs (4-15kg) who were greater than or equal to 6 years of age with a characteristic systolic heart murmur grade greater than or equal to 3 out of 6 with a maximal intensity over the mitral area and who were confirmed to be in stage B2 mitral valve disease by echocardiographic evidence of:

- Advanced MMVD defined as characteristic valvular lesions of the mitral valve apparatus.
- Mitral regurgitation on the colour Doppler echocardiogram.
- Left atrial dilation defined as a left atrial-to-aortic root ratio (LA:Ao) ≥1.6 (Hansson et al., 2002).
- Left ventricular dilatation, defined as body weight normalized left ventricular internal diameter in diastole (LVIDDN) ≥1.7.

In addition radiographic evidence of cardiomegaly (vertebral heart score (VHS) >10.5) was required (Hansson, Haggstrom, *et al.*, 2005).

The study showed that administration of pimobendan to dogs with MMVD extended the asymptomatic period by an average of 15 months and that dogs that received the drug lived significantly longer than those receiving a placebo.

The results were so convincing that the trial was terminated early as it was considered unethical to deny those dogs receiving the placebo the benefits seen in the treatment group.

The translation of the findings from this study to general veterinary practice is that middle-aged to older dogs with suspected MMVD based on the presence of a left apical systolic murmur of grade 3 out of 6 or above who are asymptomatic for heart failure should have further investigations performed to determine if the cause of the murmur is MMVD and whether they are in a stage of MMVD which would benefit from pimobendan. Should they be found to be in stage B2, treatment with oral pimobendan at a daily dose of 0.4-0.6mg/kg (divided into 12-hour dosing) should be initiated.

The identification of patients with MMVD in general practice relies heavily on physical examination and thoracic radiography. In the early stages of disease (also called the pre-clinical phase, B1), a patient with MMVD does not show any clinical signs, and often only a soft systolic murmur, with a point of maximum intensity (PMI) over the left apex of the heart, is detected on clinical examination (Häggström, Kvart and Hansson, 1995). Detection of the disease at this stage is not important for management of the patient, but it is important that these patients are identified and murmur intensity recorded in the veterinary records to allow monitoring of murmur intensity progression over time and also to prevent the use of dogs with early onset MMVD for breeding. This pre-clinical phase can last for many years and in up to 70% of cases they do not go on to develop signs of congestive heart failure.

Radiographically, these patients do not show any changes and therefore a definitive diagnosis relies on the echocardiographic identification of a thickened mitral valve and mitral regurgitation in the absence of other cardiac disease. Whilst a definitive diagnosis is ideal, it is often difficult to persuade clients to allow echocardiography or thoracic radiography to be performed when their pet is well.

As the disease progresses and the regurgitant volume increases, the intensity of the murmur may increase (Häggström, Kvart and Hansson, 1995), there may be a loss of a sinus arrhythmia and the mean heart rate may become elevated. It is essential that these changes are documented to allow monitoring of disease progression. Changes may be seen on thoracic radiographs including cardiomegaly and left atrial enlargement. An echocardiogram can help identify whether the patient is in stage B2 MMVD (Atkins *et al.*, 2009).

If the heart can no longer meet the demands of the body with these compensatory responses, signs of heart failure become apparent. These include exercise intolerance, syncope, coughing, tachypnoea, lethargy, ascites and weight loss. Dyspnoea, tachypnoea, pulmonary crackles, ascites and cachexia may all become evident on the clinical examination (Francis, 2001; Ware, 2003c). Thoracic radiographs taken at this stage may indicate cardiomegaly and left atrial enlargement in addition to evidence of left-sided congestive heart failure such as pulmonary venous distension or pulmonary oedema.

To the author's knowledge, there is no published work investigating the ability of general veterinary practitioners to detect dogs in the pre-clinical stage of mitral valve disease.

Key factors in identification of MMVD in general practice include:

- An ability to keep thorough clinical records in relation to cardiovascular parameters throughout a patient's life.
- An ability to detect and accurately interpret a heart murmur.
- An ability to detect cardiomegaly on thoracic radiographs.

This research has been divided into three chapters. Each chapter aims to look for potential gaps in general veterinary practitioners' cardiovascular assessment skills. In light of the significant clinical benefit of identification of patients in pre-clinical stages of MMVD, particular emphasis has been placed on assessment of general practitioner skill gaps in the detection of patients in pre-clinical MMVD.

Chapter I assesses the standard of record keeping in relation to cardiovascular parameters in general practice and referral practice and assesses the ability of

general practitioners to grade and interpret a heart murmur correctly by comparing the records with a consensus opinion in referral practice.
Based on a literature review (pages 7-9), the author hypothesises that there will be a poor standard of record keeping in relation to cardiovascular parameters in general veterinary practice and that there will be significant agreement between referral and general veterinary practitioners in interpretation of heart murmurs.

Chapter II investigates the accuracy of general practitioners in identification of cardiac remodelling due to MMVD on thoracic radiographs using both objective and subjective methods by comparing general practitioner interpretation with that of a consensus opinion of European Diplomates in Diagnostic Imaging and Cardiology. Based on a literature review (pages 43-54), the author hypothesises that general veterinary practitioners will be accurate in their subjective detection of marked left atrial enlargement and generalised cardiomegaly, however accuracy in detection of mild changes will be low. The author also hypothesises that there will be no significant difference in the general veterinary practitioner accuracy of detection of cardiomegaly when using VHS compared to a subjective impression alone and that general veterinary practitioners will measure a similar mean VHS value to the consensus opinion.

The final chapter (Chapter III) aims to investigate the current frequency of use of ultrasound in general practice for detection of cardiovascular disease and determine if introduction of a novel skill of focused echocardiography could improve general practitioner confidence and ability to detect cardiovascular disease.
Based on a literature review (pages 95-105), the author hypothesises that a one hour course in focused echocardiography will significantly improve general practitioners echocardiographic image interpretation and its practical acquisition.

CHAPTER I: AN ASSESSMENT OF RECORD KEEPING OF CARDIOVASCULAR PARAMETERS IN GENERAL AND UNIVERSITY REFERRAL VETERINARY PRACTICE AND ASSESSMENT FOR ANY SKILLS GAP IN MURMUR INTERPRETATION BY COMPARING THESE RECORDS

1.1 The importance of record keeping

All veterinary surgeons have a responsibility to maintain clinical records. This is clearly stated in the RCVS Code of Professional Conduct: 'clinical and client records should include details of examination, treatment administered, procedures undertaken, medication prescribed and/or supplied, the results of any diagnostic or laboratory tests (including, for example, radiograph, ultrasound or electrocardiogram images or scans), provisional or confirmed diagnoses, and advice given to the client (whether over the telephone or in person). The utmost care is essential in writing records or recording a client's personal details to ensure that they are clear, accurate and appropriately detailed' (Rcvs.org.uk, 2017) and the importance of this cannot be over-emphasised.

Throughout their professional life, general veterinary practitioners will conduct thousands of consultations and subsequently make thousands of records.

These records have many functions, but their main function is to facilitate patient care. They provide a detailed document pertaining to the history of the illness, physical examination, diagnosis, treatment planned, treatment given and follow-up.

Another very important function is communication: from practitioner to colleague, from practitioner to another veterinary professional or simply as a record of consultation and treatment and a memory aid for the initial practitioner.

There are few reports in the literature concerning the quality of record keeping in general veterinary practices, however studies in the human dental profession suggests that record keeping is poor (Sari E. Helminen, Miira Vehkalahti, 1998; Cole and McMichael, 2009) and in the human nursing profession, poor records have been shown to have a negative impact on decision making and care given (Inan and Dinç, 2013).

Based on this literature, the author anticipates that the standard of record keeping of cardiovascular parameters by general veterinary practitioners will also be poor.

Good records do not ensure that adequate care has been given, but they can provide an opportunity to evaluate the care and treatment, which poor records do not. Therefore, it is essential that clinical records are maintained at a level that allows proper assessment of the clinical history and physical examination performed.

In a time when litigation is at its peak, it would seem essential to make good clinical records. "Poor records mean poor defence; no records means no defence" (Thomas, 2016).

The importance of a good standard of clinical record keeping in patients with cardiovascular disease is high. If data are unrecorded, a major piece of information is lost which could have serious consequences for the patient.

One example is the importance of recording heart rate and rhythm. A respiratory sinus arrhythmia is an indicator of increased parasympathetic tone and reduced sympathetic tone. In dogs with heart failure, one of the compensatory responses is an increase in sympathetic tone and a decrease in parasympathetic tone. This results in an increase in heart rate and loss of the sinus arrhythmia (Martin, 2015). If this information is not recorded, then an animal who is in the early stages of heart failure with a sinus tachycardia could be missed.

Another example is the importance of recording presence or absence of a murmur. A febrile dog with a new murmur is considered the classical presentation of bacterial endocarditis (Peddle and Sleeper, 2007). If there is no previous record of presence or absence of a murmur, it makes an assessment of the importance of an auscultated murmur difficult.

1.2 The importance of the cardiac physical examination

Despite technology having a high profile in cardiology with the use of electrocardiography and echocardiography, the physical examination remains essential in general practice for detection of cardiovascular disease. With the use of the five senses and a stethoscope, a list of problems and their differentials can be made. The physical examination allows practitioners to determine if there is any cardiovascular disease present, if the cardiovascular disease is stable and to monitor the progression of any cardiovascular disease by noting changes over time.

The physical examination of a patient with suspected cardiac disease includes an observation of demeanour, a general physical examination, and a more specific cardiovascular exam (French, 2014). Vital components of a specific cardiovascular examination include assessment of the heart rate, rhythm, heart sounds (including presence or absence of a gallop sound or murmur and murmur timing, grade and PMI), pulse quality and assessment for any pulse deficits, assessment for jugular distension or pulsation, respiratory rate, effort and lung sounds (French, 2014).

1.2.1 General observation

The starting point for any cardiovascular physical examination should be a general observation. This should take into account the patients' demeanour, size, the shape of the thorax, posture, respiratory effort and assess for evidence of peripheral oedema or ascites (Johnson and Fuentes, 2010).

Patients with cardiac disease may become depressed and listless. They may be cachectic or there may be evidence of peripheral oedema or ascites. In patients with a congenital disease, their growth may be stunted. Patients with a pleural effusion may be dyspnoeic with abducted elbows and a barrel-shaped chest.

1.2.2 Respiratory effort

Whilst an increase in respiratory effort is not specific for cardiovascular disease, patients with congestive heart failure often have increased respiratory effort (dyspnoea). This can be inspiratory, expiratory or mixed. Pleural effusion results in a mixed inspiratory and expiratory pattern (sometimes called a restrictive pattern) whereas pulmonary oedema results in an expiratory pattern. An inspiratory pattern indicates upper respiratory tract disease (Johnson and Fuentes, 2010b).

1.2.3 Respiratory rate

The respiratory rate is useful in the acutely presented patient, as patients with heart failure are often tachypnoeic due to pulmonary oedema or pleural effusion. Dyspnoeic cats presenting in practice with profound tachypnoea are likely to have a cardiac cause underlying their dyspnoea (Dickson *et al.*, 2018).

Recording the respiratory rate is also useful in the monitoring of cardiac disease. Regular measurements of the resting or sleeping respiratory rate can be useful in assessing the progression of heart disease or the success of treatment for congestive heart failure (Schober et al., 2011). Research suggests that most dogs and cats without cardiac disease or with well-controlled heart disease will have a resting respiratory rate of <30 breaths/min at home (Porciello et al., 2016).

1.2.4 Mucous membrane colour

Mucous membrane colour gives information about the adequacy of tissue perfusion and the amount of oxygenated haemoglobin in the blood (Johnson and Fuentes, 2010). This is vital as it gives an indication as to whether a cardiorespiratory disease is present or not.

Pallor or pale mucous membranes can indicate two main categories of disease, anaemia, and poor tissue perfusion. The causes of poor tissue perfusion include shock and severe pain. Shock can be divided into cardiogenic causes or non-cardiogenic causes (hypovolaemia/trauma/impaired blood flow to tissues etc.).

Cyanosis is a result of deoxygenated haemoglobin in the blood, typically due to pulmonary causes (ventilation:perfusion mismatch/airway obstruction/ hypoventilation), but it can result from cardiac disease, either right to left shunting congenital anatomical defects (e.g. Tetralogy of Fallot) or congestive heart failure causing pulmonary oedema or severe pleural effusion (Gompf, 2008).

Differential cyanosis occurs where the cranial half of the body receives oxygenated blood and the caudal half of the body receives deoxygenated blood through a reverse-shunting patent ductus arteriosus (Kittleson, 1998b).

Congestion/brick red mucous membranes could indicate polycythaemia/ erythrocytosis. This can result from a true expansion of the red blood cell mass (true polycythaemia/erythrocytosis) or due to a reduced blood volume (relative polycythaemia) and may be seen in cases of reverse cardiac shunting (Stokol, 2017).

1.2.5 Capillary refill time

The normal capillary refill time should be within two seconds (Ware, 2003d). A capillary refill time greater than two seconds is indicative of poor tissue perfusion. In relation to cardiovascular disease this is a key finding, as it can give an indication of peripheral vasoconstriction secondary to markedly reduced cardiac output.

1.2.6 Jugular vein examination: distension & pulsation

The jugular vein should be examined for distension or pulsation. In a patient with right-sided heart disease the jugular vein may be distended due to increased right atrial pressure, which is transmitted to the jugular vein. Distension indicates that there is an increase in the systemic venous pressure or an obstruction between the jugular veins and right atrium. Cardiac causes of increased right atrial pressure include pericardial disease, tricuspid dysplasia, tricuspid stenosis, tricuspid endocardiosis and heartworm infection (Kittleson, 1998b).

A test that can be performed to examine jugular distension is the hepato-jugular reflex. Pressure is placed on the cranial abdomen for 30 seconds and this increases venous return to the heart. In animals with right-sided heart failure, this can further enhance jugular distension. In a normal animal, this would produce no change in the appearance of the jugular veins (Gompf, 2008).

Some arrhythmias, such as second or third-degree AV (atrioventricular) block, can cause jugular pulsation because the atria are contracting against a closed tricuspid valve (Gompf, 2008).

1.2.7 Pulse quality

Ideally, both the femoral pulses will be assessed as a part of a routine cardiovascular examination and categorised as normal, hypodynamic (weak) or hyperdynamic/'water hammer' (strong). Normal pulses should be strong and have a rapid rate of rising and fall.
Weak pulses can arise in patients with heart failure, hypotension, hypovolaemia and subaortic stenosis. Hyperdynamic pulses can arise in patients with a patent ductus arteriosus, fever, and anaemia (Sisson and Ettinger, 1999).

Pulse variation includes pulsus paradoxus (the pulse weakens markedly on inspiration in patients with pericardial effusion and cardiac tamponade) and pulsus alternans (a variation in pulse quality due to poor systolic function or an arrhythmia) (Goodwin, 1995).

1.2.8 Pulse deficits

When assessing pulse quality, the pulse rate should also be determined and compared with the heart rate. Ideally this should be done simultaneously using a finger on the femoral pulse and a stethoscope to auscultate the heart. Any reduction in the number of femoral or peripheral pulses compared with the heart rate is a pulse deficit. This can be found in many arrhythmias, such as atrial fibrillation, as they cause additional heart beats before filling has occurred, resulting in little blood being ejected and consequently no pulse is palpated (Ware, 2003d). Absent pulses can result from thromboembolism.

1.2.9 Cardiac auscultation

Several aspects should be assessed during cardiac auscultation:

Audibility of the heart

Causes of muffled heart sounds include pericardial effusion, pleural effusion, thoracic masses, obesity and myocardial failure (French, 2014).

Reasons for increased audibility of the heart sounds include the animal being underweight or diseases causing the heart to be hyperdynamic e.g. fever.

Heart rate

Tachycardia has a number of potential causes; however one of the first signs that a patient may have decompensated cardiac disease is an increase in their heart rate.

Recording the heart rate allows an immediate assessment to be made and allows for monitoring to be done over time.

Ideally, the heart rate should be assessed when the patient is calm.

The normal heart rate in a dog is 60-140bpm (French, 2014).

Heart rhythm

The most common cardiac rhythm in normal dogs is sinus arrhythmia. This is when the heart rate speeds up during inspiration and slows during expiration. It is often a sign that any heart condition is well compensated. This rhythm is heard frequently, and may be marked, in brachycephalic breeds. Sinus arrhythmia does not always correspond to respiration and can occur with other causes of increased vagal tone e.g. gastrointestinal disease or respiratory disease. Typically, the sinus arrhythmia disappears when the heart rate increases(Johnson and Fuentes, 2010).

In cats, the most common rhythm is a regular sinus rhythm. Previously a sinus arrhythmia was thought to be uncommon and likely due to increased vagal tone. However recent studies using Holter monitoring have shown that cats can have a sinus arrhythmia when relaxed in their home environment (Hanås et al., 2009).

An abnormally fast rhythm (tachycardia) can be sinus, atrial or ventricular in origin. An unusually slow rhythm (bradycardia) could, for example, be caused by 3rd degree AV block. Atrial fibrillation is an irregularly irregular rhythm, sounding chaotic. It can be differentiated from regular and fast sinus and atrial tachycardia. Ectopic beats (ventricular and supraventricular) are usually premature, and sound like irregularities in the rhythm. If these are frequent, it can be difficult to distinguish these from atrial fibrillation by auscultation.

Heart sounds

The normal heart sounds in small animals are S1 and S2. Any abnormal heart sound could indicate the presence of cardiac disease. This includes splitting of normal heart sounds and an audible S3 or S4, termed gallop sounds, which typically indicate stiff ventricular walls or rapid ventricular filling (Ware, 1995).

Murmurs

Murmurs indicate the turbulent flow of blood in the heart. The characteristics of a murmur can be used to identify the cause (Ware, 1995; French, 2014). Recording the absence of a murmur is as important as recording its presence, as it allows identification of new murmurs.

1.2.16 Thoracic auscultation

Normal lung sounds are bronchovesicular sounds. There are many cardiovascular reasons for abnormal lung sounds. Examples include muffled lung sounds, which can indicate pleural effusion and crackles, which can indicate pulmonary fibrosis or pulmonary oedema. Wheezes can indicate allergic airway disease and other pulmonary conditions (Johnson and Fuentes, 2010).

Palpation of the apex beat

A decrease in the strength of the apex beat could be due to obesity, pleural or pericardial effusion, a decrease in ventricular contractility or pneumothorax, etc. An increase in the strength of the apex beat could be due to a hyperdynamic state such as anaemia or due to the patient being underweight. Cardiac murmurs of grade V or VI/VI are identified by a thrill on palpation (Ware, 1995).

1.2.17 The importance of heart murmur interpretation:

Heart murmurs can be divided into physiological, innocent or pathological. A murmur should ideally be described using its timing (systolic, diastolic, continuous, to and fro), duration (holosystolic, systolic, pansystolic), site at which the murmur intensity is the loudest (PMI, e.g. left apical, right apical, etc.), pitch of the murmur (high, medium or low) and the intensity of the murmur graded I-VI/VI (Levine, 1933) or using the four-point scale (soft, moderate, loud, thrilling) (Ljungvall et al., 2014). The acoustic profile of the murmur and its radiation away from the PMI can also be assessed.

Murmur grading is important because studies have demonstrated an association between murmur intensity and functional class of heart disease. Soft murmurs are found only in dogs with mild MMVD (Häggström, Kvart and Hansson, 1995) and increasing murmur intensity in small-breed dogs is associated with increasing severity of MMVD (Ljungvall et al., 2009, 2014). Correct identification of a murmur and its grade could aid in the selection of patients who might benefit from further investigations, such as echocardiography and/or radiography, and subsequently from medical treatment (Boswood *et al.*, 2016).

Despite the stethoscope having been available for over 200 years, there are few studies investigating the accuracy of cardiac auscultation in veterinary medicine. This may be due to the difficulty in collecting a cross-section of stable patients with normal and abnormal auscultatory findings in one location together with a range of veterinary practitioners.

In the equine field, using digital recordings of heart murmurs, the association between the perceived grade of the murmur and the grade assigned by the principal investigators at the time of examination of the horse was highly significant. Neither the grade clinicians assigned to a murmur nor its perceived duration was affected by the clinician's level of training or hearing ability (Naylor *et al.*, 2001).

Using this information, the author proposes that the general veterinary practitioner's ability to interpret heart murmurs accurately in dogs is also likely to be good.

1.3 Study aim, hypothesis and design

1.3.1 Aim

To investigate the standard of record keeping of cardiovascular parameters in general veterinary practice and a University referral practice and assess for any skill gap in murmur interpretation by comparing these records.

1.3.2 Hypothesis

The author hypothesises that there will be a poor standard of record keeping in relation to cardiovascular parameters in general practice and that there will be significant agreement between referral and general veterinary practitioners in interpretation of heart murmurs.

1.3.3 Study design

A retrospective study. The study was granted ethical consent by the University of Glasgow's ethical committee reference: 17a17

1.4 Study method

1.4.1 General method

Clinical records from 200 canine cases referred to the University of Glasgow Small Animal Hospital Cardiorespiratory service over a period of 19 months from 86 general practices across Scotland were retrospectively audited for 12 criteria considered part of a full cardiovascular physical examination. Both referral and general practitioner notes were audited.

The 12 criteria were as follows:

- Demeanour
- Mucous membrane colour
- Capillary refill time
- Heart rate
- Heart rhythm
- Pulse quality
- Pulse deficits
- Jugular distension
- Respiratory rate
- Respiratory effort
- Lung sounds
- Presence or absence of a murmur

Each parameter was placed into one of three categories:

- **Recorded:** Parameter was recorded or a valid reason for lack of parameter was written e.g. 'Not possible to examine MM colour as dog too aggressive' 'panting'.
- **Not recorded:** No parameter recorded or no explanation was provided for why the parameter was not recorded.
- **Ambiguous answer:** Using the recorded information, it was not possible to determine if the parameter had been assessed or not and/or future monitoring was not possible using this information. Examples include: 'All other findings normal', 'No abnormalities detected (NAD) for rest of physical examination', 'Normal' or 'NAD' for heart rate or respiratory rate, 'No cardiac signs'.

Where a heart murmur was recorded, records were further analysed for

- Grade of murmur
- Timing of murmur
- PMI of murmur

To investigate for any murmur interpretation skill gap in general practice, the interpretation of the murmur in general practice was compared to the interpretation of the murmur in the referral setting. The murmur interpretation in the referral setting was a consensus opinion of a diploma holder in veterinary cardiology and veterinary residents in cardiology.

1.4.2 Exclusion criteria

- Patients who were referred with incomplete or unavailable clinical histories
- Cases of tertiary referral
- Cases with a confirmed diagnosis of respiratory disease made prior to referral

1.4.3 Scoring

Records were audited for each parameter considered a vital component of a cardiovascular physical examination. 1 point was allocated if the information was recorded and 0 points were allocated if no information was recorded or an ambiguous answer was recorded.

1.4.4 Statistical analysis

All data were analysed using the statistical software package Minitab version 17. Statistical analysis performed was Kappa analysis to determine the interrater reliability between referral and general practice on murmur grade, timing and side of maximum intensity.

1.5 Study results

1.5.1 Record keeping in general practice

Table 1. Record keeping of cardiovascular parameters in general practice. Total numbers of recorded parameters, not recorded parameters and ambiguous answers out of a possible 200 records.

Parameter	Recorded/200	Not recorded/200	Ambiguous Answer/200
Demeanour	64 (32.0%)	135 (67.5%)	1 (0.5%)
MM	117 (58.5%)	81 (40.5%)	2 (1.0%)
CRT	88 (44.0%)	110 (55.0%)	2 (1.0%)
HR	137 (68.5%)	56 (28.0%)	7 (3.5%)
Rhythm	68 (34.0%)	127 (63.5%)	5 (2.5%)
Pulse Quality	72 (36.0%)	124 (62.0%)	4 (2.0%)
Pulse deficits	55 (27.5%)	137 (68.5%)	9 (4.0%)
Jugular distension	2 (1.0%)	194 (97.0%)	4 (2.0%)
RR	55 (27.5%)	132 (66.0%)	13 (6.5%)
Respiratory Effort	27 (13.5%)	169 (84.5%)	4 (2.0%)
Lung sounds	78 (39.0%)	120 (60.0%)	2 (1.0%)
Presence/ absence of a murmur	145 (72.5%)	50 (25.0%)	5 (2.5%)

The mean score for the total parameters recorded was 4.5 out of a possible 12 points (37.8%).

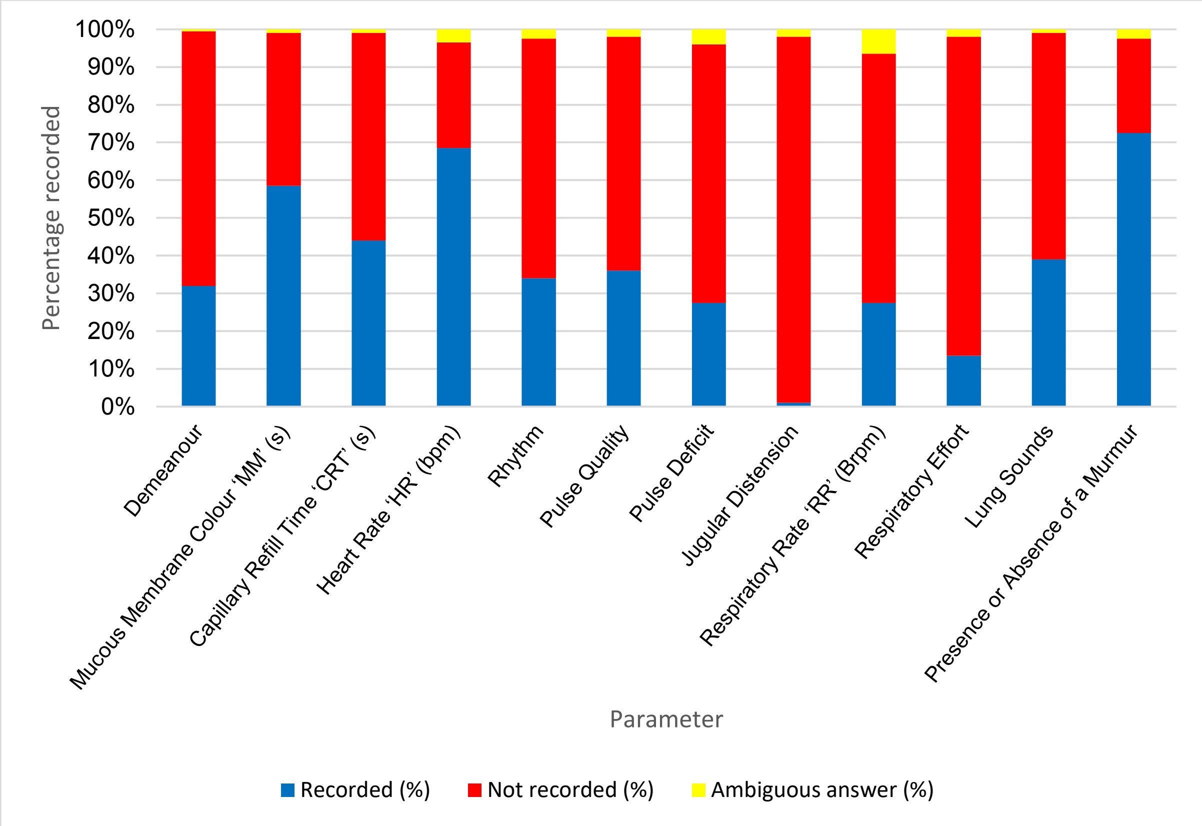


Figure 1 A graphical representation of cardiovascular record keeping in general practice. The parameter in question is displayed on the x-axis and number recorded, not recorded and ambiguous answers displayed as a percentage on the y-axis. s= seconds, brpm = breaths per minute, bpm = beats per minute.

1.5.2 Record keeping at the University of Glasgow Small Animal Hospital (referral practice)

Table 2. Record keeping of cardiovascular parameters at the University of Glasgow Small Animal Hospital. Total numbers of recorded parameters, not recorded parameters and ambiguous answers out of a possible 200 records.

Parameter	Recorded	Not recorded	Ambiguous answer
Demeanour	183 (91.5%)	15 (7.5%)	2 (1.0%)
Mucous Membrane Colour 'MM' (s)	192 (96.0%)	6 (3.0%)	2 (1.0%)
Capillary Refill Time 'CRT' (s)	168 (84.0%)	30 (15.0%)	2 (1.0%)
Heart Rate 'HR' (bpm)	196 (98.0%)	3 (1.5%)	1 (0.5%)
Rhythm	131 (65.5%)	65 (32.5%)	4 (2.0%)
Pulse Quality	163 (82.0%)	34 (17.0%)	3 (1.5%)
Pulse Deficit	161 (80.5%)	33 (16.5%)	6 (3.0%)
Jugular Distension	22 (12.0%)	168 (84.0%)	8 (4.0%)
Respiratory Rate 'RR' (Brpm)	160 (80.0%)	38 (19.0%)	2 (1.0%)
Respiratory Effort	73 (37.0%)	124 (48.0%)	3 (15.0%)
Lung Sounds	151 (75.5%)	49 (24.5%)	2 (1.0%)
Presence or Absence of a Murmur	167 (83.5%)	31 (15.5%)	2 (1.0%)

The mean score of the total parameters recorded was 8.8 out of a possible 12.0 points (73.6%).

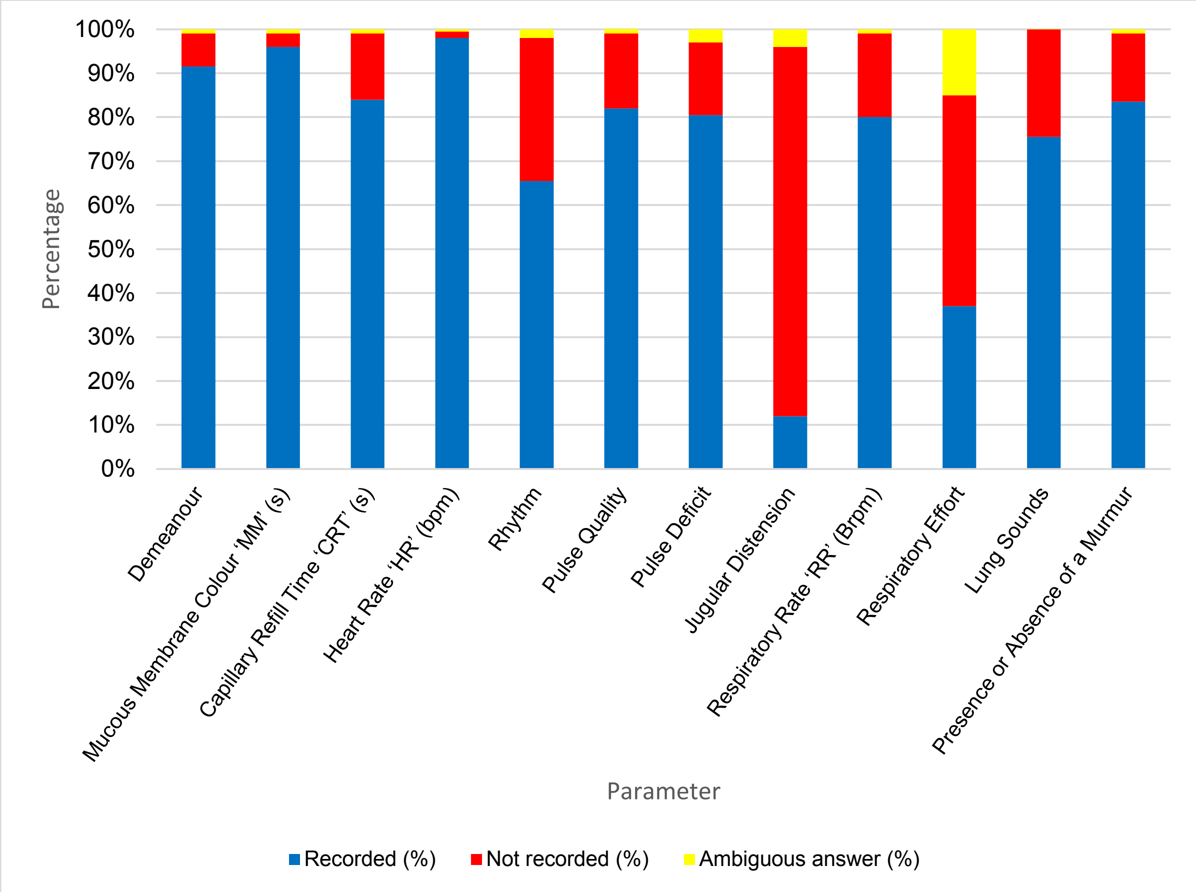


Figure 2 A graphical representation of cardiovascular record keeping at the University of Glasgow Small Animal Hospital. The parameter in question on the x-axis and number recorded, not recorded and ambiguous answers displayed as a percentage on the y-axis. s= seconds, brpm = breaths per minute, bpm = beats per minute.

1.5.3 Murmur Interpretation

Table 3. Record keeping of murmur presence or absence and of murmur grade in both general practice and at the University of Glasgow Small Animal Hospital (referral).

	Referral	General practice
Total number cases	200	200
Not recorded present or absent	31	50
Ambiguous answer	2	5
Recorded present or absent	167	145
NPA	1	4
No murmur present	55	31
Heard, but no grade recorded	0	7
Total number of recorded murmurs with grades assigned	111	103
Grade 1	10	7
Grade 2	26	28
Grade 3	23	30
Grade 4	28	18
Grade 5	21	17
Grade 6	3	3
Heard in general practice, but not recorded as present/absent in referral	5	
Heard in referral, but not recorded as present/absent in general practice	12	

NPA (not possible to assess due to a valid reason).

Table 4. Murmur grade interpretation in general practice and at the University of Glasgow Small Animal Hospital (referral practice) excluding results with no records, ambiguous answers or where a murmur was heard, but no grade assigned. A total of 119 cases remained.

Grade of murmur	Number recorded as this grade in referral	Number recorded as this grade in general practice
0	27	20
1	9	7
2	22	26
3	16	29
4	23	18
5	19	16
6	3	3
Total (excluding cases with no record, ambiguous answers or no assigned grade)	119	119

Table 5. Agreement and differences in murmur grade interpretation in general practice and referral practice (University of Glasgow Small Animal Hospital).

	Murmur grade General practice						
Murmur grade Referral	0	+1	+2	+3	-1	-2	-3
0	18 (66.6%)	3 (11.1%)	4 (14.8%)	2 (22.2%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
1	2 (22.2%)	3 (33.3%)	2 (22.2%)	0 (0.0%)	2 (22.2%)	0 (0.0%)	0 (0.0%)
2	14 (63.6%)	6 (27.2%)	0 (0.0%)	0 (0.0%)	2 (9.0%)	0 (0.0%)	0 (0.0%)
3	9 (56.2%)	4 (25.0%)	1 (6.0%)	0 (0.0%)	2 (12.5%)	0 (0.0%)	0 (0.0%)
4	8 (34.7%)	4 (17.3%)	1 (4.3%)	0 (0.0%)	7 (30.4%)	3 (13.0%)	0 (0.0%)
5	10 (53.6%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	6 (31.5%)	3 (15.7%)	0 (0.0%)
6	2 (66.6%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (33.3%)	0 (0.0%)
Total	63 (52.9%)	20 (16.8%)	8 (6.7%)	2 (1.6%)	19 (15.9%)	7 (5.8%)	0 (0.0%)

0 = No difference in grade, +1 = 1 grade higher, +2 = 2 grades higher, +3 = 3 grades higher, -1 = 1 grade lower, -2 = 2 grades lower, -3 = 3 grades lower.

There were 2 murmurs auscultated in referral which were not auscultated in general practice ('missed murmurs').

There were 9 murmurs which were not auscultated in referral but were heard in general practice.

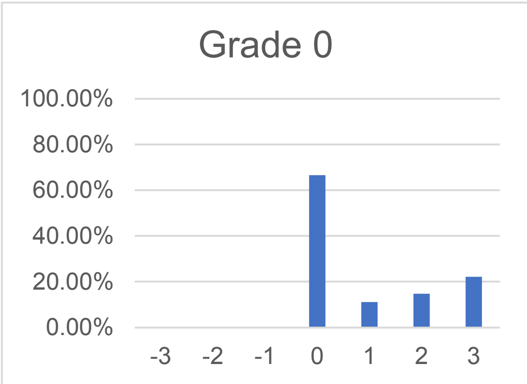
30 murmurs were graded higher in general practice than the grade assigned in referral practice. 26 murmurs were graded lower.

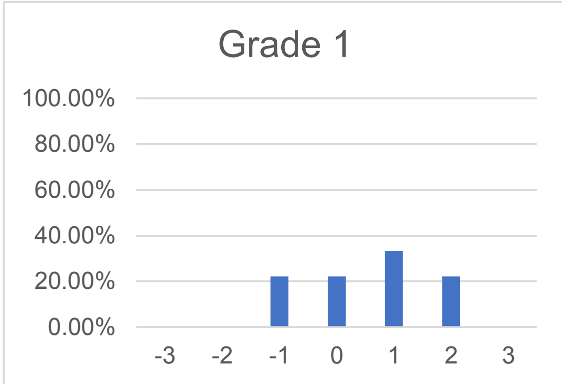
Table 6. Kappa analysis of agreement between referral and general practice on murmur grading.

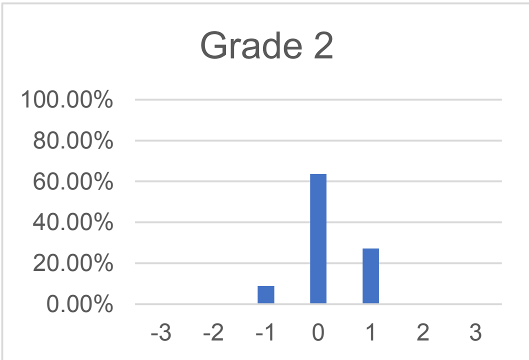
	Murmur Grade Referral							
Murmur Grade General Practice	0	1	2	3	4	5	6	Total
0	18	2	0	0	0	0	0	20
1	3	2	2	0	0	0	0	7
2	4	3	14	2	3	0	0	26
3	2	2	6	9	7	3	0	29
4	0	0	0	3	8	6	1	18
5	0	0	0	2	4	10	0	16
6	0	0	0	0	1	0	2	3
Total	27	9	22	16	23	19	3	119

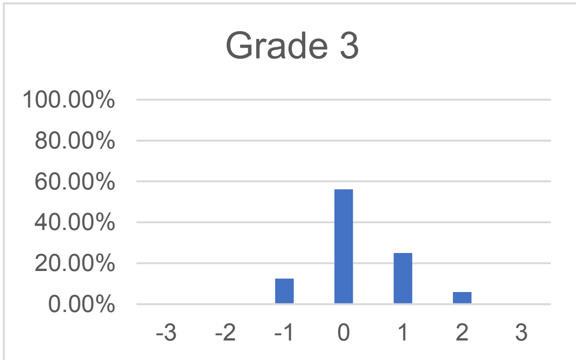
Agreement	Expected Agreement	Kappa	Std. Error.	Z	Prob>Z
83.87%	46.64%	0.6976	0.0614	11.37	0.0000

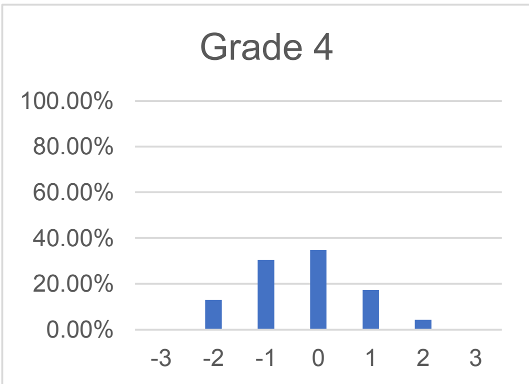
The KAPPA statistic for agreement between general practice and referral practice (University of Glasgow Small Animal Hospital) murmur grading is 0.7, which is a substantial agreement.

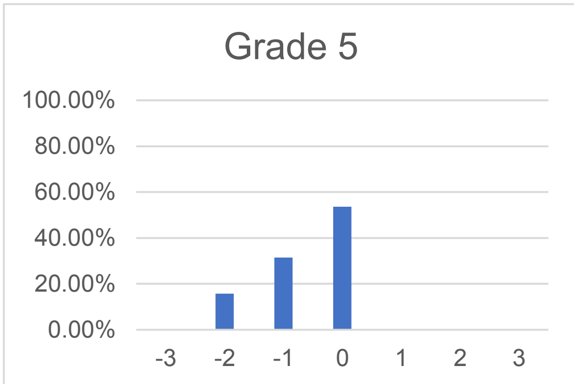

Grade 0
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
-3 -2 -1 0 1 2 3

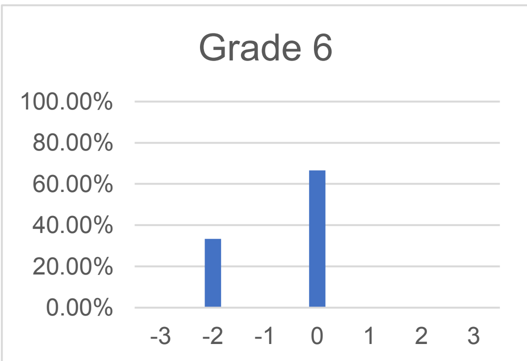

Grade 1
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
-3 -2 -1 0 1 2 3


Grade 2
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
-3 -2 -1 0 1 2 3


Grade 3
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
-3 -2 -1 0 1 2 3


Grade 4
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
-3 -2 -1 0 1 2 3


Grade 5
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
-3 -2 -1 0 1 2 3


Grade 6
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
-3 -2 -1 0 1 2 3

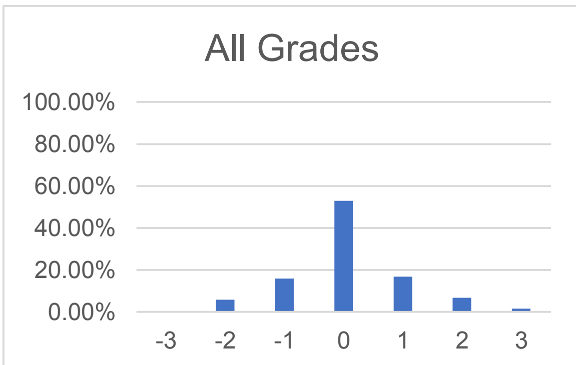

All Grades
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
-3 -2 -1 0 1 2 3

Figure 3

Graphical representations of percentage agreement between referral (University of Glasgow Small Animal Hospital) and general veterinary practice on the absence of murmurs (grade 0) and murmur grades one out of six to six out of six. Percentage of general practitioners that agreed with the murmur grade assigned in referral practice displayed on the y-axis and the difference between murmur grade displayed on the x-axis.

The percentage agreement on murmur grade between referral (University of Glasgow Small Animal Hospital) and general practice is 53% with 85.6% agreement within 1 grade.

1.5.4 Murmur timing

Table 7. Record keeping of murmur timing at the University of Glasgow Small Animal Hospital and in general practice in all cases when the presence of a murmur was recorded with a grade assigned, or a murmur was recorded but no grade was assigned.

	Total	Recorded	Not recorded
Referral Practice	111	86	25
General Practice	110	40	70

Table 8. Record keeping of murmur timing in referral and general practice.

	Referral	General practice
Recorded	86	40
Not Recorded	25	70
Systolic	82	37
Diastolic	0	0
Continuous	4	3

Table 9. Comparison of murmur timing interpretation in referral practice and general practice. Including only those records in which timing was recorded in both general practice and referral.

	Referral	General practice
Systolic	27	27
Continuous	3	3

There was 100% agreement between referral and general practice on murmur timing. Kappa = 1.0.

1.5.5 Murmur PMI (side and apex/base)

Table 10. Record keeping of side of PMI of the heart murmur in referral and general practice.

	Total	Recorded	Not recorded
Referral practice	111	98	13
General practice	110	43	67

Table 11. Number of left- and right-sided heart murmurs of the 98 sides recorded in referral practice.

Total	Left	Right
98	90	8

Table 12. Record keeping of the apical or basilar PMI of the heart murmur in referral practice and general practice.

	Total	Recorded	Not recorded
Referral practice	111	78	33
General practice	110	16	94

Table 13. Apical or basilar PMI of the 78 recorded in referral practice.

Total	Apical	Basilar
78	52	26

Table 14. Number of left and right murmurs of the 43 sides recorded in general practice.

Total	Left	right
43	37	6

Table 15. Record keeping of the apical or basilar PMI of the 16 heart murmurs recorded in general practice.

Total	basilar	apical
16	6	10

Table 16. Left and right sided murmurs recorded in both referral and general practice.

Total of 37	Referral	General Practice
left	34	33
right	3	4

Table 17. Kappa agreement between referral and general practice for heart murmur side of maximum intensity.

Referral	General Practice		
	Left	Right	Total
Left	32	2	34
Right	1	2	3
Total	33	4	37

Agreement	Expected agreement	Kappa	Std. Err	Z	Prob>Z
91.89%	82.83%	0.527	0.162	3.25	0.0006

The kappa agreement is 0.53. This is a moderate agreement.

1.6 Discussion

The results from this study highlight a high prevalence of poorly recorded findings relating to cardiovascular parameters in general veterinary practice. It is worth noting that the records assessed were from patients referred to the cardiology department for a suspected cardiovascular disease. In this situation, it would be expected that record keeping of cardiovascular parameters would be better than normal, raising the concern that even fewer parameters are recorded in the general consultation when animals are presented for problems other than cardiovascular disease.

Unfortunately, it is unclear if the poor records are due to:

- Lack of assessment of the parameter (practitioner did not consider this essential)
- Lack of knowledge (practitioner did not know how to assess the parameter)
- Lack of interpretation (practitioner performed the examination, but did not know how to interpret the findings)
- External factors (conditions in the consultation preventing auscultation of an abnormality)
- Poor record keeping itself (the practitioner assessed the parameter, interpreted it correctly, but did not record the findings)

Although records were more complete at the University of Glasgow, there were still significant gaps. The author cannot confirm that this was not due to poor knowledge or lack of assessment, however this is assumed unlikely. The reason for the lack of recorded parameters in this situation was suspected to be due to inadequate record keeping itself.

The teaching of record keeping skills in Veterinary school could play a major role in developing the record keeping skills of future practitioners. It would seem essential therefore that academic assessment measures are carried out to ensure that veterinary record keeping competencies are achieved. Positive changes have been seen in dental students' record-keeping following an audit (Pessian and Beckett, 2004) and this may be something that can be implemented in final year veterinary student training.

In the human literature, it has been shown that surgical checklists represent a relatively simple and promising strategy for addressing surgical patient safety worldwide (Treadwell, Lucas and Tsou, 2014). Surgical checklists have been associated with increased detection of potential safety hazards, decreased surgical complications and improved communication among operating staff. One potential strategy to improve record keeping in a veterinary consultation is the addition of software that contains checklists against which a vet can be guided to ensure the minimum requirements are fulfilled.

In addition, veterinary apps on mobile tablets offer a replacement for paper records or static computers and allows entry of parameters at the bedside.

As technology continues to advance, devices such as wireless pet monitoring collars, which use non-invasive sensors to read an animal's temperature, pulse, respiration, activity patterns, positions and heart rate variability may be seen more frequently and used as part of data collection in a veterinary consultation.

The increase in availability of digital stethoscopes and digital recordings of murmurs could improve teaching and learning of murmur interpretation in veterinary schools and help to standardise assessment of murmur grades, timing and PMI.

To overcome the problem of time constraints, the use of voice-activated recording systems could become commonplace in veterinary consultations. The recent technology of smart phones and tablet devices with the capacity to record voices could mean that consultations are saved and attached as files in a patient's treatment record. This could potentially be converted into a written document through voice recognition software.

Whilst it is not realistic to expect all parameters to be recorded every time, there should be a minimum requirement of parameters recorded in every possible clinical scenario. This would constitute good practice.

In 2018, post the data collection for this research, a paper was published to determine whether historical and clinical examination findings could differentiate between acute cardiac and non-cardiac dyspnoea in cats in primary practice (Dickson et al., 2018). It identified that dyspnoeic cats presenting in practice with hypothermia, tachycardia, gallop sounds or profound tachypnoea were likely to have a cardiac cause underlying their dyspnoea. Although diagnosis would still need to be confirmed, it suggested that clinicians may be able to stratify risk and prioritise further investigation based on these findings. Therefore, in the case of a dyspnoeic patient, the author recommends that a minimum database of heart rate, rhythm, respiratory rate, respiratory effort and rectal temperature would be considered good practice.

The author recommends that practitioners confidence could be improved by attending continued professional development highlighting the importance of the cardiovascular physical examination and refreshing practitioners on how to perform tests (e.g. assessing jugular distension) and to interpret findings.

1.6.1 Causes for poor record keeping

The causes of poor record keeping have not been investigated in this study, however possible suggestions include the time constraints faced in general practice, the influence of others, consulting conditions, patient demeanour and financial pressure. Semi-structured interviews or focus groups with general veterinary practitioners could be used to investigate this further.

Time constraints

Ten-minute consultations remain a standard in general veterinary practice (Gray and Cripps, 2005).

Practitioners see a large number of patients in a day and these consultations have been shown to be more complex than they initially seem (Gray and Cripps, 2005; Everitt et al., 2013). Previous research has suggested that consultations often take longer than 10 minutes especially if it is a complex case or the first consultation rather than a recheck appointment (Shaw et al., 2008; Everitt et al., 2013) These studies did not include the time spent reading or writing clinical notes prior to or following the consultation suggesting that the total period for the complete consultation would be even longer.

In light of this, it would suggest that there is little time for record keeping and/or that it happens in haste at the end of the consult. Alternatively, records are added later in the day when details have been forgotten.

In the human literature, increases in length of consultation have been shown to be positively associated with detection and management of conditions (Freeman, 2002). In the veterinary literature there is evidence to suggest that the length of consultation is related to client satisfaction (Cape, 2002; Coe, 2008).

It is unclear whether the length of consultation would affect record keeping, however, it would seem logical that it would.

It may be appropriate for practices to schedule longer consultation times or have designated times for record keeping because, unfortunately, lack of time is not a defence against litigation.

The Influence of work colleagues

The influence of a poor standard of record keeping by other colleagues in a practice may have a negative effect on a new graduate or other colleagues. New graduates coming into a practice may be susceptible to influences of other more qualified practitioners. Whilst there are recommendations for record keeping, there are no standardisations or legal requirements.

Financial constraints

Pressure from employers to see additional consultations in time that would normally be spent typing up records.

Conditions of the consultation

Noise (building work/barking etc.) could potentially reduce the ability to detect subtle changes on physical examination.
Poor lighting could potentially reduce the ability of the practitioner to detect changes on physical examination.

Temperament of a patient

It is inevitable that, for some patients, performing a complete physical examination is not possible (nervous, aggression, barking, panting etc.). However, in this situation, it is vital that an inability to record findings and the reasons for this are noted in the records.

1.6.2 Acronyms or ambiguous answers

In relation to the records examined, acronyms or ambiguous answers were a feature. Examples include the use of words such as 'adequate', 'normal' or the use of acronyms such as 'NAD' 'WNL' (within normal limits).
There is no way to quantify these remarks and therefore they are open to misinterpretation. If an open remark is written such as 'NAD on rest of physical examination', It is unknown if the parameter was examined at all.

1.6.3 The least recorded parameter

As can be seen from the results, in both general practice and referral practice the parameter least recorded was the result of a jugular examination (Figure 1 & 2). The author proposes this may be due to the need to clip the patient's fur in order to make an assessment (especially if the fur is thick) and this may be resisted by the owner or vet, reducing the examination of this parameter.

1.6.4 The impact of poor record keeping

The impact of poor record keeping has not been investigated in this study. However, the author proposes that it has a negative impact as it increases the workload for staff, undermines patient care and puts the practitioner at risk of legal and professional complications.

As stated earlier, the records assessed were from practitioners referring patients to the University of Glasgow Small Animal Hospital. It would seem even more important when multiple professional environments and staff are involved that records are of a good standard. Good records facilitate continuity of care and enhance ability of practitioners to work well together, which poor records do not.

1.7 Murmur interpretation

1.7.1 Murmur grading

The intensity of a murmur has been shown to be a guide to its severity in dogs with mitral valve disease (Ljungvall et al., 2014) and pulmonic and aortic stenosis (Caivano *et al.*, 2018), therefore accurate grading by vets in general practice is essential.

In this study, the overall agreement between the perceived murmur grade assigned by the referral veterinary cardiology department and the general practitioners was substantial (0.70 kappa statistic) (Table 6).

Of the general practitioners, 66.7% agreed that no murmur was present in the animals subsequently assessed as ‘no murmur present’ in the referral setting. 11.1% recorded a grade 1 murmur, 14.8% recorded a grade 2 murmur and 22.2% auscultated a grade 3 murmur. Two murmurs with recorded grade 1 at referral which were not detected in general practice. This would suggest that very few murmurs were missed by general practitioners and the tendency of general practitioners was to over-interpret.

In general practice, vets had a tendency to over-grade murmurs assigned a grade 1-3 at referral, and had a tendency to under-grade murmurs assigned a grade 4-6 (Figure 3).

It is interesting to note that despite the recent introduction of the simplified 4-grade murmur scale (Ljungvall et al., 2014), 100% of practitioners still used the Levine method of grading out of 6. However the simplified scale has not been widely publicised.

1.7.2 Murmur timing

Interpretation of whether a murmur is systolic, diastolic or continuous helps to identify the underlying lesion causing the murmur.

This study has shown a perfect agreement between general practitioners and referral practice on murmur timing (1.0 kappa statistic) (Table 9). Unfortunately, no diastolic murmurs were available for assessment, which prevents investigation of practitioners' ability to correctly identify diastolic murmurs.

1.7.3 Murmur PMI

This study has shown a moderate agreement between general practitioners and referral practice on the side of maximum intensity of murmurs (0.53 kappa statistic) (Table 17).

1.8 Limitations

The study has a number of limitations inherent to its retrospective nature. Due to poor record keeping, the final numbers of cases that could be analysed for heart murmurs was reduced.

Lack of randomization: the analysed records represent a sample of practitioners referring cases to the University of Glasgow Small Animal Hospital. The practices sampled in this study were not randomly drawn from the total population of general practitioners across the United Kingdom and, therefore, cannot represent the entire population of UK vets.

Previous research has found that diagnosis of mild mitral regurgitation by auscultation varies depending on observer experience, circulatory status of the patient, and how difficult the dog was to auscultate (Pedersen et al., 1999). The retrospective design of this study meant that it was not possible to take these factors into consideration. Any small differences in the way the patient was approached, handled and conditions of the consultation room may have affected the patients' circulatory status and subsequently the grade of murmur auscultated. Therefore, the different conditions in which the animals were auscultated may have increased or decreased the murmur grade.

Unfortunately, no diastolic murmurs were available for assessment, which prevents investigation of practitioners' ability to correctly identify diastolic murmurs.

Whilst all appointments at the University of Glasgow Small Animal Hospital were within a two-week window of the consultation at the referring vet, a change in parameters between referral and general practice cannot be excluded. For example, rupture of a chorda tendinea and a subsequent increase in murmur intensity between initial auscultation and referral cannot be excluded.

1.9 Conclusion chapter I

The results from this study have identified a poor standard of record keeping by general veterinary practitioners for important cardiovascular parameters. This echoes findings in both the medical and dental professions (Sari E. Helminen, Miira Vehkalahti, 1998; Cole and McMichael, 2009; Inan and Dinç, 2013).

General practitioners (compared to a referral consensus opinion) had a substantial agreement on murmur grade (K = 0.7), a perfect agreement on murmur timing (K = 1.0) and a moderate agreement on the side of maximum intensity of murmur (K = 0.5).

These findings suggest that practitioners are able to grade heart murmurs accurately and therefore could potentially correctly select patients who would benefit from further investigation to confirm the cause of the murmur as MMVD and potentially benefit from medication. However the significant loss of information due to poor record keeping could prevent early identification of patients with cardiac disease or identification of progression of cardiac disease and subsequently, patients may not receive the benefits of medication.

Records should be factual, clear, consistent and accurate. They should be written as soon as possible after the consultation has occurred and they should follow a logical sequence with clear checkpoints and goals and answer the question “if I were caring for this patient for the first time, what would I need to know?”

CHAPTER II: AN ASSESSMENT OF RADIOGRAPHIC DETECTION OF CARDIAC DISEASE BY GENERAL VETERINARY PRACTITIONERS, SPECIFICALLY RADIOGRAPHIC DETECTION OF LEFT ATRIAL ENLARGEMENT AND GENERALISED CARDIOMEGALY CAUSED BY MYXOMATOUS MITRAL VALVE DISEASE

2.1 Introduction

For many years, thoracic radiography in combination with a clinical examination and electrocardiogram was the main method of diagnosis of canine cardiac disease. The introduction of echocardiography has provided veterinarians with a more accurate method of determining chamber size, cardiac function, assessing valve leaflets and blood flow. However, both availability of and expertise in cardiac ultrasonography remain limited in general veterinary practice and therefore echocardiography often requires referral. For this reason, thoracic radiography remains one of the most important diagnostic tests for the diagnosis of cardiac disease.

Thoracic radiography can be used to identify cardiac remodelling such as generalised cardiomegaly, specific chamber enlargement (which can be indicative of the type of cardiac disease), to identify signs of heart failure (pulmonary venous distension and pulmonary oedema) and to monitor responses to cardiac medication (Bahr, 2012). In dogs with mitral valve disease, thoracic radiographs can be evaluated to determine the severity of disease as the left atrium enlarges as the disease progresses (Lord *et al.*, 2010).

The findings from the recent EPIC study suggest that patients in the pre-clinical stage of MMVD who are administered pimobendan have an extended asymptomatic period of an average of 15 months and dogs that receive the drug live longer (Boswood *et al.*, 2016). In order for patients to benefit from pimobendan, it is essential that dogs who could benefit from this medication can be correctly identified in general practice.

All the dogs in the EPIC study (Boswood *et al.*, 2016) were of small to medium size (4-15kg), greater than or equal to 6 years of age, had a characteristic systolic heart murmur greater than or equal to 3/6 with a maximal intensity over the mitral area and were confirmed to be in stage B2 mitral valve disease (Atkins *et al.*, 2009) based on echocardiographic evidence of advanced MMVD defined as:

- Characteristic valvular lesions of the mitral valve apparatus
- Mitral regurgitation on the colour Doppler echocardiogram

- Left atrial dilation defined as a left atrial-to-aortic root ratio (LA:Ao) ≥1.6 (Hansson *et al.*, 2002)
- Left ventricular dilatation, defined as a body weight normalized left ventricular internal diameter in diastole (LVIDDN) of ≥1.7 (Cornell *et al.*, 2004)

The radiographic criterion was radiographic evidence of cardiomegaly (vertebral heart sum (VHS) >10.5) (Hansson, Häggström, *et al.*, 2005).

The pimobendan data sheet states that it is ‘for use in the preclinical stage of myxomatous mitral valve disease (stage B2, according to ACVIM consensus: asymptomatic with mitral murmur ≥ 3/6 and cardiomegaly due to myxomatous mitral valve disease) and that a diagnosis should be made by means of a comprehensive physical and cardiac examination which should include echocardiography or radiography where appropriate’.

With the knowledge that practitioners are able to detect and accurately grade a heart murmur (Chapter I) it then becomes essential that dogs in mitral valve disease stage B2 (signs of left sided enlargement or generalised cardiomegaly) or greater who would benefit from pimobendan can be accurately identified on thoracic radiographs.

The consequences of both a false positive detection of cardiomegaly and false negative are undesirable. A false positive could result in a patient receiving pimobendan too soon, which research has suggested could worsen the mitral regurgitation, cause myocardial hypertrophy or acute focal haemorrhages, endothelial papillary hyperplasia, and infiltration of chordae tendineae with glycosaminoglycans in the mitral valves of dogs (Tissier et al., 2005; Chetboul et al., 2007). A false negative could mean that the patient would not receive the full benefits of pimobendan.

2.2 Evaluation of cardiac size and shape on thoracic radiographs

2.2.1 Generalised cardiomegaly

Even though generalised cardiomegaly can occur in various cardiac diseases, mitral regurgitation is one of the most common causes (Kittleson, 1998a). Whilst moderate and severe generalised cardiomegaly is thought to be easily detectable, detection of mild changes can be challenging.

Different methods can be used to evaluate for cardiomegaly, including both subjective and objective methods (Toombs and Ogburn, 1985). These methods take into account the size of the heart compared with the volume of the thoracic cavity, the position of the trachea and the position of the heart in relation to other organs.

These include:

- A decrease in distance between the heart and diaphragm (Johnson *et al.*, 2011) .
- Dorsal displacement of the trachea on the lateral view (Johnson *et al.*, 2011).
- The vertebral heart score measurement on the lateral view (Buchanan and Bucheler, 1995; Ware, 2003b).
- An increase in the number of intercostal spaces covered by the cardiac silhouette (greater than 2.5 (deep chested breeds) -3.5 intercostal spaces (barrel-chested breeds)) on the lateral view (Buchanan, 1977; Baines, 2010).
- Cardiac width 2/3rds (approximately 60-65%) of the width of the thoracic cavity on the DV view (Baines, 2010).
- Height exceeding 2/3rds (approximately 70%) of the height of the thoracic cavity on the lateral view (Poteet, 2008; Johnson *et al.*, 2011).
- Round silhouette on the DV and lateral view (Johnson *et al.*, 2011).
- Straight caudal margin of the heart on the lateral view (Johnson *et al.*, 2011)
- General impression of increase in size on both the lateral and DV view (Ware, 2003b; Johnson *et al.*, 2011)
- Reversed D shape of the cardiac silhouette on the DV view (Johnson *et al.*, 2011).

In order to make a subjective assessment, the film reader must be familiar with the appearance of a normal cardiac silhouette and take into account the fact that if comparing the size of the cardiac silhouette against the thorax, adjustments must be made for different conformations of the thorax (deep chested/shallow chested etc.).

On the lateral view, cardiomegaly may appear as an increase in height and width of the cardiac silhouette. It can be assessed by comparing the number of intercostal spaces the width of the heart occupies. As the heart increases in size, this number increases (Buchanan, 1977). However again, the shape of the dog's chest can affect this, with shallow chested dogs having greater width.

As the cardiac size increases in height, the trachea is dorsally displaced. Therefore, a decrease in the normal angle between the trachea and spine (30 degrees) is suggestive of cardiac enlargement. This measurement is also affected by breed variation with shallow chested dogs having a reduced angle and deep-chested dogs have a larger angle.

On the DV view, the heart may be seen to increase in width and length. This can result in a more rounded appearance of the heart and occupation of approximately 60-65% of the chest diameter.

2.2.2 The Vertebral heart score (VHS)

The VHS was first introduced in 1995 (Buchanan and Bucheler, 1995). It was based on the observation of a correlation between heart size and length of thoracic vertebrae. Thoracic vertebral bodies (v) were used as a measurement system.

The vertebral heart score (also called 'vertebral heart sum' or 'size') was created as an objective way of identifying and quantifying cardiomegaly. It has been shown that VHS correlates with other methods of measuring cardiomegaly like echocardiography and electrocardiography and it is considered to be the gold standard by many in determining cardiomegaly (Nakayama, Nakayama and Hamlin, 2001). Other studies have, however, shown that little value is added when evaluating radiographs for cardiac disease using VHS compared with making a subjective interpretation (Lamb et al., 2000).

Using a lateral thoracic radiograph of good diagnostic quality and clearly visible thoracic vertebrae T4-T12, the long axis of the heart is measured from the carina of the main-stem bronchus to the apex of the heart. This measurement is transferred to the cranial edge of vertebral body T4 and the number of vertebral bodies that fall within the caliper points are counted. The short axis of the heart is then measured at the widest part, at 90° to the long axis, and again this measurement is transferred to the vertebrae starting at the cranial edge of T4 and the number of vertebral bodies that fall within the measurement are counted. The two measurements are then added together and this is translated into thoracic vertebral body length to the nearest 0.1v (Buchanan and Bucheler, 1995).

The original study found that the vertebral heart size of the 100 normal dogs was 9.7 +/- 0.5 vertebrae (9.2-10.5v) and that chest configuration had no effect on the measurement (Buchanan and Bucheler, 1995).

However, since this study other research has identified breed specific differences in the vertebral heart score reference range, with most breed ranges being larger than that found in the original study (Lamb *et al.*, 2001; Bavegems *et al.*, 2005; L. M. Martin *et al.*, 2007; Kraetschmer *et al.*, 2008; Jepsen-Grant, Pollard and Johnson, 2013; Bodh *et al.*, 2016). It has become apparent that there is a need to establish vertebral heart scores for each breed.

2.2.3 Breed specific VHS

Table 18. Breed specific vertebral heart scores.

Breed	VHS	Reference
Whippets	11.0 +/- 0.5	(Bavegems et al., 2005)
Beagles	10.3 +/-0.4	(Kraetschmer et al., 2008)
Greyhounds	10.5±0.1	(L. M. Martin *et al.*, 2007)
Cavalier King Charles Spaniels	10.6 +/- 0.5	(Lamb et al., 2001)
Pug	10.7 +/- 0.9	(Jepsen-Grant, Pollard and Johnson, 2013)
Pomeranian	10.5 +/- 0.9	(Jepsen-Grant, Pollard and Johnson, 2013)
Yorkshire Terrier	9.9 +/- 0.6	(Jepsen-Grant, Pollard and Johnson, 2013)
Dachshund	9.7 +/- 0.5	(Jepsen-Grant, Pollard and Johnson, 2013)
Bulldog	12.7+/- 1.7	(Jepsen-Grant, Pollard and Johnson, 2013)
Shih Tzu	9.5 +/- 0.6	(Jepsen-Grant, Pollard and Johnson, 2013)
Lhasa Apso	9.6 +/- 0.8	(Jepsen-Grant, Pollard and Johnson, 2013)
Boston Terrier	11.7 +/- 1.4	(Jepsen-Grant, Pollard and Johnson, 2013)
Indian Spitz	10.21 +/-0.23	(Bodh et al., 2016)
Labrador Retriever	10.39 +/- 0.19	(Bodh et al., 2016)
Mongrel	9.82+/- 0.21	(Bodh et al., 2016)
Boxer	11.6 +/- 0.8	(Lamb et al., 2001)
German Shepherd	9.7 +/- 0.7	(Lamb et al., 2001)
Dobermann	10.0 +/- 0.6	(Lamb et al., 2001)

In addition to the breed, many other factors can affect interpretation of the cardiac silhouette. Technical factors like exposure settings, film type and developer should always be taken into account and standardised. Ideally, practitioners should take a minimum of two orthogonal views in an examination for cardiac disease and the patients should be positioned as straight as possible as rotation can cause misinterpretation of the cardiac silhouette (Ware, 2003b). Radiographs should be taken as close to peak inspiration as possible as expiration can cause the cardiothoracic ratio to increase as much as 17%, which gives a false impression of cardiomegaly (Silverman and Suter, 1975).

2.2.4 Other factors that can affect VHS

- Phase of the cardiac and respiratory cycle: Inspiratory systolic VHS was found to be significantly higher than expiratory systolic VHS. Inspiratory diastolic was not significantly different from expiratory diastolic VHS (Olive et al., 2015).

- Obesity: Accumulation of fat in the abdomen pushes the diaphragm forward and decreases the size of the thoracic cavity, making the heart appear larger. There may also be an accumulation of fat around the heart in the pericardial space, which may make the heart appear larger or an accumulation in the thorax which may make the size of the thoracic cavity appear smaller and therefore the heart appear larger (Kittleson, 1998a; Jepsen-Grant, Pollard and Johnson, 2013)

- Anaemia: Moderate to severe anaemia has been shown to produce a compensatory left sided cardiomegaly and subsequent increase in the vertebral heart score measurement (Levine et al., 1977).

- Side of recumbency: Radiographs of patients in right lateral recumbency have a higher vertebral heart score than those in left lateral recumbency (Bavegems et al., 2005; Greco et al., 2008).

- Anaesthesia and manual ventilation: VHS has been found to be smaller in manually ventilated dogs under anaesthesia compared with those breathing spontaneously (Webster, Adams and Dennis, 2009).

- Pericardial effusion: Pericardial effusion causes increases in measurements of lateral VHS compared with values for all dogs without PE (Guglielmini et al., 2012).

- Presence of abnormal vertebrae: Anomalous vertebrae in the thoracic spinal column have been associated with a significant increase in VHS in Bulldogs (Jepsen-Grant, Pollard and Johnson, 2013).

2.2.5 Left atrial enlargement

In myxomatous mitral valve disease the left atrium is the chamber that typically receives the largest regurgitant volume and the left side of the heart typically becomes more enlarged than the right. There is no published method on objective measurement of left atrial size on thoracic radiographs; therefore detection relies on subjective assessment. Left atrial enlargement is generally straightforward to detect when moderate or severe on both the lateral and DV views. On the lateral view, an enlarged left atrium elevates the trachea and left main-stem bronchus. The degree of tracheal elevation correlates with the severity of cardiac enlargement.

On the DV view, left atrial enlargement can be seen as increase in size of the left auricle at the 2-3 o clock position. As the body of the left atrium lies between the two main-stem bronchi, an increase in size may increase the angle between the two bronchi. This is often described by the term ‘bowlegged cowboy’(Johnson *et al.*, 2011).

2.2.6 Current recommendations

The ACVIM consensus statement for degenerative mitral valve disease advises that baseline radiographs should be performed for dogs with a new murmur, followed by subsequent yearly radiographic evaluation. Their advice is that calculation of the vertebral heart score and progression should be analysed to allow for identification of patients at higher risk of developing congestive heart failure (Atkins et al., 2009).

In the Cavalier King Charles Spaniel before the onset of congestive heart failure, it has been shown that the VHS is slow to rise until 6 to 12 months prior (Lord et al., 2010) and that rate of change in vertebral heart score per month is predictive of onset of congestive heart failure (Lord et al., 2011). It has been suggested that a ‘risk zone’ could be determined, identifying dogs at risk of imminent congestive heart failure detected by an increase in rate of change of VHS within the last year.

2.3 Observer variation

In the author's experience, general practitioners use subjective and objective methods to examine for cardiomegaly and often a combination of the two methods is used.

If subjective methods and vertebral heart scores are to be used to determine if cardiac disease is present and if changes in vertebral heart scores or the subjective appearance are to be used to assess for progression of cardiac disease, it is essential that general veterinary practitioners can perform this accurately. It is also essential that they are aware of factors that could potentially affect their interpretation and that findings are noted in the clinical record.

A study in 2000 by Lamb and others assessed its participants' (one veterinary radiologist, one veterinary nurse and one veterinary medicine resident) ability to evaluate thoracic radiographs subjectively and objectively and the influence of the VHS method on the accuracy of their radiographic diagnoses of cardiac disease (Lamb et al., 2000). The results showed that the participants had similar mean values for VHS, but a maximal difference of >1.0v. The difference in measurement values were not related to observer experience and all observers were moderately accurate in diagnosing cardiac disease when using a subjective assessment. Whilst VHS would have been expected to improve the accuracy of diagnosing cardiomegaly, in this study, the accuracy of diagnosis did not change significantly as a result of using VHS as an adjunct to a subjective assessment of the radiographs.

In 2001, Nakayama and others (2001) found low inter-observer variability with VHS (coefficients of variation 2.7% and 2.8%). However the 9 practitioners involved in this study were all experienced in the interpretation of thoracic radiographs and the VHS was only measured from one normal dog and one dog with severe cardiomegaly.

In 2005, Hansson (Hansson, Häggström, *et al.*, 2005) asked 16 observers representing four levels of experience (European diplomates in diagnostic imaging, small animal clinicians with more than 15 years of experience, trainee clinicians in their 2nd or 3rd year of a specialisation in canine and feline diseases and fifth year veterinary students) to evaluate radiographs of Cavalier King Charles Spaniels with varying degrees of cardiomegaly caused by mitral regurgitation. Almost identical mean VHS values were found amongst the four levels of experience. The mean difference was 1.05+/- 0.32v. Observers were asked to measure the VHS using the method by Buchanan. Clarification was given as to which structures should be used as the reference points for measurement. It was shown that the VHS was independent of observer experience but dependent of individual observers' selection of reference points and the transformation of long and short axis dimensions into VHS units.

In 2009, Hansson (Hansson et al., 2009) investigated 16 readers' performance (European diplomates in diagnostic imaging, small animal clinicians with more than 15 years of experience, trainee clinicians in their 2nd or 3rd year of a specialisation in canine and feline diseases and fifth year veterinary students) in diagnosis of signs of mitral valve disease on radiographs of Cavalier King Charles Spaniels. This was done by comparing the accuracy and variability among readers with an expert consensus diagnosis. The readers were asked to subjectively evaluate for heart enlargement, left atrial enlargement and signs of heart failure in dogs with mitral regurgitation. The study found that experienced readers were more confident of their diagnosis and performed better than inexperienced readers in difficult cases and that LA enlargement was a more reliable radiographic sign of mitral regurgitation than heart enlargement.

To the best of the author's knowledge, there is no research investigating the accuracy of general veterinary practitioners in interpreting cardiomegaly caused by MMVD without prior teaching or clarification of reference points and using either the VHS or subjective method of assessment.

2.4 Study aims, hypotheses and design

2.4.1 Aim

The primary aim of this study was to investigate the accuracy and variability amongst general veterinary practitioners in the diagnosis of cardiomegaly and left atrial enlargement caused by myxomatous mitral valve disease on thoracic radiographs by both subjective and objective methods.

A further aim was to investigate the technique used by general practitioners when performing thoracic radiography for investigation of cardiac disease, which factors are taken into consideration when assessing for cardiomegaly and how assessment for cardiomegaly and left atrial enlargement is achieved in daily practice.

2.4.2 Hypotheses

- General veterinary practitioners measure a similar mean VHS value to a consensus opinion of European diplomates on thoracic radiographs.
- The mean VHS variance between general practitioners is approximately 1.0v as found in previous studies.
- General veterinary practitioner subjective detection of left atrial enlargement is more accurate than subjective detection of generalised cardiomegaly.
- There is no significant difference in the general veterinary practitioner accuracy of detection of cardiomegaly when using VHS compared to a subjective impression.

2.4.3 Study design

A prospective, observational study. The study was granted ethical consent by the University of Glasgow's ethical committee reference: 17a17.

2.5 Materials and method

Fifteen sets of right lateral (RL) and dorsoventral (DV) thoracic radiographs of Cavalier King Charles Spaniels aged from three years to thirteen years with a systolic murmur of grade 3 intensity or greater were retrospectively selected from examinations performed on dogs attending the University of Glasgow Small Animal Hospital Cardiorespiratory clinic between 2010 and 2017.

All dogs had undergone a clinical examination including cardiac auscultation by a board certified veterinary cardiologist (AF and PW) at the time of the radiograph. In all cases, the cause of the murmur was confirmed as myxomatous mitral valve disease (MMVD) using echocardiography.

All radiographs were considered of good diagnostic quality and exposed as close to inspiration as possible.

The radiographs were assigned by a consensus opinion to the following categories: normal left atrium (n = 5), mild left atrial enlargement (n = 3), marked left atrial enlargement (n = 7), no generalised cardiomegaly (n = 7), mild generalised cardiomegaly (n = 3) and marked cardiomegaly (n = 5). The radiographs were assessed by a board certified diagnostic imaging specialist (GH) and the author. Both assessors were blinded to clinical information about the patients except for breed.

Subjective assessment for generalised cardiomegaly was performed for each radiograph using criteria in table 19 (below) adapted from (Hansson et al., 2009), followed by vertebral heart score measurement.

The VHS of the Cavalier King Charles Spaniels used in this study ranged from 10.7-15.4v.

Each radiograph was subjectively assessed for left atrial enlargement using the criteria in table 20 (below) adapted from Hansson et al. (2009). Left atrial enlargement was confirmed on echocardiography (table 20).

Table 19. Criteria for categorisation of thoracic radiographs.

	Occupation of the thorax	Tracheal displacement
No Cardiomegaly	Normal size/shape relative to the thorax	None
Mild Cardiomegaly	Rounded appearance on lateral and DV views	Mild
Marked cardiomegaly	Heart silhouette occupying most of the thorax on the lateral and DV views	Marked

DV= dorsoventral

Table 20. Criteria for categorisation of thoracic radiographs into no left atrial enlargement (LAE), mild left atrial enlargement and marked left atrial enlargement.

	Caudal border of the heart	Compression and deviation of mainstem bronchus	LA:Ao echocardiographic 2D ratio
No LAE	Normal cardiopulmonary structure	None	<1.6:1
Mild LAE	Straight	Mild	>1.6<2.0:1
Marked LAE	Straight	Marked	>2.0:1

LA:Ao = left atrium to aortic ratio.

All echocardiographic measurements were performed by the author who was blinded to the case details using the right parasternal short axis view of the base of the heart. The method used for the 2-D measurements was as described by Hansson et al. (2002). For the LA and Ao ratios, the first frame after aortic valve closure was used, which is early diastole. In 2-D, transverse dimensions of Ao and LA were measured. For Ao, the first caliper was placed at the midpoint of the convex curvature of the wall of the right aortic sinus. The second caliper was positioned at the point where the aortic wall and the non- coronary and the left coronary aortic cusps merge. The LA was measured by extending the line from the same point where the second caliper was positioned to the blood-tissue interface of the LA wall, measuring the internal diameter. The LA:Ao ratios were calculated as an index for atrial size.

2.5.1 Exclusion criteria

- Radiographs of non-diagnostic quality.
- Radiographs taken in left lateral recumbency (for consistency, only radiographs of right lateral recumbency were chosen).
- Radiographs of patients with extreme obesity.
- Radiographs of anaesthetised dogs.
- Radiographs of patients with a pericardial effusion.
- Radiographs of patients with anaemia.

Each set of radiographs (RL and DV) was assigned a random number between 1 and 15. Using a random order generator (Haar, 1998), the image order was generated. Images were uploaded to an online computer based program and two online assessments were generated. The image order was the same for all participants.

2.5.2 Participants

Twenty-three general small animal veterinary practitioners participated in the study. The practitioners were volunteers from practices in the Glasgow area. They represented various lengths of qualification.

2.5.3 Instructions to readers

The readers were informed that all radiographs were of Cavalier King Charles Spaniels, that all dogs were in various stages of mitral valve disease and they all had a systolic heart murmur of grade 3 out of 6 or louder. The proportion of dogs with left atrial enlargement or cardiomegaly was not given.

The participants were asked to complete a questionnaire (Supplementary material 1) prior to assessing the radiographs. They were asked to rate their confidence in detection of cardiomegaly on radiographs, how many years they had been qualified, if they had attended any further training in interpretation of thoracic radiographs, how many radiographs and which views they would typically take to assess for cardiomegaly in practice. Participants were then asked to complete two assessments.

Assessment 1

The participants were asked to subjectively interpret the radiographs for cardiomegaly and left atrial enlargement using both the RL and DV views. They should determine whether cardiomegaly was present and were given the choice of ‘yes’ or ‘no’ answers. They were then asked if left atrial enlargement was present and were given the choice of ‘yes’ or ‘no’. It was specified not to measure the vertebral heart score in this part of the assessment. There was no time limit to the assessment.

Following this, participants were asked to complete assessment 2.

Assessment 2

Participants were asked to measure a vertebral heart score on the 15 right lateral radiographs. They were advised only to attempt the measurement if they felt competent to perform this task and to write ‘0’ in the answer box provided if they did not feel competent.

Participants were not aware that the radiographs were the same used in the first assessment. The order was randomised, however the same order was used for all participants. They were not provided with any training material prior to or during this assessment. Rulers, pens and paper were available.

Both assessments were completed on desktop computers and practitioners were shown how to enlarge the image if required.

Following the assessment, the practitioners were asked to complete a second questionnaire (Supplementary material 2). The questions assessed how they typically detected cardiomegaly and left atrial enlargement on thoracic radiographs in general practice and the factors that they took into consideration. They were asked what they would use as the upper end of normal vertebral heart score for a Cavalier King Charles Spaniel. This individual interpretation was to be used to assess whether the individual's VHS would result in a correct diagnosis of cardiomegaly.

Practitioners were not given any feedback or training throughout the assessments, however following completion they could ask questions or for feedback on areas of misinterpretation.

2.5.4 Statistical analysis

Statistical analysis was performed using the software program Minitab version 17.

The proportion of practitioners that got all of the diagnoses correct for both the generalized cardiomegaly and left atrial enlargement was compared using a 2-sided Z test for two proportions. The test was conducted at the 5% significance level and no adjustment is made for multiple testing.

In relation to the VHS scoring, the assessors score was compared to the mean score obtained using a 1-sample t-test at the 5% significance level. No adjustment was made for multiple testing.

2.6 Results

23 practitioners participated in the study. 17 practitioners (74%) had participated in further training since graduation. This included CPD and rotating internships and modules for certificates. 6 had not participated in any further training since graduation (26%).
All 23 participants completed the first assessment. Two practitioners did not know how to perform a vertebral heart score and therefore their answers were excluded from assessment two.

When asked how confident they were in detection of cardiomegaly on thoracic radiographs, one practitioner had no confidence, twelve said they were mildly confident and ten were moderately confident. No practitioner was very confident (Supplementary material.3).

When asked how many radiographs practitioners typically took in practice to assess for cardiomegaly, 18 practitioners said they took two radiographs, 5 practitioners said they took 3 radiographs. No practitioner said they took one, four or five radiographs (Supplementary material.4).

When asked how patients were prepared for thoracic radiographs to assess for cardiomegaly, 6 practitioners said they typically sedate their patients, 8 said they anaesthetize their patients, 7 said their patients were conscious and restrained with sandbags, 2 said their patients were conscious and held (Supplementary material.5).

When asked which radiographs they typically took in practice to assess for cardiomegaly, 22 practitioners typically took a right lateral radiograph, 19 typically took a dorsoventral radiograph, 8 typically took a left lateral radiograph and 3 typically took a ventrodorsal radiograph (Supplementary material.6).

When asked to mark which factors practitioners typically take into consideration when taking thoracic radiographs to assess for cardiomegaly, 10 said they considered body condition, 20 said they consider the breed, 17 said they consider the phase of respiration, 21 said they consider the positioning of the radiograph, 6 said they consider the haematology results, 12 said they consider the side of recumbency, 9 said they consider if the patient is anaesthetised, 5 said they consider abnormal skeletal pathology and 3 said they consider heart rate (Supplementary material.7).

When asked how they typically assessed for cardiomegaly on thoracic radiographs, 3 practitioners said they assessed for any decrease in distance between heart and diaphragm (DDHD), 21 practitioners said they assessed dorsal displacement of the trachea (DDT), 17 said they measured the vertebral heart score (VHS), 17 said they assessed for an increase in the number of intercostal spaces covered by the cardiac silhouette (ICS), 15 said they assessed for cardiac width exceeding 2/3rds of the width of the thoracic cavity (CW), 10 said they assessed for cardiac height exceeding 2/3rds of the height of the thoracic cavity on lateral view, 13 said they assessed for a round cardiac silhouette (RS), 6 said they assessed for straight caudal margin of the heart (SCM), 10 said they assessed for an overall general impression of increase in size (GI) and 5 said they assessed for a reversed D shape on the DV view (RDS) (Supplementary material.8).

No practitioner said that they used VHS alone to make an assessment for cardiomegaly. 6 practitioners used subjective assessment only.
The majority (74%) of practitioners assessed for cardiomegaly using a combination of VHS and subjective methods.

When asked how they typically assessed for left atrial enlargement on thoracic radiographs, 18 practitioners said they assessed for a left auricular bulge (LAB) on the DV view, 12 said they assessed for dorsal deviation and compression of left main stem bronchus (DDCLMSB), 11 said they assessed for dorso-caudal bulging of soft tissue opacity on lateral view (‘tenting’) and 7 said they assessed for the ‘cowboy sign’ on the DV view (CBS) (Supplementary material.9).

When practitioners were asked what the upper limit of the normal vertebral heart score was for a Cavalier King Charles Spaniel, the average was 10.9v, ranging from 10.5-12.0v.

Assessment One

Subjective identification of no cardiomegaly

The 23 practitioners were shown 7 images with no cardiomegaly and had to correctly identify its absence. Therefore, the possible answers were a true negative (correctly identifying the absence of cardiomegaly) and a false positive (an incorrect response stating that cardiomegaly was present).

Analysis of the 7 images with no cardiomegaly showed that the median number of images correctly identified as no cardiomegaly was 4 (57.14%).

The interquartile range, a measure of variability that shows where the middle 50% of the responses are, was 3 to 5. This means that 50% of the responses received scored between 3 (42.86%) and 5 (71.43%) correct.

No participant answered all 7 (100%) correctly and 1 individual did not give any correct answer.

Subjective identification of mild cardiomegaly

The participants were shown 3 images with mild cardiomegaly and were asked to identify its presence. For this section, the optional answers were a true positive (correctly identifying the presence) or a false negative (incorrectly recording the absence of cardiomegaly).

Analysis of the 3 images with mild cardiomegaly showed that the median number of images correctly identified was 2 (66.67%).

The interquartile range here was 2 to 3 showing that 50% of respondents scored between 2 and 3 correct. This is much less variable than the results with no cardiomegaly.

Nine (39.13%) of responders managed to score all three images correctly. Twelve (52.17%) scored 2 correctly and 1 (4.35%) scored one and none correctly. Interestingly, the individual did not identify absence of cardiomegaly in any case managed to correctly determine the presence of cardiomegaly in 6 out of 7 cases in the previous assessment.

Subjective identification of severe cardiomegaly

The practitioners were shown 5 images in which severe cardiomegaly was present. They were again asked to identify the presence or absence of the condition. Therefore, the available responses were true positive and false negative.

Analysis of the 5 images showed that the median number of questions correct was 5 (100%) and there was next to no variability in the responses received.

Twenty (86.96%) correctly identified severe cardiomegaly in all five images. Two individuals (8.70%) answered correctly in 4 cases and 1 individual in 3 cases (4.35%).

Subjective identification of left atrial enlargement

In this section, the 23 responders were shown 5 images where there was no left atrial enlargement, 3 where there was mild left atrial enlargement and 7 images in which marked left atrial enlargement was present.

Subjective identification no left atrial enlargement

For these images, the responses received were true negative (correct diagnosis of no left atrial enlargement) and false positive (incorrect diagnosis of left atrial enlargement).

The results showed that the median number of correct diagnoses was 4 (80%) with an interquartile range of 3 to 5.

6 of the 23 responders (26.09%) made the correct diagnosis in 5 (100%), 4 (80.00%) and 3 (60.00%) of cases. 4 (17.39%) made the correct diagnosis for 2 (40.00%) of the images and 1 (4.35%) of the 23 responders made the correct diagnosis once (20.00% of cases correct).

Subjective identification of mild left atrial enlargement

For the images, the responses received were true positive (correct diagnosis of left atrial enlargement) and false negative (incorrect diagnosis of no left atrial enlargement).

For these images, the median number correct was 2 (66.67%) with an interquartile range of 1 to 3.

6 (26.09%) of the 23 responders made the correct diagnosis for 3 (100.00%) and 2 (66.67%) of images. 7 (30.43%) of the 23 responders made 1 correct diagnosis (33.33%) and 4 (17.39%) of the 23 responders made no correct diagnoses.

<u>Subjective identification of marked left atrial enlargement</u>

For the images, the possible responses were true positive (correct diagnosis of left atrial enlargement) and false negative (incorrect diagnosis of no left atrial enlargement).

The median number of correct responses was 6 (85.7%) and the interquartile range was 4 to 7. Hence there was a moderate amount of variability in the responses.

Nine (39.13%) of the 23 responders made 7 (100.00%), and 6 (85.71%) correct diagnoses. 1 (4.35%) of the 23 responders made 5 correct diagnoses and 4 (17.39%) of the 23 responders made 4 correct diagnoses.

<u>Comparing these two methods</u>

The proportion that got all of the diagnoses correct for both the generalized cardiomegaly and left atrial enlargement was compared using a 2-sided Z test for two proportions. The test was conducted at the 5% significance level and no adjustment is made for multiple testing.

<u>No symptoms</u>

The results (0/23 versus 6/23) showed that that the subjective evaluation of left atrial enlargement resulted in a 26% (95% CI 8.00% to 44.00%) increase in correct diagnoses. This increase was significant with a p-value of 0.0216.

<u>Mild symptoms</u>

The results (9/23 versus 6/23) showed that the generalized cardiomegaly results were not significantly different to the left atrial enlargement results ($p = 0.5302 > 0.05$).

Severe symptoms

The results (20/23 versus 9/23) showed that the generalized cardiomegaly responses were significantly ($p=0.0018<0.05$) greater than those associated with the left atrial enlargement. The estimated increase was 47%, 95% CI 23.59% to 72.06%.

Assessment two

In this experiment, participants (n = 21) were shown 15 images (7 with no CM, 3 with mild CM and 5 with severe CM) and asked to measure the VHS. These scores were then compared to an independent, experienced assessors score.

Here the assessors score was compared to the mean score obtained using a 1-sample t-test at the 5% significance level. No adjustment was made for multiple testing at this time.

No cardiomegaly

Image 1: Here the assessors score was 11. The mean score from the 21 responders 11.05 and standard deviation was 0.822 which indicates relatively low variability. The maximum score was 13 and the minimum was 9.5. The hypothesis test suggests there is no evidence to suggest the responses received were different to the consensus ($p = 0.7934$).

Image 2: Here the assessors score was 11. The mean score from the 21 responders was 10.938 with a standard deviation of 0.8657. The maximum score was 13.2 and the minimum score was 9.5. The hypothesis test shows there is no evidence to suggest there is a difference between the scores received and the consensus ($p = 0.7466$).

Image 3: Here the assessors score was 11.6. The mean score from the 21 respondents was 11.33 with a standard deviation of 1.1559 (moderate variability). The maximum score was 13 and the minimum was 8.5. The hypothesis test shows there was no evidence of a difference between the consensus and the scores received ($p = 0.2947$).

Image 4: Here the assessors score was 11.7. The mean score from the 21 respondents was 11.50 with a standard deviation of 0.847. The maximum score was 13.00 and the minimum was 10.00. The hypothesis test shows there was no evidence to suggest there was a difference between the scores and the consensus.

Image 5: Here the assessor score was 11.9. The mean score from the 21 responders was 11.70 with a standard deviation of 1.1356. The maximum was 14 and the minimum was 9. The hypothesis test showed there was no evidence to suggest a difference between the consensus and the individual scores ($p = 0.436$).

Image 6: Here the assessor score was 11.3. The mean score from the 21 responders was 11.28 with a standard deviation of 1.1473. The maximum was 14 and the minimum was 9.0. The hypothesis test showed there was no evidence to suggest there was a difference between the consensus and the individual scores ($p = 0.9476$).

Image 7: Here the assessor score was 10.7. The mean score from the 21 responders was 10.476 with a standard deviation of 0.9847. The maximum was 13.2 and the minimum was 8. The hypothesis test showed there was no evidence of a difference between the consensus and the individual scores ($p = 0.8269$).

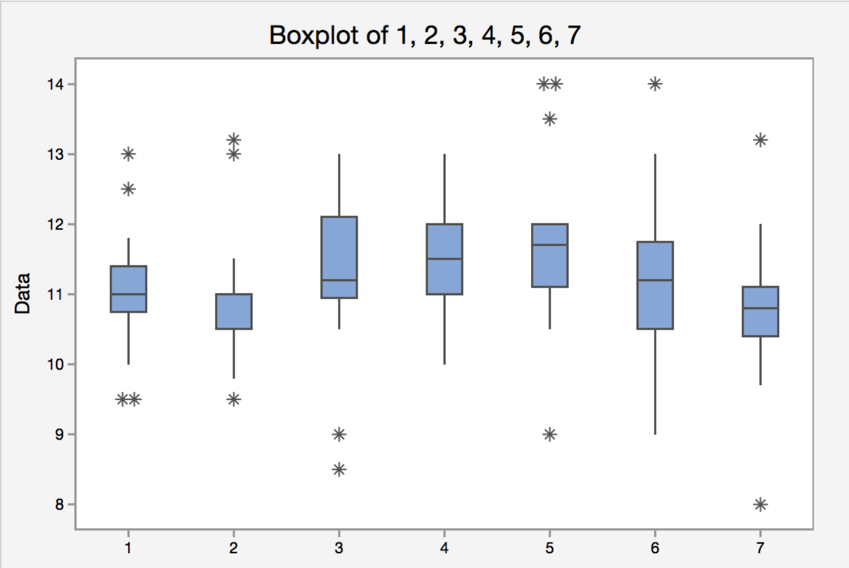


Figure 4 A box plot of the general practitioners' vertebral heart scores for images 1 to 7, which represented those patients with no cardiomegaly. The box represents the central 50% of the values. The horizontal line within each box is the median. The vertical line is the range. * = outliers.

Mild cardiomegaly

Image 8: Here the assessor score was 13.2. The mean score for the 21 responders was 10.2 with a standard deviation of 0.9103. The maximum was 15 and the minimum was 11. The hypothesis test showed that there was no evidence to suggest the individual scores were different to the consensus (p = 0.372).

Image 9: Here the assessor score was 13.2. The mean score for the 21 responders was 12.795 with a standard deviation of 1.185. The maximum was 16 and the minimum was 10.5. The hypothesis test showed there was no evidence of a difference between the individual scores and the consensus (p =0.1332).

Image 10: Here the assessor score was 11.4. The mean score for the 21 responders was 11.5 with a standard deviation of 0.7765. The maximum score was 13.5 and the minimum was 10. The hypothesis test showed there was no evidence of a difference between the individual scores and the consensus (p=0.5617).

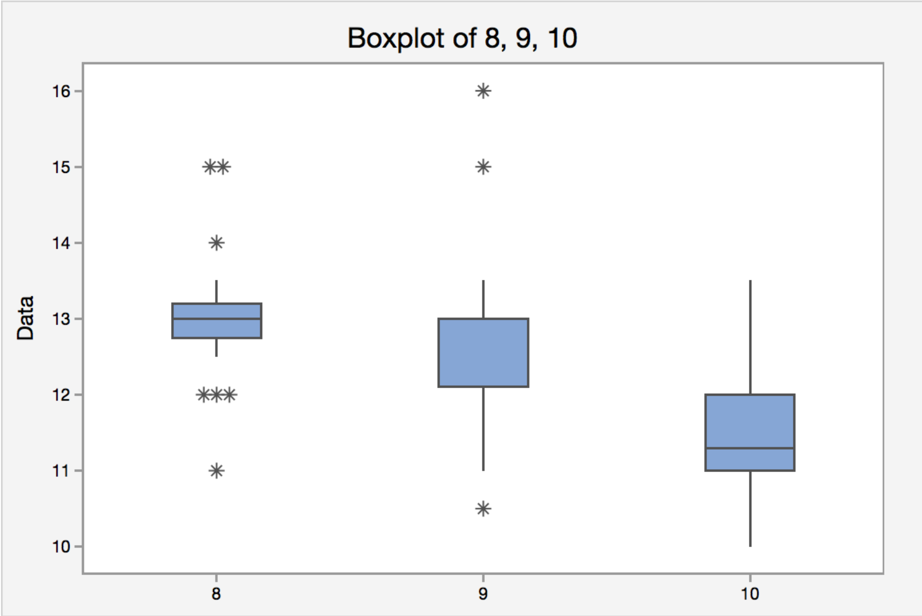


Figure 5 A box plot of the practitioners' vertebral heart scores for images 8 to 10, which represented those patients with mild cardiomegaly. The box represents the central 50% of the values. The horizontal line within each box is the median. The vertical line is the range. * = outliers.

Severe cardiomegaly

Image 11: Here the assessor score was 15.4. The mean score from the 21 responders was 14.19 with a standard deviation 1.6309. The maximum score was 18 and the minimum was 12. The hypothesis test showed there was evidence to suggest the individual scores were significantly lower than the assessors score (0.0029).

Image 12: Here the assessor score was 15. The mean score from the 21 responders was 15.33 with a standard deviation of 1.155. The maximum score was 19 and the minimum score was 13.5. The hypothesis test showed there was no evidence to suggest a difference between the individual scores and the consensus ($p = 0.201$).

Image 13: Here the assessor score was 14.9. The mean score from the 21 responders was 14.814 with a standard deviation of 1.335. The maximum score was 18 and the minimum score was 12.4. The hypothesis test showed there was no evidence of a difference between the individual scores and the consensus ($p = 0.7717$).

Image 14: Here the assessor score was 13.9. The mean score from the 21 responders was 13.29 and the standard deviation was 1.3164. The maximum score was 16 and the minimum score was 11. The hypothesis test showed there was evidence to suggest there was a difference between the consensus and the individual values ($p = 0.0465$).

Image 15: Here the assessor score was 12. The mean score from the 21 responders was 12.376 with a standard deviation of 0.8426. The maximum score was 14 and the minimum score was 11. The hypothesis test showed there was no evidence of a difference between the consensus and the individual scores ($p = 0.054$).

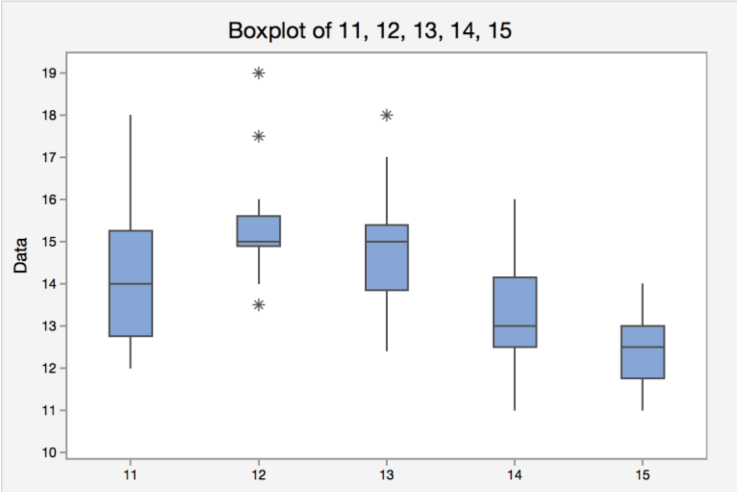


Figure 6 A box plot of the practitioners’ vertebral heart scores for images 11 to 15, which represented those patients with severe cardiomegaly. The box represents the central 50% of the values. The horizontal line within each box is the median. The vertical line is the range. * = outliers.

Individual scores for VHS interpretation

Here the practitioner vertebral heart scores were compared to the individual maxima and classified as true diagnoses or false diagnoses based on the subjective interpretation of experts.

VHS detection of no cardiomegaly

Practitioners were shown 7 of these images.

The median number of correct diagnoses was 3 (42.8%) with an interquartile range of 1 to 5, showing large variability. The maximum was 7 correct and the minimum was 0 (Figure 7).

3 (14.28%) of the 21 responders made the correct diagnosis in all cases, 1 (4.76%) made six correct diagnoses, 2 (9.52%) made 5 correct diagnoses, 3 (14.28%) made 4 correct diagnoses, 4 (19.05%) made 3 correct diagnoses, 2 (9.53%) made 2 correct diagnoses, 3 (14.29%) made 1 and no correct diagnoses.

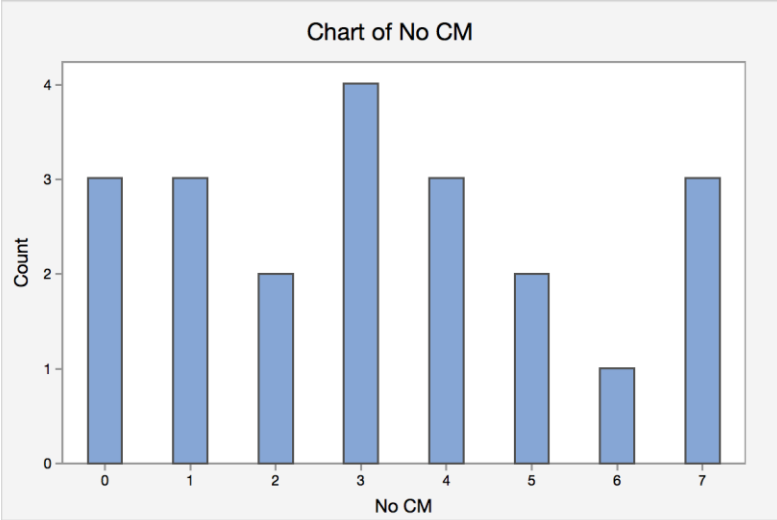


Figure 7 A graphical display of number of practitioners (y-axis) who correctly identified the absence of cardiomegaly in 1-7 images (x-axis). No practitioner got all 7 correct. Count = number of practitioners. CM = Cardiomegaly.

In terms of the individual images:

- Image 1: 13 (61.90%) made the correct diagnosis
- Image 2: 13 (61.90%) made the correct diagnosis
- Image 3: 7 (33.33%) made the correct diagnosis
- Image 4: 7(33.33%) made the correct diagnosis
- Image 5: 6 (28.57%) made the correct diagnosis
- Image 6: 9 (42.86%) made the correct diagnosis
- Image 7: 13 (61.90%) made the correct diagnosis

VHS detection of mild cardiomegaly

Practitioners were shown 3 of these images and the responses were true positive or false negative.

The median number of correct diagnoses was 3 (100%) with an interquartile range of 2 to 3. The maximum was 3 and the minimum was 2 (Figure 15).

13 (61.90%) of the 21 responders made 3 correct diagnoses and 8 (38.10%) made 2 correct diagnoses.

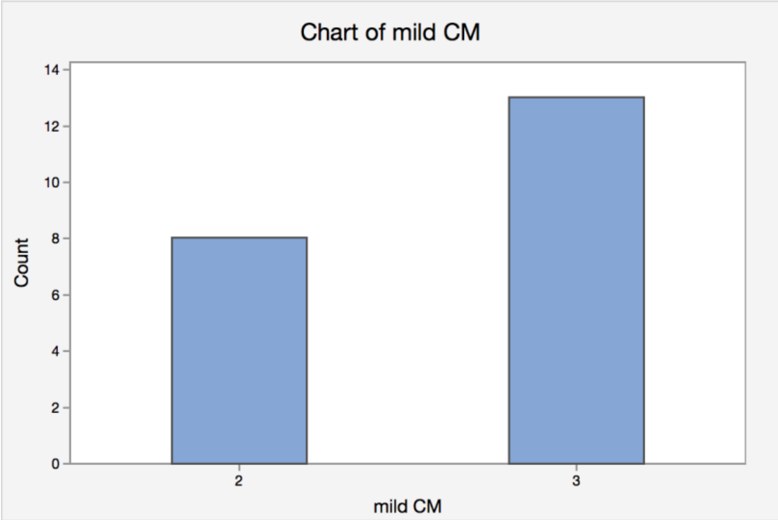


Figure 8 A graphical display of number of practitioners (y-axis) who correctly identified the presence of mild cardiomegaly in 2-3 images (x-axis). No practitioner got just 1 correct. Count = number of practitioners. CM = Cardiomegaly.

In terms of the individual images:

- Image 8: 20 (95.24%) made the correct diagnosis.
- Image 9: 20 (95.24%) made the correct diagnosis.
- Image 10: 15 (71.43%) made the correct diagnosis.

VHS detection of severe cardiomegaly

Practitioners were shown 5 of these images and the responses were true positive or false negative.

The median number of correct responses was 5 (100%) with an interquartile range of 5 to 5. The minimum number of correct diagnoses was 2 and the maximum was 5 (Figure 16).

Nineteen (90.48%) made 5 correct diagnoses, 1 (4.76%) made 4 correct diagnoses and 1 (4.76%) made 2 correct diagnoses.

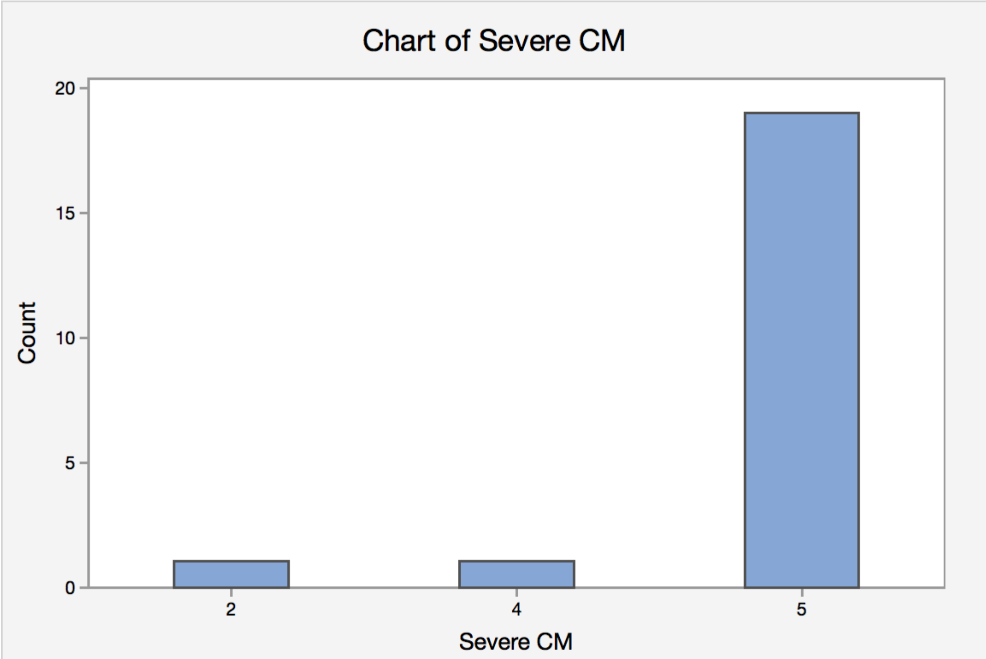


Figure 9 A graphical display of number of practitioners (y-axis) who correctly identified the presence of severe cardiomegaly in 2-5 images (x-axis). No practitioner got just 1 correct. Count = number of practitioners. CM = Cardiomegaly.

In terms of the individual images:

- Image 11: 20 (95.24%) made the correct diagnosis.
- Image 12: 21 (100.00%) made the correct diagnosis.
- Image 13: 21 (100.00%) made the correct diagnosis.
- Image 14: 20 (95.24%) made the correct diagnosis.
- Image 15: 19 (90.48%) made the correct diagnosis.

<u>Comparing subjective interpretation to VHS</u>

The proportion getting all diagnoses correct using the scoring method was compared to the subjective method for assessment of generalised cardiomegaly using a z test for two proportions at the 5% significance level.

No cardiomegaly (score vs generalized): There was no evidence of a difference between the two measures (p = 0.1004).

Mild cardiomegaly (score vs generalized): There was no evidence of a difference between the two proportions (p = 0.227)

Severe cardiomegaly (score vs generalized). There was no evidence of a difference between the two proportions (p = 1).

2.7 Discussion

This study was designed to evaluate the ability of general practitioners to detect changes associated with MMVD on thoracic radiographs.

This research suggests that in general practice, at least 2 thoracic views are taken to make an assessment for cardiomegaly. These are most commonly a right lateral and a dorsoventral view, which follows the guidelines recommending two orthogonal views (Johnson *et al.*, 2011).The majority (87%) of practitioners in this investigation were aware of the breed effect on VHS, however only 43% and 52% of practitioners took body condition score and side of recumbency into account respectively, which highlights the need for further CPD to refresh or inform practitioners of the factors that can affect interpretation of cardiomegaly on thoracic radiographs.

Interestingly, no practitioner was very confident in their detection of cardiomegaly on thoracic radiographs with the majority (96%) having mild and moderate confidence, however practitioners continue to take radiographs and use them as a method of assessment. This raises the question of how this situation is managed in general practice. The author suspects that a second opinion from a veterinary cardiologist or radiologist is sought, however further investigation is warranted.

Using the results from the subjective assessment of generalised cardiomegaly, practitioners were accurate in the correct detection of severe generalised cardiomegaly (median correct detection of severe cardiomegaly was 100%). This suggests that these patients would be correctly identified in practice and potentially receive the benefits of further investigation and medication.

Practitioners were accurate in the detection of severe left atrial enlargement (median number of correct responses was 85.7%). This suggests that using subjective assessment alone for left atrial enlargement could result in (median of 14.3%) patients not receiving the benefits of medication.

When comparing the proportion of participants who correctly identified severe cardiomegaly or left atrial enlargement in all radiographs, the number of correct responses for subjective assessment for generalised cardiomegaly responses was significantly higher than then number associated with the detection of severe left atrial enlargement. This disagrees with the results from previous study (Hansson et al., 2009) which suggested that subjective assessment of LAE was more accurate than generalised cardiomegaly for detection of cardiac disease due to MMVD.

Therefore, when assessing for severe cardiac changes associated with MMVD, this study suggests that a generalised subjective impression is more accurate than subjective assessment for left atrial enlargement. It has to be taken into account that many practitioners correctly identified severe left atrial enlargement in 6 out of 7 radiographs. Therefore, these results should not be over-interpreted; studies with larger participant numbers will be required to elucidate this question.

In the detection of mild generalised cardiomegaly, practitioner median correct detection was 66.6%. This suggests that a proportion of patients in general practice (median 33.4%) with mild cardiomegaly, potentially would not receive the benefit of further investigation and medication based on radiographic interpretation.
When assessing for mild LAE, the median number correct was 66.67%. Similarly, these results suggest that one third of patients with mild disease might not benefit from potentially life-prolonging medication.

Neither the subjective assessment for generalised cardiomegaly or the subjective assessment for LAE were more accurate in the detection of mild changes.

In the subjective detection of no generalised cardiomegaly, practitioners correctly identified no cardiomegaly in 57.14% of cases. This suggests that some patients may be incorrectly diagnosed with cardiomegaly in general practice and could receive medication unnecessarily if a diagnosis was based on radiographic interpretation of generalised cardiomegaly alone (median 42.9%). Practitioners were significantly (p-value of 0.0216) more accurate in detection of normal patients when using the subjective assessment for LAE. This would suggest that when trying to distinguish normal cardiac silhouette from patients with an enlarged cardiac silhouette due to MMVD, practitioners should use the subjective assessment for LAE. This agrees with the findings from previous study (Hansson et al., 2009) suggesting LAE assessment is more accurate than assessment for generalised cardiomegaly.

This research suggests that when making a subjective assessment for cardiomegaly, both generalised cardiomegaly and left atrial size should be taken into account to make an accurate assessment.

Practitioner ability to accurately measure a vertebral heart score was high. In most cases there was no statistical evidence of a difference between the consensus opinion and the individual scores. The pooled variance resulted in 1.132v difference between consensus opinion of specialists and general practitioners, which is similar to results found in previous studies (Lamb et al., 2000 Hansson, Häggström, *et al.*, 2005). The consensus opinion VHS and individual scores differed on two images. Both radiographs represented severe cardiomegaly. On one radiograph, marked pulmonary changes may have made it difficult to identify cardiac borders. The other patient had mild kyphosis. This could explain the practitioners' difficulty accurately estimating VHS.

When practitioners were asked what their upper limit for Cavalier King Charles Spaniel Specific VHS, the answers ranged from 10.5-12.0v. Using their individual answers and individual vertebral heart scores compared to the subjective consensus opinion, the proportion getting all diagnoses correct using the scoring method compared to the subjective method for assessment of generalised cardiomegaly were not significantly different. This agrees with findings from previous studies (Lamb *et al.*, 2000; Hansson, Häggström, *et al.*, 2005). Therefore, using practitioner individual upper limit for VHS, this research would suggest that there is little advantage of determining a VHS over a subjective impression.

However, it is worth noting that in this study the practitioners were not supplied with a breed specific VHS for the Cavalier King Charles Spaniel. They were asked to use the upper limit VHS that they would typically use to make an assessment in practice. Given that the measured vertebral heart scores obtained by general practitioners were not significantly different to those of the consensus opinion, this method should be more accurate if practitioners are reminded of the breed specific vertebral heart score.

In this study, the range of VHS for patients with no cardiomegaly or left atrial enlargement subjectively and no left atrial enlargement on echocardiography determined by consensus opinion of diplomates was 11.0-11.9v. This is higher than the range suggested by Lamb (Lamb et al., 2001), whose upper limit was 11.1v. Using Lamb's reference range for the VHS defined by the subjective consensus opinion, 40% of the 'normal' Cavalier King Charles Spaniels would have been considered to have cardiomegaly and therefore potentially receiving treatment unnecessarily. Using the vertebral heart score cut off of 10.5v in the EPIC study, all of the 'normal' Cavalier King Charles Spaniels in this study (defined by subjective impression consensus opinion) would have been considered to have cardiomegaly and therefore potentially received treatment unnecessarily.

In the study by Lamb (Lamb et al., 2001), the normal range encompassing 5^{th} to 95^{th} percentiles using 27 Cavalier King Charles Spaniels was 9.9-11.7v. Using this range resulted in 90% (10/11) of the normal subjective appearance being classed as normal using the VHS.

Therefore, to ensure that a VHS is of value, the author suggests that large numbers of breed 'normals' need to be used to establish a more reliable reference range.

2.8 Limitations

This study has a number of limitations inherent to its design. They can be classified as participant-associated and case- and radiograph-associated bias.

First of all, as participants were volunteers, and 74% had participated in further training in thoracic image interpretation since graduation, there is concern that the population tested may be biased towards practitioners who were keen to learn and more skilled than the average practitioner at thoracic interpretation.

Furthermore, the participants may have been affected by learning during the assessment as they were asked to read radiographic films of the same breed in different stages of cardiac disease. This may have caused them to change their decisions as they progressed through the assessment. Numbers of reviewed radiographs were too low to assess this further, however an overall pattern of improvement with the number of radiographs reviewed was not seen.

Whilst the assessments aimed to detect how readers would act in general practice, the setting of the examination may have caused the participants to behave differently than they would have done in practice with no supervision (Gur, 2004).

Several limitations were associated with the cases and the radiographs used for the assessment. This study involved only the Cavalier King Charles Spaniel. This breed was chosen as there is a heritable component, higher prevalence and an earlier onset of MMVD than in other breeds (Serfass et al., 2006). However, as it only represented one breed, this study can only represent general practitioner detection of cardiomegaly and left atrial enlargement in this breed and not all breeds of dog.

This study only evaluated the ability of readers to detect two signs of mitral valve disease on radiographs, generalised cardiomegaly and left atrial enlargement. In practice, the reader may have to determine if there is congestive heart failure, concurrent respiratory disease or other disease present. This study also only included patients with a grade 3 murmur or greater. It did not include patients without mitral valve disease, which may complicate and potentially affect interpretation of cardiomegaly.

The radiographs were of good diagnostic quality, had correct positioning and exposure therefore reducing error in reader interpretation and practitioners may have performed better in these assessments than in practice.

2.9 Conclusion chapter II

This research suggests that the accuracy of diagnosis of cardiac changes on thoracic radiograph due to MMVD did not change significantly as a result of using VHS as an adjunct to a subjective assessment of the radiographs.

General practitioners were found to have a high level of accuracy in the detection of patients with marked generalised cardiomegaly (median number of images correctly identified was 100%) and patients with no left atrial enlargement (median number of images correctly identified was 80%) using subjective methods of assessment, however their accuracy was lower in detection of those with mild changes (median number of images correctly identified with mild cardiomegaly and mild left atrial enlargement was 66.67%). Whilst practitioners were accurate in their ability to measure a vertebral heart score (VHS), the lack of a clear upper limit for VHS meant that VHS added no significant value in aiding correct diagnosis.

Patients in stage B2 MMVD have mild changes on thoracic radiographs, therefore this research suggests that in general practice, patients in the early stages of cardiac remodelling and those who might benefit greatly from the positive effects of medication may go undiagnosed. This highlights that radiographic examination may not be sufficiently reliable in the evaluation of mild cardiomegaly and emphasizes the need for echocardiography to assist diagnosis of patients with B2 MMVD.

CHAPTER III: INTRODUCTION OF THE NOVEL TOOL OF FOCUSED ECHOCARDIOGRAPHY TO GENERAL VETERINARY PRACTITIONERS TO AID DETECTION OF CARDIAC DISEASE

3.1 Focused sonography in the human medical literature

Since the 1990s, focused assessments using sonography for trauma or triage (FAST) have been first-line standard of care in human patients following trauma. Unlike comprehensive sonography, focused examinations are limited to investigating the cause of a patient's clinical signs to aid rapid diagnosis of potentially life threatening conditions and to guide treatment decisions (Labovitz et al., 2010).
Lung ultrasonography has been termed the 'modern stethoscope', exceeding chest auscultation and radiography with regards to sensitivity and specificity for pneumothorax, pleural effusion, pericardial effusion and lung consolidation (Filly, 1988, Hew and Heinze, 2012).

The sensitivity and specificity of focused ultrasonography in diagnosing pleural, pericardial, and peritoneal effusion has been shown to be comparable to computerised tomography (CT) (Boulanger et al., 1996; Kirkpatrick, 2007), and its use can significantly reduce the number of radiographs and CT images required in critically ill patients (Peris et al., 2010), reducing exposure to potentially harmful radiation.

The application of focused emergency ultrasonography for the detection of traumatic and non-traumatic lung injury has been investigated in human medicine (Chandra and Narasimhan, 2010; Nalos et al., 2010; Gargani, 2011) and a bedside lung evaluation (BLUE) has been used in people to accurately detect the presence of pulmonary contusions, cardiogenic and non-cardiogenic pulmonary oedema, pneumonia, pulmonary thromboembolism, and other pathological interstitial-alveolar lung conditions (Soldati et al., 2011).

3.2 Focused echocardiography in the medical literature

The first introduction of focused echocardiography in human medicine was in 1992, when it was shown that a limited echocardiogram performed by emergency physicians could reduce the time to diagnosis of penetrating cardiac injury and improve the survival rate (Plummer et al., 1992). Since this time its use has expanded to the point where joint consensus statements have been published by the American Society of Echocardiography and the American College of Emergency Physicians, which support its use in emergency departments to expedite the diagnosis of life-threating cardiac conditions (Labovitz et al., 2010). It has now developed into a first line test for cardiac evaluation of symptomatic patients (Labovitz et al., 2010).

Since its first introduction, ultrasound machines have been miniaturized and the technology has improved to such an extent that portable machines are being used to perform bedside focused echocardiograms. The use of these portable machines has been shown to substantially increase the detection of cardiovascular abnormalities during emergency patient triage and augment the physical examination to improve diagnostic accuracy (Vourvouri et al., 2003; Kobal et al., 2004; Senior et al., 2004; Weston et al., 2004; Liu et al., 2005; Scholten et al., 2005). The definition of focused cardiac ultrasonography is 'a focused examination of the cardiovascular system performed by a physician using ultrasound as an adjunct to the physical examination to recognise specific ultrasonic signs that represent a narrow list of potential diagnoses in specific clinical settings' (Spencer et al., 2013).

It is important to note that focused ultrasound examinations are designed to identify a significant abnormality as present or absent, quantify the abnormality as moderate to severe deviations from normal, but not to define or diagnose a condition. The purpose of focused echocardiography is not to replace a complete diagnostic echocardiogram.

There are many applications of focused echocardiography in the emergency setting, including:

- Identification of non-traumatic hypotension (Plummer et al., 1992).

- Accurate assessment of left ventricular function (C. L. Moore et al., 2002; Randazzo et al., 2003; Melamed et al., 2009) with sensitivities and specificities of up to 100% and 96% respectively (Spencer et al., 2013) with the rudimentary descriptive nomenclature used in focused assessments shown to have good correlation with echocardiographic interpretations (Christopher L Moore et al., 2002).
- Identification of hypovolaemic patients (Brennan et al., 2007; Stawicki et al., 2009)
- Providing diagnostic and prognostic information for the patient in cardiac arrest (Bocka, Overton and Hauser, 1988; Mayron et al., 1988; Salen et al., 2005; Soar et al., 2005; Breitkreutz, Walcher and Seeger, 2007).
- Detection of pericardial effusion in both medical and trauma patients (Mayron et al., 1988; Rozycki et al., 1998, 1999; Mandavia et al., 2001; Jones, Tayal and Kline, 2003), giving vital information regarding the presence, volume, and functional relevance of a pericardial effusion, expediting the decision to perform pericardiocentesis, with fewer reported complications and higher success rates (Mazurek, Jehle and Martin, 1991; Tayal and Kline, 2003; Labovitz et al., 2010).
- Assessment of left atrial size (Kimura et al., 2005, 2010).
- Assessment for left ventricular enlargement (L. D. Martin *et al.*, 2007; Martin *et al.*, 2009).
- Assessment for left ventricular hypertrophy (Perez-Avraham et al., 2010).

Other potential uses include identification of conditions including intra-cardiac masses, thrombi, and endocarditis. However their identification should prompt referral for complete echocardiography.

3.3 Focused sonography in the veterinary literature

Over the past two decades, focused assessment with sonography has been an emerging field in veterinary medicine. FAST examinations have become the standard of care in many emergency and intensive care settings because they are safe, non-invasive, rapid, repeatable, and portable, and can be performed at the time of initial triage during patient resuscitation (Boysen, 2014).

The FAST scan mostly seems to benefit patients presented with cardiovascular instability or respiratory distress, where the aetiology is uncertain.

FAST scans in the veterinary field have been shown to rapidly answer clinical questions and detect life threatening conditions that may have been missed on physical examination and other diagnostic tests and positively affect patient care (Lisciandro et al., 2008, 2009; Lisciandro, 2011).

3.3.1 AFAST

The abdominal focused assessment with sonography for trauma (AFAST) is a rapid and focused examination of four sites in the abdomen designed to rapidly exclude the presence of free abdominal fluid (typically haemorrhagic) (Boysen, 2014).

The first published veterinary introduction to this technique was in 2004 (Boysen et al., 2004). This described the use of AFAST in dogs following vehicular trauma and found AFAST to be a simple and rapid technique that could be performed on dogs in an emergency setting by veterinary clinicians with minimal previous ultrasonographic experience. Additionally, this work identified that the presence of haemoabdomen in dogs following trauma was much more common that previously assumed, at rates of up to 45%. In 2009, Lisciandro et al. published work supporting these findings.

The AFAST assesses four points on the abdomen, starting with the diaphragmatico-hepatic (DH) view, moving to the spleno-renal (SR) view, the cysto-colic (CC) view and finally the hepato-renal (HRe) view. The major objective is to look for abnormal anechoic shapes in the abdomen, which would indicate fluid. It can be performed using a curvilinear probe with a frequency

suitable for most cats and dogs. Patients are generally positioned in lateral recumbency or modified sternal recumbency and fur is not shaved but parted to limit the examination time.
In 2009 Lisciandro also introduced the concept of an abdominal fluid scoring system (AFS) in dogs following motor vehicle trauma. This found that initial and serial AFAST with applied AFS allowed a rapid, semi-quantitative measure of free abdominal fluid in traumatized patients, which was clinically associated with severity of the injury, and reliably guided clinical management.

With the frequent use of the AFAST, it has become clear that its use extends beyond that of patients following trauma. Additional uses include detection of peritonitis and abdominal effusions other than haemoabdomen, for example uroabdomen secondary to a ruptured bladder. Therefore the AFAST3 was introduced; this is the concept of using focused abdominal ultrasound for trauma, triage, and tracking (monitoring) (Lisciandro, 2011).

3.3.2 TFAST

In 2008, work was published documenting the use of the Thoracic focused assessment with sonography for trauma (TFAST) in dogs following blunt or penetrating trauma (Lisciandro, 2008). The aim of this study was to estimate the relative accuracy of a TFAST protocol for rapid diagnosis of pneumothorax and other thoracic injury (fluid in the pleural or pericardial space) in traumatized dogs. The dogs in this study were evaluated with ultrasound using the 4-point thoracic FAST protocol. This consists of bilateral 'chest tube' site (CTS) views and bilateral pericardial site (PCS) views. Traumatized dogs were evaluated with a conventional ultrasound machine before thoracic radiography and thoracocentesis. Pneumothorax was diagnosed by the absence of the 'glide sign,' defined as the lack of the normal dynamic interface between lung margins gliding along the thoracic wall during respiration. Concurrent thoracic trauma was diagnosed by the presence of pleural or pericardial fluid or the presence of a 'step sign,' defined as an abnormal glide sign. The accuracy of TFAST was calculated relative to thoracic radiographic findings. Overall sensitivity, specificity and accuracy of TFAST relative to thoracic radiographs were 78.1%, 93.4% and 90.0% respectively, demonstrating that TFAST could be used as a screening test in patients following trauma without the need to transport them to radiography.

As with AFAST, the clinical uses of TFAST have extended beyond trauma and a TFAST3 has been introduced. The concept is similar to the AFAST3 with the final T no longer standing for trauma, but for 'trauma, triage and tracking' (Lisciandro, 2011).

In 2016, work was published evaluating the use of AFAST and TFAST in non-traumatized dogs and cats in the emergency and critical care setting and comparing the prevalence of free fluid identified by these techniques between stable and unstable patients (McMurray, Boysen and Chalhoub, 2016). A significantly greater proportion of unstable patients were found to have free fluid compared to stable patients, supporting the use of AFAST and TFAST in this setting.

3.3.3 Vet BLUE

More recently, the concept of a Veterinary Bedside Lung Ultrasound Examination (Vet BLUE) has been introduced. This is a more comprehensive ultrasonographic examination of the lungs than TFAST.

The Vet BLUE is designed so that regionally based lung ultrasonographic findings can be correlated to thoracic radiographs. It uses 4 bilateral lung views (8 views in total). The first point is the caudodorsal lung lobe (cdll) site, which is the same point referred to as the CTS in TFAST. The lungs are also observed at the perihilar (phll), middle (mdll), and cranial lung lobe (crll) regions. During the Vet BLUE each of these views is observed for basic lung ultrasound artefacts using the 'wet' versus 'dry' lung principle. The benefits of the Vet BLUE are that it can rule out any significant interstitial oedema by finding 'dry' lungs (A-line glide sign) in all lung regions, detect signs of interstitial oedema (cardiogenic and non-cardiogenic) using the 'wet' lung principle of lung rockets (B-lines, also called ultrasound lung rockets [ULRs]), semi-quantitate the degree of pulmonary oedema by counting the number of URLs at various sites and aid monitoring of the response to therapy of many lung conditions. It can also help to recognise additional lung conditions such as consolidation (using the 'shred sign' and 'tissue sign') and nodules such as neoplasia or abscesses ('nodule' sign). The clinically relevant 'wet lung' conditions in the acute care setting include cardiogenic and non-cardiogenic pulmonary oedema (non-trauma), lung contusions (trauma), lung haemorrhage (non-trauma, coagulopathic) and acute pneumonias. The regional B-line/URL distribution helps discriminate among these conditions. In the acute setting, 'wet lung' seen in the dorsal lung fields (perihilar and caudodorsal sites) is generally considered to be representative of pulmonary oedema (cardiogenic or non-cardiogenic). 'Wet lung' in the ventral lung fields is generally considered to be pneumonia. (Lisciandro, 2014).

In 2014, work was published investigating the frequency of ultrasound lung rockets in dogs without clinical signs of respiratory disease and with radiographically normal lung findings (Lisciandro, Fosgate and Fulton, 2014). The overall frequency of ultrasound lung rockets was 11% in dogs without respiratory disease versus 100% in those with left-sided heart failure. The low frequency and number of ultrasound lung rockets observed in dogs without respiratory disease and with radiographically normal lungs suggests that Vet BLUE was clinically useful for the identification of canine respiratory conditions.

In 2017, work was published demonstrating that lung ultrasonography had a good diagnostic accuracy to identify cardiogenic pulmonary oedema. Dogs were divided into stages of heart disease (Atkins et al., 2009). Dogs in stage B1 had absent or rare B-lines in 14 of 15 cases (93.3%). Dogs in stage B2 had absent or rare B-lines in 16 of 18 cases (88.9%). All dogs in stage C without radiographic signs of pulmonary oedema had absent or rare B-lines. Dogs in stage C with radiographic signs of pulmonary oedema had numerous or confluent B-lines in 18 of 20 cases (90%). Lung ultrasonographic examination detected pulmonary oedema with a sensitivity of 90%, specificity of 93%, and with positive and negative predictive values of 85.7 and 95.2%, respectively (Vezzosi et al., 2017).

<u>3.3.4 Global FAST</u>

The most recent addition to focused ultrasonography is the Global FAST concept (GFAST3). This is the combination of AFAST, TFAST and Vet BLUE used as a standardised ultrasonographic examination and as an extension of the physical examination. It is based on training included in the medical school curriculum, including Harvard medical school (Lisciandro and Lisciandro, 2017). It has been shown that these examinations can be performed quickly (3 minutes or less) whilst the patient is being triaged (Lisciandro et al., 2008, 2009; Lisciandro, 2011).

3.3.5 Focused echocardiography

Both the TFAST (Boysen et al., 2004; Lisciandro et al., 2008) and AFAST (Lisciandro et al., 2009; Lisciandro, 2011) have components of focused echocardiography.

In the TFAST at the PCS view, the ultrasound probe is moved through the short and long axis views to rule out pericardial fluid. In the AFAST, the 'Diaphragmatico-hepatic' (DH) view is used for intra-abdominal and intra-thoracic imaging. If pleural or pericardial effusion is suspected using AFAST, then the practitioner is advised that the TFAST PCS views (pericardial site) should be added to confirm changes seen.

A retrospective review showed the DH view of AFAST was clinically helpful for the detection of pericardial effusion (Lisciandro, 2016).

In 2013, a study was conducted (Tse et al., 2013) to determine whether a training course in focused echocardiography could improve the proficiency of non-cardiology house officers (veterinary interns and residents) in accurately interpreting cardiovascular disease and echocardiography finding in dogs entering the emergency room. Participants underwent training in focused echocardiography, consisting of a 6-hour curriculum of lectures, clinical cases, and hands on echocardiography. Post-training, most participants could correctly identify pleural effusion and pericardial effusion and could discriminate a normal left atrial size from atrial enlargement. However, successful identification of a cardiac mass and assessment of volume status, identification of ventricular enlargement or hypertrophy remained low.

To the author's knowledge, the ability of general veterinary practitioners to acquire the skill of performing and interpreting a focused echocardiogram has not been assessed.

3.4 Justification for the use of focused echocardiography in general small animal veterinary practice

Cardiac emergencies are a frequent part of general veterinary practice. This includes a variety of diseases such as congestive heart failure, pericardial effusion and thromboembolic disease. Patients are presented with a variety of clinical signs and histories, which are often compatible with other diseases, e.g. respiratory and neurological diseases, and often in a compromised state, which limits physical examination.

In the case of heart failure, there is no single diagnostic test that confirms the syndrome; a diagnosis is made based on history, clinical signs, signalment and diagnostic testing. The most useful tests in this situation are radiography and echocardiography. The detection of cardiomegaly, pulmonary venous distension and alveolar/interstitial lung patterns, in combination with the other abnormalities, are very suggestive of cardiac disease and congestive heart failure. However, positioning and sedation for this carry significant risk. Even if a radiograph is obtained, interpretation has its difficulties e.g. pleural effusion, a common manifestation of congestive heart failure in cats, can obscure the cardiac silhouette, lungs and vasculature on the radiograph. A faster and more accurate diagnosis of cardiac disease and failure can facilitate treatment being initiated and outcome and survival improved.

More recent advances in the diagnosis of heart failure are the use of cardiac biomarkers such as amine terminal pro B-type natriuretic peptide (NT-proBNP) and cardiac troponin I (cTnI). In dogs NT-proBNP >3000pg/ml and in cats values >1000pg/ml are very suggestive that the cause of acute dyspnoea is congestive heart failure (Singletary et al., 2012). However, justification for taking a blood sample in a dyspnoeic patient is limited and there are concerns about the influence of systemic disease on the results obtained, as the value can be affected by comorbid diseases such as renal disease.
In order to stabilise patients prior to radiography, they are often treated with a range of drugs that could treat a variety of conditions. This is not always in the patient’s best interest. It limits the ability to determine what, if any, drugs made an improvement and in some conditions certain drugs may be contraindicated, for example corticosteroids in cardiovascular disease.

One of the major advantages of FAST protocols is the speed at which they can be performed. Both human and veterinary trauma studies have reported examination times of 3 minutes or less (Boulanger et al., 1996; Lisciandro et al., 2008, 2009). They can be performed alongside the patient receiving oxygen and emergency treatment and have been shown to be extremely beneficial in patient triage. Therefore the author proposes this may also be possible with a focused echocardiogram. Another major advantage is the fact that they can be performed with the patient in sternal recumbency (Lisciandro et al., 2008) reducing the potential stress of positioning and restraint on the patient. Echocardiography of dogs in a standing position has been shown to be as good as that obtained with the dog in lateral recumbency for most measured variables. The patient can receive oxygen and could be given a low dose of sedation if required (Chetboul et al., 2005). The author proposes that a focused echocardiogram, performed with the patient in a sternal or standing position, would be comparable to that performed with the patient in lateral recumbency.

Taking measurements is a core component of comprehensive echocardiography and there are many books and other publications available on this subject. Focused echocardiography relies on subjective impressions only. The rationale behind this is that devices used for focused echocardiography have variable capabilities in terms of measurements and often electrocardiographic gating is not readily available. Measurements made incorrectly can be misleading. In addition, rapid evaluation is the major strength of a focused echocardiogram and pausing to take measurements reduces its value in the emergency setting.

3.5 Study aim, hypothesis and design

3.5.1 Aims of this study

To assess the baseline ability of general veterinary practitioners to:

- Identify echocardiographic two-dimensional (2D) anatomy.
- Subjectively differentiate cardiovascular disease from the normal cardiovascular appearance on video loops of echocardiography.
- Obtain 3 standard right-sided echocardiographic views.

To design and evaluate whether a short, one-hour training course in focused echocardiography could improve general veterinary practitioners' echocardiographic image interpretation and its practical acquisition.

3.5.2 Hypothesis

The author hypothesises that a one hour course in focused echocardiography will significantly improve general practitioners' echocardiographic image interpretation and its practical acquisition.

3.5.3 Study design

This was a prospective, educational study.

The study was granted ethical consent by the University of Glasgow's ethical committee reference: 17a17

The lecture and training materials were designed in collaboration with Board Certified Veterinary Cardiologists from the University of Glasgow Small Animal Hospital.

Informed consent was given from the dog owners for the use of their dogs in this study. All dogs were restrained by their owners or veterinary students and housed between sessions.

Signed consent was given from all voluntary veterinary participants.

3.5.4 Designing a training course

Continuing Professional Development (CPD), is the process of maintaining, improving and broadening skills and knowledge, as well as developing personal qualities, which help to ensure that the practitioner remains professionally competent. Currently the RCVS recommends that veterinary surgeons complete a minimum of 105 hours of CPD every 3 years.

The RCVS Codes of Professional Conduct state that all vets are obliged to maintain and continue to develop their professional knowledge and skills. CPD is therefore mandatory for all vets and should be seen as the continuous progression of capability and competence (Professionals, 2018).

There are many different forms of CPD such as lectures, workshops and distance learning. Recent studies suggest that traditional CPD activities are ineffective at improving practitioner performance and patient care outcomes.

In contrast, interactive CPD activities that encourage reflection on practice, provide opportunities to practice skills and focus on outcomes, are the most effective at improving practice and patient health outcomes (Wallace and May, 2016). These results were central to the design of the following CPD tool.

3.6 Materials and methods

3.6.1 Setting

University of Glasgow Small Animal Hospital.

3.6.2 Study subjects

40 general veterinary practitioners. Practitioners came from 15 different general practices across the Glasgow area.

Length of qualification varied from 3 months to 36 years.

3.6.3 Animal subjects

Healthy dogs were used as study subjects during the practical sessions. The dogs used had normal cardiovascular anatomy.

They were all body condition scored at 4-5/9 and were considered medium-sized breeds (weight range 20-25 Kilograms).

3.6.4 Exclusion criteria

Practitioners were excluded if they had undergone further cardiac training in the form of an Advanced Veterinary Practitioner Certificate in Cardiology or those who were already performing comprehensive echocardiograms.

3.6.5 Interventions

A fifty-minute didactic lecture and a ten-minute practical session.

3.6.6. Equipment used

Portable ultrasound machines: Mindray-M7 and a Mindray-Z6.[1]

Phased array transducers (frequency 2-10 Megahertz, which, was suitable for the dogs used in the practical sessions).

[1] Shenzhen Mindray Bio-Medical Electronics Co., Ltd.

3.7 Study setting and population

Invitations were sent to general veterinary practices across Glasgow inviting practitioners with limited prior experience in veterinary echocardiography to participate in the training session. Practitioners were excluded if they had a certificate in echocardiography or were already performing echocardiography on a frequent basis.

40 places were available and these were filled on a “first come first served” basis. All participants attended all parts of the study and completed all tests and self-assessments pre- and post-training.

The training session was given over seven evenings between the 7th August and 28th August 2017 to accommodate practitioner working days. The training session took a total of 2.5 hours including computer assisted and practical assessments.

3.8 Study protocol

In the medical literature, recommendations for cardiac ultrasound training for non-echocardiographers includes didactic education, image acquisition, image interpretation, and hands-on education (Spencer et al., 2013).
There is a wide range of suggested number of examinations (50–400) required to be performed to demonstrate proficiency (Shackford et al., 1999), however there is no standardisation.

The author has included these techniques in the design of the training session. On arrival, participants were randomly assigned a number, which was the only means of identification throughout the study.

Participants were asked to complete a pre-course questionnaire (Supplementary material 3). This assessed:

- Availability of ultrasound in their practice.
- Frequency of use of ultrasound in cardiac conditions in the past three months.
- Confidence in obtaining the three standard echocardiographic right-sided views of the heart.
- Confidence in the detection of left atrial enlargement, poor systolic function, pericardial effusion and cardiac tamponade on echocardiography.

The questionnaire was assessed and participants who answered they would be ‘mildly’, ‘moderately’ or ‘very confident’ in obtaining some views were asked to complete a six-minute pre-course practical test in which they were asked to obtain three cardiac views (a ‘right parasternal long axis 4 chamber view’, a ‘right parasternal short axis view of the left ventricle’ and a ‘right parasternal short axis view of the left atrium and aorta’) on a live dog. They were given two minutes to obtain each view and asked to alert the clinician when they were happy with the view obtained.
The arrangement of the room and machines were pre-set by the assessors. Depth, focus, width and gain were set. Cardiac presets were used and phased array probes.

Participants who answered that they would ‘not know where to start’ were not asked to complete the practical assessment as this was felt to be of limited value and allocated a score of zero.

Images and cine loops of the obtained views were saved and the quality of the image was analysed using a scoring system (Supplementary material 4). Images were graded on a 3-point scale based on pre-determined factors considered essential for each view, for example for the right parasternal long axis 4 chamber view it was considered an excellent image if all 4 chambers were visible, the interventricular septum was horizontal across the screen and the left ventricle was not foreshortened. Participants that did not participate in the initial practical test scored an ‘unsatisfactory image obtained’ in all 3 categories.

Following this, all participants were asked to complete an online, 8 question test (Figure 10).

Figure 10 Image of the online setup for general veterinary practitioners to complete the online assessments.

This test was on basic cardiac anatomy (Figure 11). They were given echocardiographic images of the heart and asked five questions related to cardiac anatomy and three questions related to cardiac views.

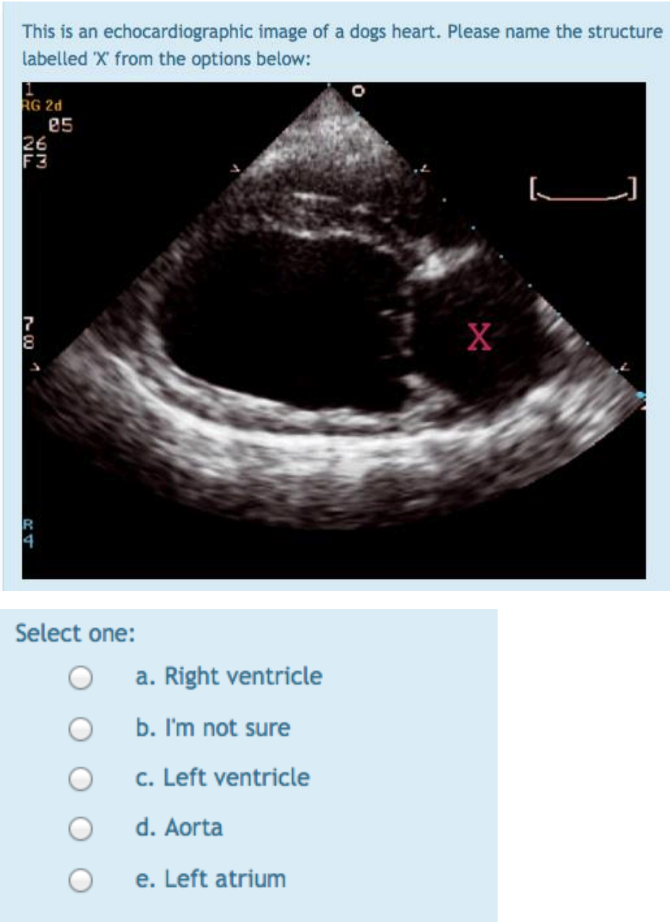
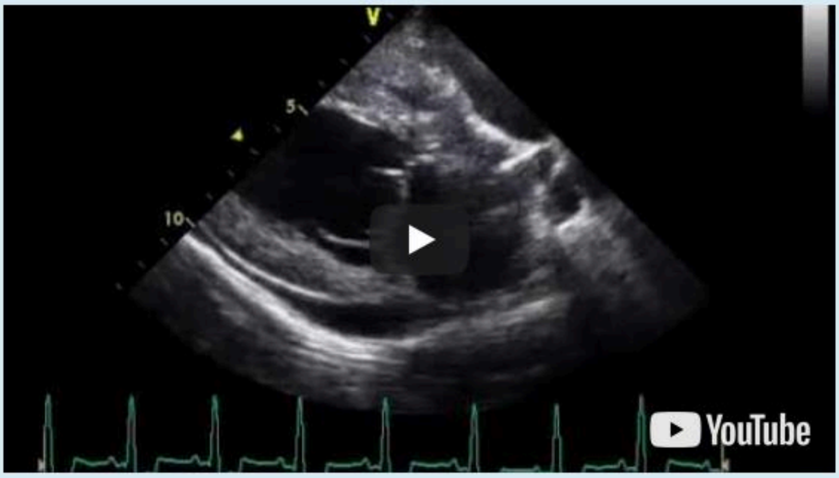


Figure 11 Example question from the anatomy test. In this question, practitioners were asked to identify the structure labelled ‘X’ on the image. They had a choice of 5 answers, one of which was correct.

All questions were multiple choice with one correct answer and the order randomised for each participant with a computer random order generator. Multiple choice answers consisted of 4 possible cardiac anatomy options and one 'I don't know' option.

Practitioners were then asked to complete a second online computer-based test. This was based on subjective echocardiographic image interpretation. This consisted of 27 multiple choice questions. Each question had a 30 second video loop of echocardiography, which could be played as often as the practitioner wished (Figures 12, 13 & 14).

A right parasternal long axis 4 chamber view of the heart is obtained. This should be interpreted as...

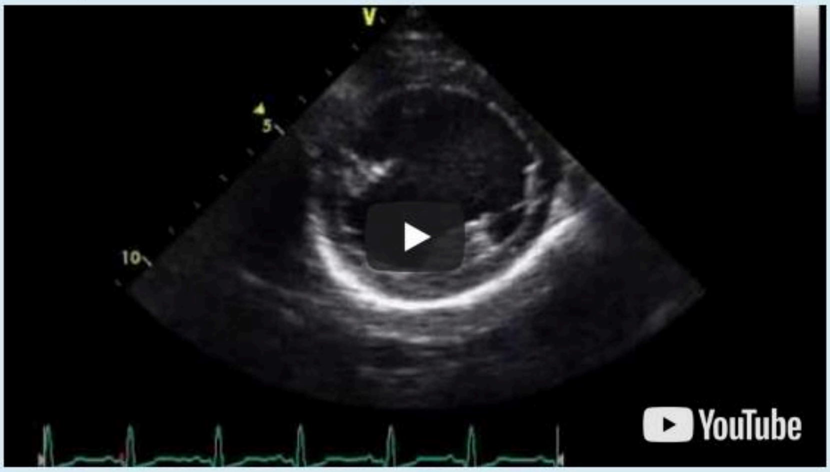


Select one:

- a. No pericardial effusion
- b. Pericardial effusion
- c. I'm not sure

Figure 12 Example question from the focused echocardiography video image test, investigating practitioner assessment of pericardial effusion.

A right parasternal short axis view of the left ventricle at the level of the papillary muscles is obtained. This should be interpreted as...

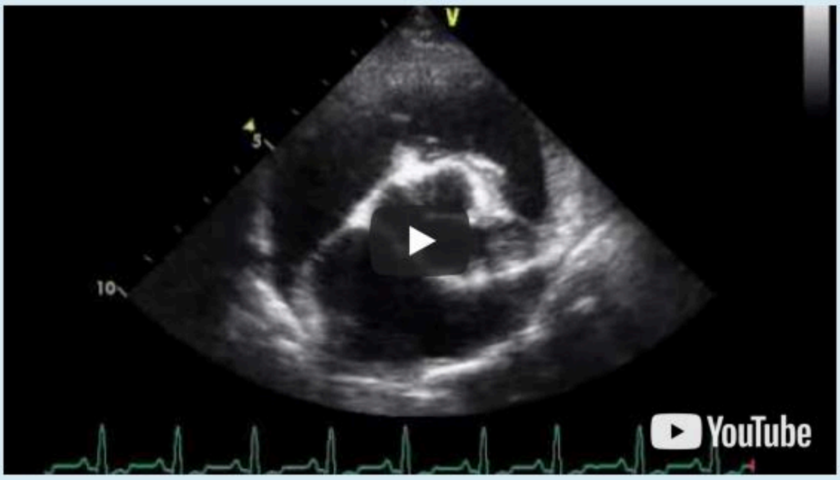


Select one:

- a. Normal systolic function
- b. I'm not sure
- c. Reduced systolic function (FS <20%)

Figure 13 Example question from the focused echocardiography video image test, investigating practitioner assessment of systolic function.

A right parasternal short axis view of the base of the heart (left atrium and aorta) is obtained. This should be interpreted as...



Select one:

- a. I'm not sure
- b. Increased LA:Ao (>1.6: 1)
- c. Normal LA:Ao

Figure 14 Example question from focused echocardiography video image test investigating practitioner assessment of left atrial size.

The multiple choice consisted of 3 possible options, for example:
Question: 'you obtain a right parasternal long axis 4 chamber view, this should be interpreted as 'pericardial effusion', 'no pericardial effusion' and one 'I don't know option'.

All Images had been obtained on a Vivid 7 Dimension ultrasound machine and were divided into categories based on measurements made by diploma holders (or residents in training) in veterinary cardiology.

The videos consisted of normal and abnormal cardiac anatomy. Images were divided into three views.
Right parasternal long axis 4 chamber view (9 images in total):

- Three marked pericardial effusion (>2cm effusion around the heart [2 x 2cm effusion and 1 x 3cm effusion]).
- Three mild pericardial effusion (<1cm around the heart).
- Three without pericardial effusion.

Right parasternal short axis view of the left atrium (LA) and aorta (Ao) (9 images in total):

- Three markedly enlarged LA:Ao (LA:Ao>2.0:1 [2.1:1, 2.6:1 and 3.4:1]).
- Three mildly enlarged LA:Ao (LA:Ao >1.6- 2.0 [1.7:1, 1.8:1, 1.9:1]).
- Three normal LA:Ao (LA:Ao<1.6:1[1.2:1, 1.3:1, 1.4:1]).

Right parasternal short axis view of the left ventricle (9 images in total):

- Three severely reduced systolic function (FS <10% [6%, 8%, 8%]).
- Three reduced systolic function (FS <20% >10% [13%, 15%, 16%]).
- Three normal systolic function (FS >30% [30%, 36%, 39%]).

Images were shown in a random order generated by the computer program.
Example: 'You obtain a right parasternal long axis 4 chamber view of the heart'. 'This should be interpreted as':

- option 1: no pericardial effusion.
- option 2: pericardial effusion.
- option 3: I'm not sure.

The rationale behind providing nine images in each section was to ensure that the range of severity of each condition was included and to prevent participant image fatigue.

The order of both tests was randomised by a random order generator. Participants were scored out of 8 possible marks in the anatomy test and 27 marks in the echocardiography video image test. An incorrect answer or ‘I don’t know’ answer scored no points, the correct answer scored 1 point. Questions had to be answered in a sequential fashion. There was no option to review or change answers or restart the test and there was no time limit.

The tests were automatically graded by the computer program once completed. It was required that the first test be completed prior to the second test being available.
Following the tests, practitioners attended a 50-minute lecture.

3.9 The lecture

Practitioners were introduced to the concept of focused echocardiography, its current uses and advantages, for example:

- It is safer than radiographs as there is no radiation exposure.
- It is cheap and available (not an additional expense to practice).
- It can aid decision making in the emergency setting in veterinary medicine.

Practitioners were told that over the next 50 minutes they would be taught the 3 echocardiographic views and use these to determine if any of 3 areas of assessment were present or absent. The three chosen areas thought to be most relevant for cardiac emergencies seen in general practice were:

- Pericardial effusion +/- tamponade.
- Left atrial enlargement as a marker of potential congestive heart failure.
- Reduced systolic function as a marker of potential forward heart failure.

The practitioner was told that every time they performed a focused echo they should use all 3 views and assess for all 3 things and they were introduced to the concept, that unlike comprehensive echocardiography, no measurements would be taken and that all impressions would be subjective only.

Practitioners were then taught the indications for performing a focused echocardiogram e.g. findings from the clinical history (acute respiratory distress, collapse, suspected cardiogenic arterial thromboembolism, suspected pericardial effusion, suspected congestive heart failure etc.), physical examination (including muffled heart sounds, pulmonary crackles etc.) and results from other diagnostic tests (radiographic cardiomegaly, electrical alternans noted on an electrocardiogram etc.).

Practitioners were informed that the focused echocardiogram should be used in combination with the history, physical examination and other diagnostics rather than as a replacement for these.

They were taught that its main use should be in an emergency, however it could also be used if referral was not an option.

Practitioners were told that the objectives of the training were to be able to:

- Recognise normal cardiac anatomy on 2D echocardiographic images.
- Subjectively identify and differentiate an enlarged left atrium from a normal sized left atrium as a potential marker of left sided congestive heart failure.
- Subjectively identify and differentiate reduced systolic function as a potential marker of low cardiac output, to identify pericardial effusion and cardiac tamponade.
- To be able to obtain the echocardiographic views considered key for focused echocardiography.

Emphasis was placed on the fact they were being taught basic echocardiography to aid decision-making in emergency potential cardiac patients rather than comprehensive echocardiography and that the tool could be used to aid detection or exclusion of cardiac disease, but could not identify the cause of the cardiac disease (they were not taught any Doppler echocardiography or measurement which would aid diagnosis).

They were advised that referral for a complete echocardiogram was warranted in any patient in which their focused echocardiogram detected an abnormality or in which an abnormality was suspected, but no abnormality was detected. Practitioners were advised to mention to the owner that it was a new 'use' of echocardiography with the aim of giving a better insight into the case and if necessary, referral could be done.

Following this introduction, a basic anatomy review was given and guidelines were given for performing a focused echocardiogram, including patient preparation and patient positioning. In light of the fact that the majority of cardiac emergencies are unstable and dyspnoeic, the standing position was chosen for this training course. However, practitioners were informed that should the patient be stable, right lateral recumbency is preferable, as it would allow better imaging through the cardiac window (the heart is closer to the thoracic wall with less lung interference) (Figure 15).

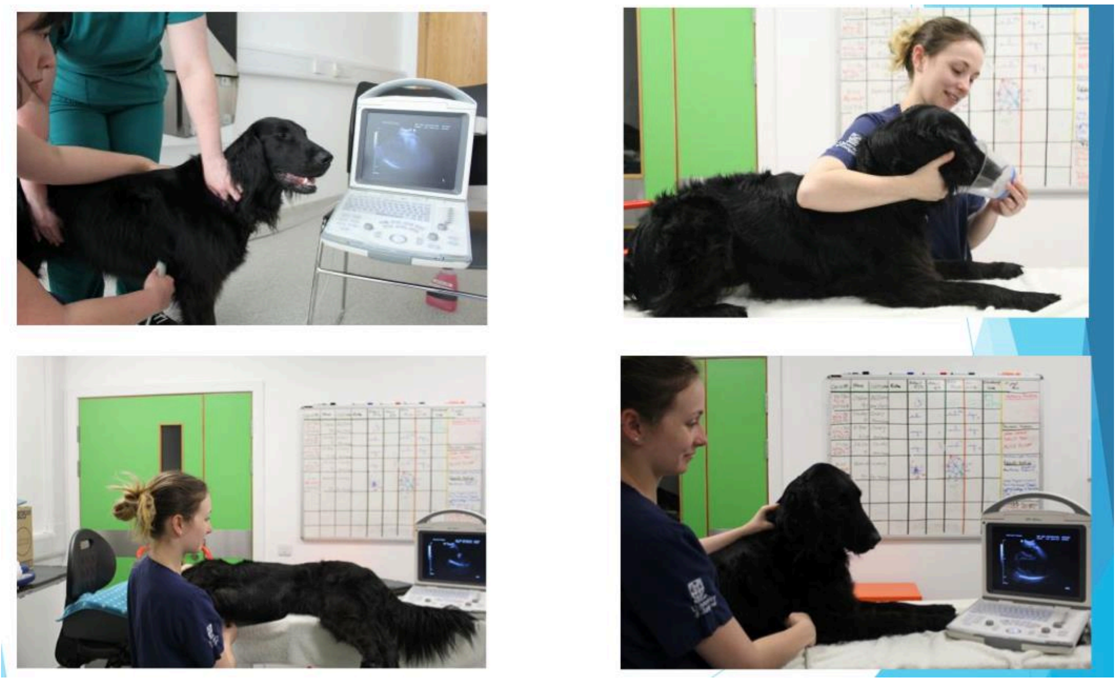


Figure 15 Examples of the different positions that animals can be in to perform a focused echocardiogram: standing, sternal with oxygen, sternal no supplemental oxygen and right lateral recumbency (clockwise from top left).

Acoustic gel was recommended. Shaving or clipping of the fur was discussed. It was not considered essential for every case especially if they had short fur. Rather than count rib spaces, practitioners were advised to place the probe at the PMI of the apex beat.

3.10 Image acquisition of echocardiographic views

3 standard echocardiographic right-sided views were chosen (Boon, 2011):

- Right parasternal long axis 4 chamber view.
- Right parasternal short axis view of the left ventricle at the level of the papillary muscles.
- Right parasternal short axis view of the left atrium and aorta.

Practitioners were taught to obtain these views in order, to use all 3 views as part of a focused echocardiogram in all patients and markers for indicating the correct view had been obtained were shown. A clock face analogy was used for the positions on the thorax (Figure 23 & 24).

Right parasternal long axis 4 chamber view

Practitioners were taught to palpate the chest wall and place the ultrasound transducer at the PMI of the patient's apex beat rather than count rib spaces, as this was felt to be more feasible in the emergency situation. They were asked to point the reference marker towards the patient's spine and hold the probe on the chest wall. The probe should be perpendicular to the patient's heart.
They were taught that the correct image should display all 4 chambers, a horizontal septum and the image should be optimised for the left ventricle.

They were taught that this view was useful for all the components we were assessing for pericardial effusion, cardiac tamponade, left atrial enlargement, spontaneous echocardiographic contrast. They were taught that the base of the heart should be displayed on the right of the screen. As part of the clock face analogy, the thumb was at 12 'o' clock (Figure 16).

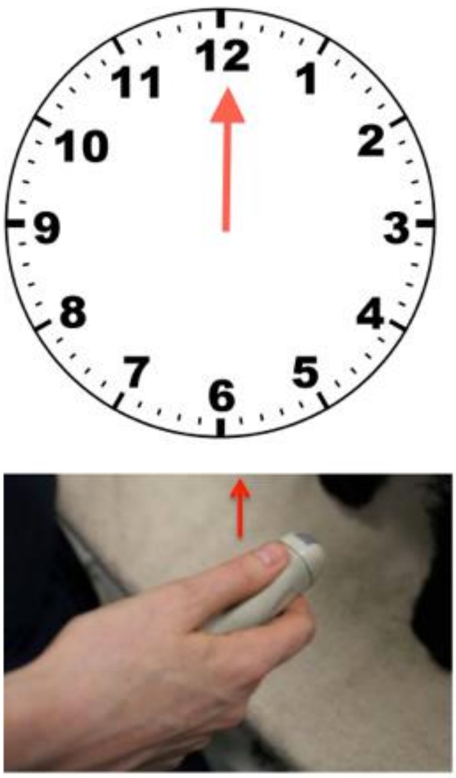


Figure 16 Image of the 12 'o' clock position of thumb used to obtain the right parasternal long axis 4 chamber view.

Right parasternal short axis view of the left ventricle at the level of the papillary muscles

Practitioners were taught to start with the long axis 4 chamber view and rotate the probe through 90 degrees so that the reference marker was roughly pointing towards the patient's elbow (3 'o' clock position).

They were advised that the image should display a convex right ventricle, a circular left ventricle and that the papillary muscles should be as symmetrical as possible.

As part of the clock face analogy, the thumb was at 3 'o' clock (Figure 17).

Figure 17 Image of the 3 'o' clock position of thumb used to obtain the right parasternal short axis view of the left ventricle.

Right parasternal short axis view of the base of the heart optimising for the left atrium and aorta

From the level of the papillary muscles, the practitioner was advised to fan upwards with the probe towards the cervical spine and stop when the aorta was visible in cross section at the level of the aortic valve.

They were advised that the image should display all 3 cusps of the aortic valve and that the intra-atrial septum should be seen.

They were advised that all 3 views should be used together to minimise the risk of interpreting normal cardiac anatomy for pathology and vice versa.

Following this, the lecture covered the three areas that were being evaluated:

- Pericardial effusion +/- tamponade.
- Left atrial enlargement as a marker of congestive heart failure.
- Poor systolic function as a marker of forwards heart failure.

The echocardiographic appearance of the areas of evaluation were discussed; the views used for each area were:

- Pericardial effusion +/- tamponade (right parasternal long axis 4 chamber view and right parasternal short axis view of the left ventricle).
- Left atrial enlargement as a marker of congestive heart failure (right parasternal short axis view of the heart base at the level of the left atrium and aorta).
- Poor systolic function as a marker of forwards heart failure (right parasternal short axis view of the left ventricle at the level of the papillary muscles and right parasternal long axis 4 chamber view).

Video loops of echocardiograms ranging from mild to severe pericardial effusion, left atrial enlargement, and poor systolic function (confirmed by measurements made of LA:Ao, ejection fraction and fractional shortening) were shown. Common causes of the changes were discussed and anatomy was identified.

Practitioners were taught that cardiac tamponade was the right atrium collapsing during diastole, that a left atrium to aortic ratio of greater than 2.0 in a patient with respiratory distress was highly suggestive of congestive heart failure (Boon, 2011b; Smith and Dukes-McEwan, 2012) and that a percentage change in internal diameter of the left ventricle when contracting of less than 20% was suggestive of reduced systolic function (Boon, 2011a).

Case examples and management of the cases in an emergency were given. Practitioners were taught, via case based examples, that the priority of the emergency therapy was to provide oxygen and to support or improve the cardiac output and to reduce fluid accumulation via diuresis or thoracocentesis or vasodilation.

Following the lecture, all practitioners were then asked to repeat the anatomy and subjective echocardiographic assessment tests. The order of all questions was again randomised.

3.11 Practical training and assessment

All practitioners then received a one to one, ten-minute, practical training session with one of two assessors (both assessors had been trained by a clinician with a Diploma in cardiology, one was the author and the other a veterinary cardiology certificate holder), before being asked to complete the timed practical assessment.

All practitioners received the same practical training session. They were shown how to hold the probe and how to obtain the views discussed in the lecture using the dogs. They were given 10 minutes to obtain the views and given immediate feedback on how to alter the views as necessary to achieve a diagnostic image.

Following this, participants were individually examined on their ability to obtain 3 echocardiographic views. They were given two minutes to obtain correctly each predetermined echocardiographic view (for example, ‘Please obtain a right parasternal long axis 4 chamber view’) and asked to say when they were happy with the view obtained.

Assessors completed the post-assessment form (Supplementary material 5).

All dogs were in a standing position for the echocardiographic examination and were comfortably restrained by either their owner or a veterinary student with whom they were comfortable. No sedation was given. No dog received a total of more than 4 x 6 minute sessions.

Following the practical training session, all participants were asked to complete a questionnaire about confidence in obtaining the echocardiographic views and diagnosing pericardial effusion, poor systolic function and left atrial enlargement (Supplementary material 6).

3.12 Statistical analysis

All data were analysed using the statistical software package Minitab version 17.

Primary analyses

The primary outcome for the study was to determine whether the anatomy and video interpretation scores had changed following the training intervention. The paired study design meant that differences between pre- and post-training were analysed using a two-sided paired t-test at the 5% significance level.

Secondary analyses

A number of secondary analyses were conducted. All secondary analyses were conducted at the 5% significance level.

First, generalised linear modelling techniques were used to see if there was an association between the experience (years) of those in the study and the scores at baseline.

Second, in order to see the effect of further training (CPD etc.) on the baseline scores, a two-sided two-sampled t-test was conducted.

Third, a Pearson correlation was conducted to investigate whether there was relationship between the pre-training echo video scores and experience (years) or further training (CPD etc.).

3.13 Results

In total, forty general veterinary practitioners of varying years qualified (3 months – 36 years) participated in this study. All practitioners completed all parts of the study (the pre-course assessments, lecture, practical training and post-course assessments).

Of these practitioners, 39 (97.5%) had an ultrasound machine available in their practice. Of these, 33 (84.6%) had a portable ultrasound machine and 6 (15.4%) had a static ultrasound machine (Figure 18 & Supplementary material 7).

Of those with an ultrasound machine, 23 (59.0%) had never used the ultrasound machine to look at the heart, 16 (41.0%) had (Figure 19).

The frequency of the machine use varied from 11 (28.2%) using it less than 5 times in the preceding 3 months, 3 (7.7%) used it 5-10 times, 1 (2.6%) using it 10-20 times and 1 (2.6%) using it more than 20 times (Figure 20 & Supplementary material 8).

Anatomy test

For the anatomy test pre-training, the mean score was 4.5 out of a possible 8 marks (standard deviation [SD] 2.3). Following the training, the mean score increased to a mean score of 7.3 out of a possible 8 marks (SD 1.1) (Figure 21 & Supplementary material 9).

The p-value for the paired t-test was significant ($p<0.0001$). There is evidence that post-training, the scores increased by 2.8 (95% confidence interval [CI] 2.2 – 3.5 on average).

A secondary analysis was conducted to see if the pre-training scores were associated with years since graduation. The general linear modelling showed that experience was a significant predictor ($p = 0.011<0.05$) of the baseline score. That said, the model only explained 14.34% (R-sq adj) of the variability in the scores suggesting that there may be better measures of performance. It is worth noting that there was no association between the post-training scores and experience ($p = 0.4519$).

Another secondary analysis was conducted to see if the pre-scores differed for those who had engaged in further training. Of the 40 individuals in the survey, 11 (27.5%) had engaged in further training while 29 (72.5%) had not. For those who had engaged in further training, the mean pre-score was 6.36 (SD 1.80) and for those who had not, the mean pre-score was 3.83 (SD 2.1392). The difference in the scores was significantly higher (2.54, 95%CI 1.14 – 3.94 ($p < 0.001$) for those who had engaged in further training.

For those who had not engaged in further training ($n = 29$) the mean post anatomy score was 7.3 with a standard deviation of 1.2. For those who had engaged in further training ($n=11$) the mean post anatomy score was 7.4 with a standard deviation of 1.0. A two-sample t-test, conducted at the 5% significance level, gave a p-value of 0.889 which suggested there was no evidence of a difference in scores post training for those who engaged in further training.

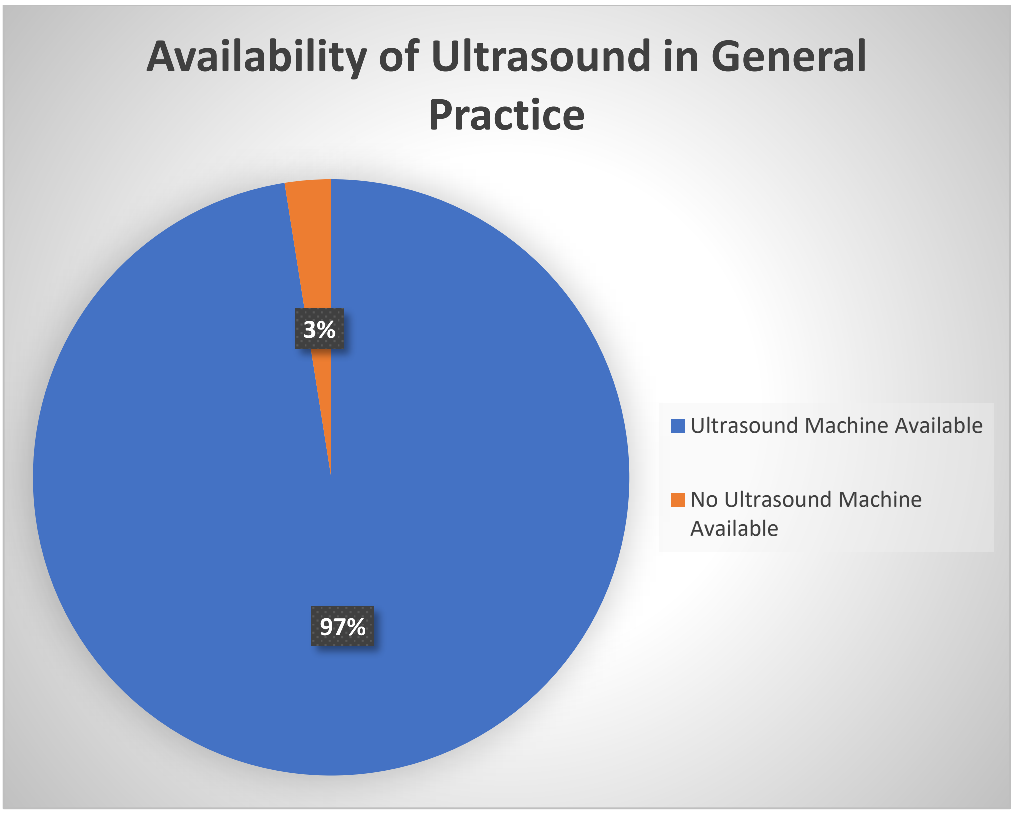


Figure 18 A pie chart display of the availability of ultrasound to general practitioners.

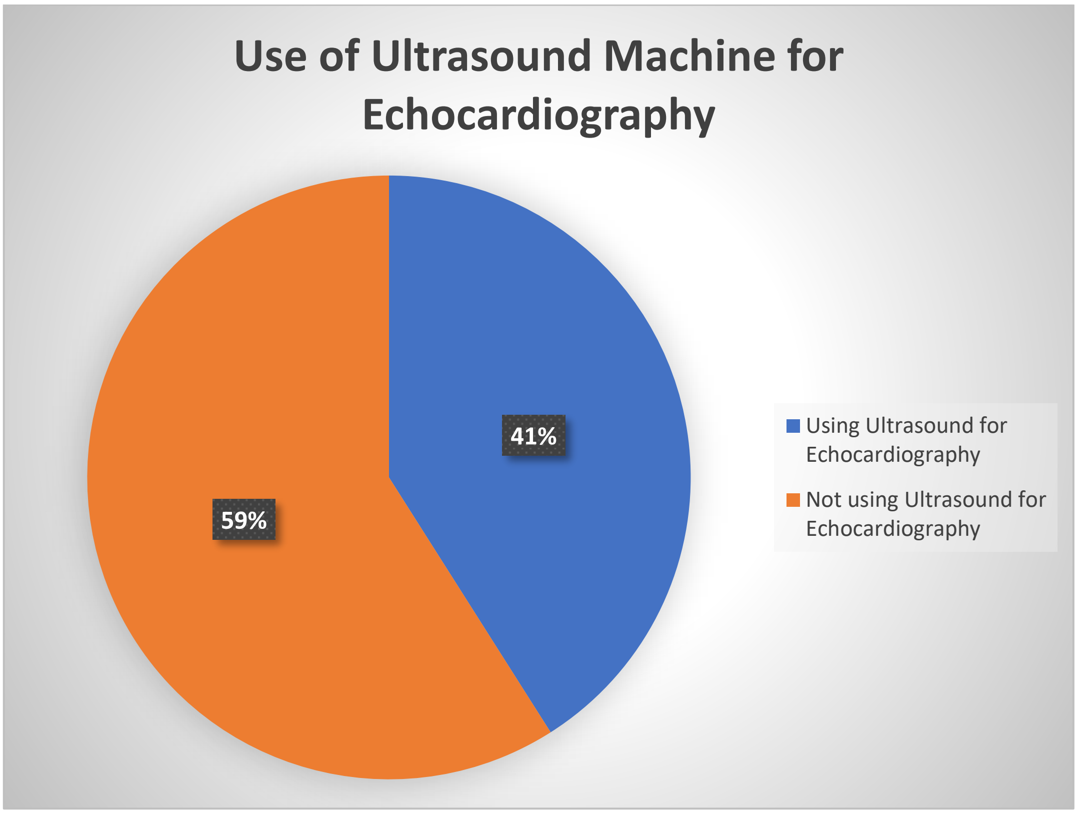


Figure 19 A pie chart display of the general practitioner use of ultrasound for echocardiography.

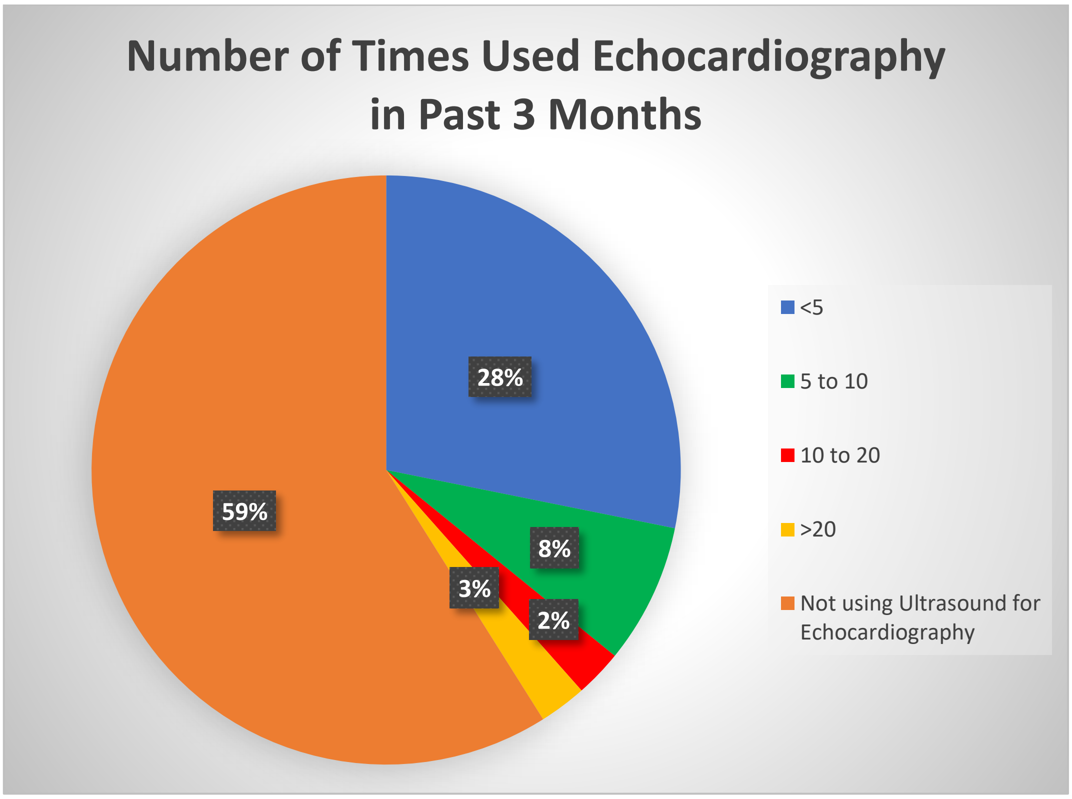


Figure 20 A pie chart display of the general practitioner use of echocardiography in the past 3 months.

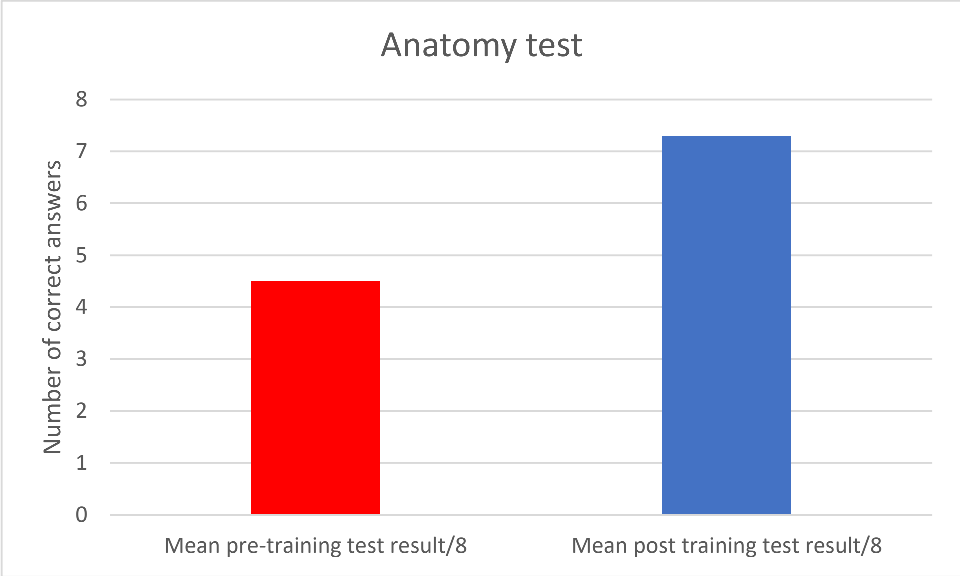


Figure 21 A graphical display of anatomy test results pre and post training.

Test assessing interpretation of video loops of echocardiography

In relation to the test assessing the practitioners' ability to interpret video loops of echocardiography, pre-training the mean score was 18.9 out of a possible 27 marks (SD 4.39) (Figure 22). Post-training the mean score was 24.0 out of a possible 27 marks (SD 1.36). On average, the scores were 5.7 (95%CI 4.258 – 7.142) higher post training ($p<0.0001$).

As a secondary analysis, a Pearson correlation was conducted at the 5% significance level to investigate whether there was relationship between the pre-testing echo video scores and experience. The correlation coefficient was 0.23 which suggests a weak positive correlation. This was not statistically significant ($p= 0.169$).

There was no evidence of a correlation between the post-testing echo video scores and experience (correlation 0.29 ($p=0.78$)).

In relation to the pre-training test, for those who did not engage in extra training, the mean score was 18.04 out of 27 (SD 4.532). For those who did engage in extra training the mean score was 21.0 out of 27 (SD 3.26). On average, the scores for those who did extra training were significantly higher than those that did not extra training ($p = 0.0305$).

In relation to the post-training test, for those who did not engage in extra training, the mean score was 24.38 out of 27 (SD 1.374). For those who did engage in extra training the mean score was 25.0 out of 27 (SD 1.27). The p-value for the test was not significant at the 5% level ($p = 0.192$).

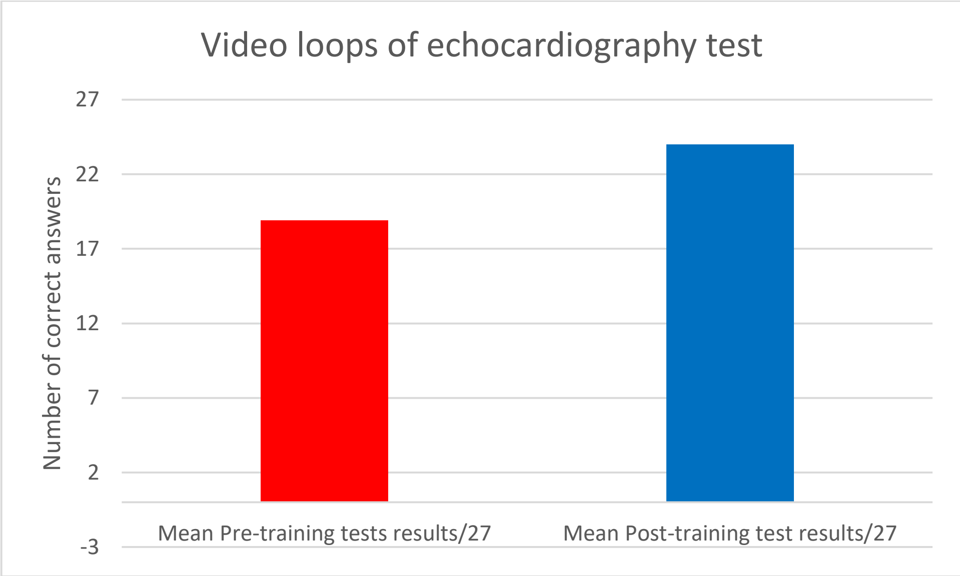


Figure 22 A graphical display of video echocardiography test results pre and post training (Supplementary material 10.).

Pericardial effusion, atrial enlargement and poor systolic function

The mean score pre-training in detection of pericardial effusion was a mean score of 6.65 out of a possible 9 marks and post-training this was 8.05 out of a possible 9 marks.

The mean pre-training score in detection of left atrial enlargement was a mean score of 4.72 out of a possible 9 marks and post-training was a mean score of 7.97 out of a possible 9 marks.

The mean score in detection of systolic function was a mean score of 7.45 out of a possible 9 marks pre-training and post training a score of 8.52 out of a possible 9 marks (Table 21).

Table 21. Mean pre and post training test results for detection of pericardial effusion, left atrial enlargement and poor systolic function

	Pre-training test result (Mean score/9)	Post-training test result (Mean score/9)
Pericardial effusion	5.75	8.0
Left atrial enlargement	4.7	7.97
Poor systolic function	7.45	8.52

Pericardial effusion (Table 22 & 23)

In relation to the images assessing practitioner's ability to detect pericardial effusion, study participants were shown 9 images of this condition: 3 with no pericardial effusion, 3 with mild pericardial effusion and 3 with severe pericardial effusion.

Table 22. The total scores for the 40 individuals in the pre-training and post-training assessment for pericardial effusion.

Score	Pre-training result	Pre-training Percentage	Post training results	Post training percentage
0	0	0.0%	0	0.0%
1	0	0.0%	0	0.0%
2	1	2.5%	0	0.0%
3	1	2.5%	0	0.0%
4	0	0.0%	0	0.0%
5	3	7.5%	0	0.0%
6	11	27.5%	1	2.5%
7	16	40.0%	11	27.5%
8	4	10.0%	13	32.5%
9	4	10.0%	15	37.5%

Table 23. Pre and post training score in detection of no pericardial effusion (PE) mild pericardial effusion and severe pericardial effusion

	Number of images correct	Pre-training	Post-training
Score for no PE	0	1 (2.5%)	0
	1	6 (15.0%)	2 (5.0%)
	2	11 (27.5%)	14 (35.0%)
	3	22 (55.0%)	24 (60%)
Score for mild PE	0	7 (17.5%)	0
	1	15 (37.5%)	4 (10%)
	2	9 (22.5%)	10 (25%)
	3	9 (22.5%)	26 (65%)
Score for severe PE	0	0	0
	1	1 (2.5%)	5.0%
	2	6 (15.0%)	0
	3	33 (82.5%)	38 (95%)

Left atrial enlargement (Table 24 & 25)

In relation to the images assessing practitioners ability to detect left atrial enlargement, study participants were shown 9 images of this condition: 3 with no left atrial enlargement, 3 with mild left atrial enlargement and 3 with severe left atrial enlargement.

Table 24. The total scores for the 40 individuals pre and post training for left atrial size assessment videos

Score	Pre-training result	Pre-training Percentage	Post training results	Post training percentage
0	5	12.5%	0	0
1	2	5.0%	0	0
2	3	7.5%	0	0
3	0	0	0	0
4	5	12.5%	0	0
5	8	20%	0	0
6	5	12.5%	4	10.0%
7	6	15.0%	6	15.0%
8	5	12.5%	17	42.5%
9	1	2.5%	13	32.5%

Table 25. Pre and post training scores for the detection of no left atrial enlargement, mild left atrial enlargement and severe left atrial enlargement

	Number of Images correct	Pre-training	Post-training
Score for no LAE	0	11 (27.5%)	3 (7.5%)
	1	13 (32.5%)	3 (7.5%)
	2	8 (20.0%)	8 (20.0%)
	3	8 (20.0%)	26 (65.0%)
Score for mild LAE	0	9 (22.5%)	0
	1	12 (30.0%)	1 (2.5%)
	2	11 (27.5%)	14 (35.0%)
	3	8 (20.0%)	25 (62.5%)
Score for severe LAE	0	6 (15.0%)	0
	1	6 (15.0%)	2 (5.0%)
	2	12 (30.0%)	0
	3	16 (40.0%)	38 (95.0%)

LAE = Left Atrial Enlargement

Reduced systolic function (Table 26 & 27)

In relation to images assessing practitioner ability to detect reduced systolic function, participants were shown 9 images of this condition: 3 with normal systolic function, 3 with mildly reduced systolic function and 3 with severely reduced systolic function.

Table 26. The total scores for the 40 individuals: Pre and Post-training scores for the 9 systolic function videos

Score	Pre-training result	Pre-training Percentage	Post training results	Post training percentage
0	1	2.5%	0	0%
1	0	0%	0	0%
2	0	0%	0	0%
3	0	0%	0	0%
4	0	0%	0	0%
5	1	2.5%	0	0%
6	5	12.5%	0	0%
7	10	30.0%	5	12.5%
8	12	25.0%	9	22.5%
9	11	27.5%	26	65.0%

Table 27. Pre and post training scores for detection of normal systolic function, mildly reduced systolic function and severely reduced systolic function.

	Number images correct	Pre-training	Post-training
Score for normal SF	0	1 (2.5%)	0
	1	6 (15.0%)	0
	2	12 (30%)	0
	3	21 (53.5)	100%
Score for mildly reduced SF	0	1 (2.5)	0
	1	5 (12.5%)	4 (10.0%)
	2	14 (37.5%)	10 (25.0%)
	3	19 (47.5%)	26 (65%)
Score for severely reduced SF	0	1 (2.5%)	0
	1	4 (10.0%)	0
	2	0	1 (2.5%)
	3	35 (87.5%)	39 (97.5%)

SF = Systolic Function

The total score for the 9 images with normal or no/mild/severe pericardial effusion, systolic function and left atrial size pre-and post-training were calculated and compared using paired t-tests. Here a Bonferroni correction was made to the significance level to allow for multiple testing. This means that each of the three tests below were tested at the 1.6% significance level.
For the echocardiographic video images, which were normal, Pre-training, the mean score was 6.0 (SD 1.935). Post-training, the mean score was 7.98 (SD 1.121). On average, the scores post-training were 1.98 (95%CI 1.231 – 2.719) higher. The p-value for the test showed this difference was significant ($p<0.0001$).

For the echocardiographic video images that were mildly different from normal, pre-training, the mean score was 5.25 (SD 0.30). Post-training, the mean score was 7.7 (SD 0.18). On average, the scores post-training were 2.45 (95%CI 1.92 – 2.98) point higher. The p-value for the test showed this difference was statistically significant ($p<0.001$).

For the echocardiographic video images, which were severely different to normal, pre-training, the mean score was 7.6 (SD 0.245). Post-training, the mean score was 8.88 (SD 0.33). On average, the scores post training were 1.28 points higher (95%CI 0.75 – 1.80). The p-value for the test showed this difference was statistically significant ($p<0.001$).

The practical assessment (Figure 23)

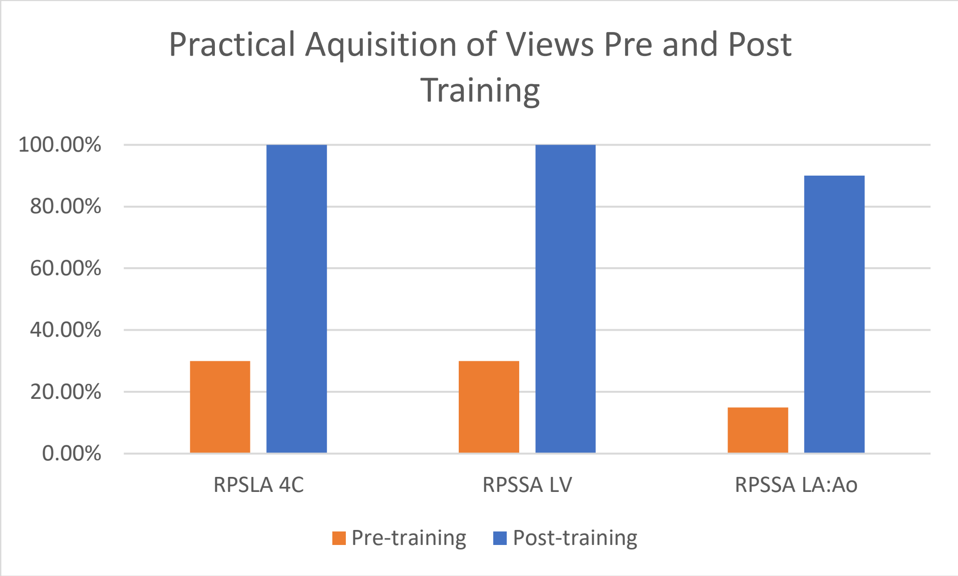


Figure 23 A graphical display of practitioner ability to practical acquire echocardiographic views: Right parasternal long axis 4 chamber view (RPSLA 4C), right parasternal short axis view of the left ventricle at the level of the papillary muscles (RPSSA LV) and right parasternal short axis view of the heart base at the level of the left atrium and aorta (RPSSA LA:Ao) pre and post training (Supplementary material 11).

In relation to the practical assessment, pre-training, 28 (70.0%) obtained no image of the right parasternal long axis 4 chamber view, 12 (30%) obtained a view with 8 (20.0%) obtaining a satisfactory image, and 4 (10.0%) obtaining an excellent image.
Post-training, 100% obtained a view with 1 (2.5%) obtaining a satisfactory image and 39 (97.5%) obtaining an excellent image.

Pre-training, 28 (70.0%) obtained no image of the right parasternal short axis at the level of the left ventricle papillary muscles, 9 (22.5%) obtained a satisfactory image, and 3 (7.5%) obtained an excellent image. Post-training, 40 (100.0%) obtained excellent images.

Pre-training, 34 (85.0%) obtained no image of the right parasternal short axis view of the left atrium and aorta, 5 (12.5%) obtained a satisfactory image, 1 (2.5%) obtained an excellent image.

Post-training, 4 (10.0%) obtained no image, 18 (45.0%) obtained a satisfactory image and 18 (45.0%) obtained an excellent image.

<u>Practitioner confidence (Figure 24)</u>
In relation to practitioner confidence in obtaining any echocardiographic views, pre-training, 25 (62.5%) felt no confidence, 13 (32.5%) felt mildly confident confidence and 2 (5.0%) felt moderately confident.

Post-training, 4 (10.0%) felt mild confidence, 20 (50.0%) felt moderately confident and 16 (40.0%) felt very confident.

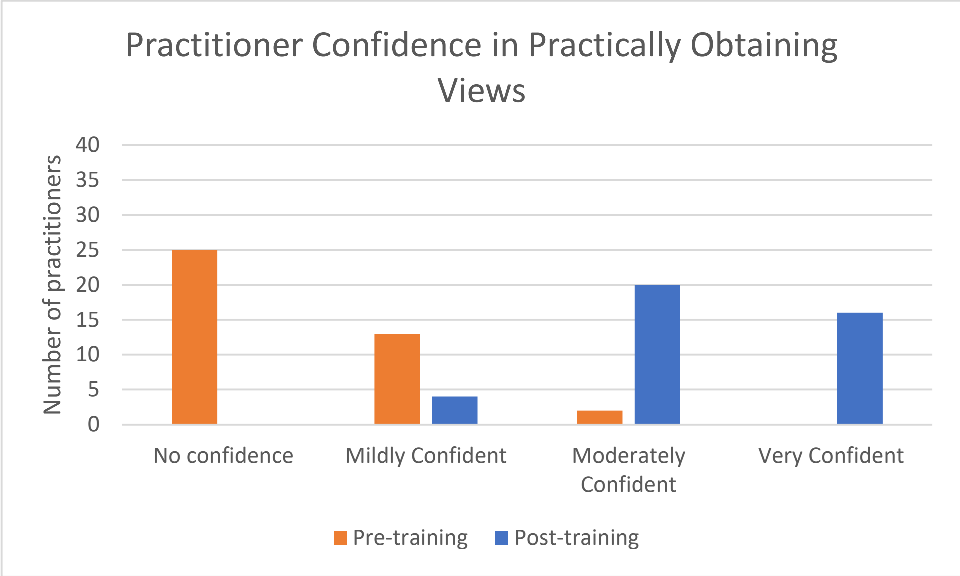


Figure 24 A graphical display of practitioner confidence in practically obtaining echocardiographic views pre and post training (Supplementary material.12). Number of practitioners on the y-axis and practitioner confidence on the x-axis.

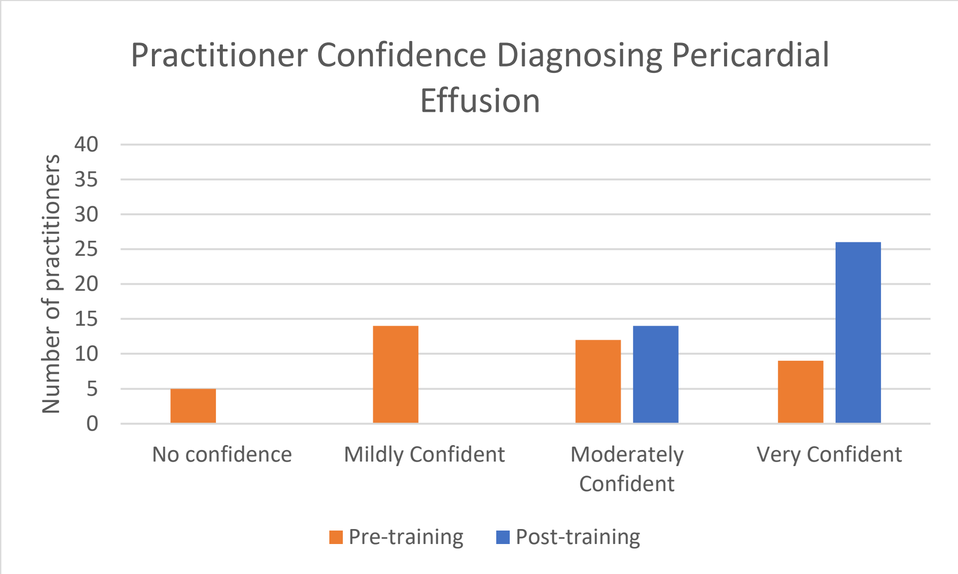


Figure 25 A graphical display of practitioner confidence in diagnosing pericardial effusion pre and post training. Practitioner confidence on the x-axis and number of practitioners on the y-axis.

In relation to confidence in diagnosing pericardial effusion, pre-training, 5 (12.5%) felt no confidence, 14 (35.0%) felt some confidence, 12, (30.0%) felt confident and 9 (22.5%) felt very confident.
Post-training, 14 (35.0%) felt moderately confident and 26 (65.0%) felt very confident (Figure 25).

In relation to confidence in diagnosing cardiac tamponade, pre-training, 20 (50.0%) felt no confidence, 17 (42.5%) felt some confidence, 2 (5.0%) felt confident and 1 (2.5%) felt very confident.

Post-training, 1 (2.5%) felt no confidence, 7 (17.5%) felt some confidence, 22 (55.0%) felt confident and 10 (25.0%) felt very confident.

In relation to confidence in diagnosing left atrial enlargement, pre-training, 21 (52.5%) felt no confidence, 14 (35.0%) felt some confidence and 5 (12.5%) felt moderately confident. Post-training, 1 (2.5%) felt no confidence, 3 (7.5%) felt some confidence, 22 (55.0%) felt confident and 14 (35.0%) felt very confident (Figure 26).

In relation to confidence in diagnosing reduced systolic function.
Pre-training, 31 (77.5%) felt no confidence and 9 (22.5) felt mildly confident.
Post-training, 2 (5.0%) felt mild confidence, 28 (70.0%) felt moderately confident and 10 (25.0%) felt very confident (Figure 27).

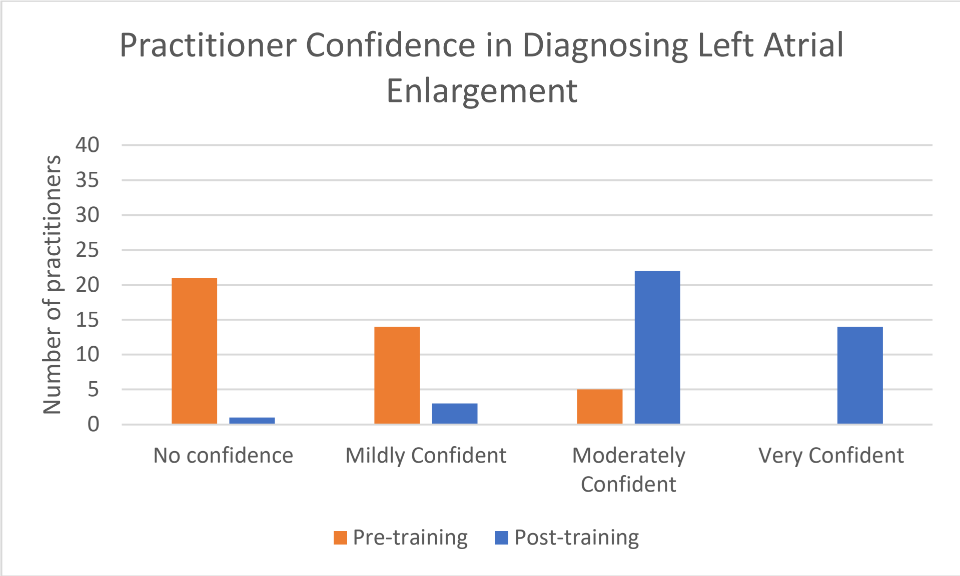


Figure 26 A graphical display of practitioner confidence in diagnosing left atrial enlargement pre and post training. Number of practitioners on the y-axis and practitioner confidence on the x-axis.

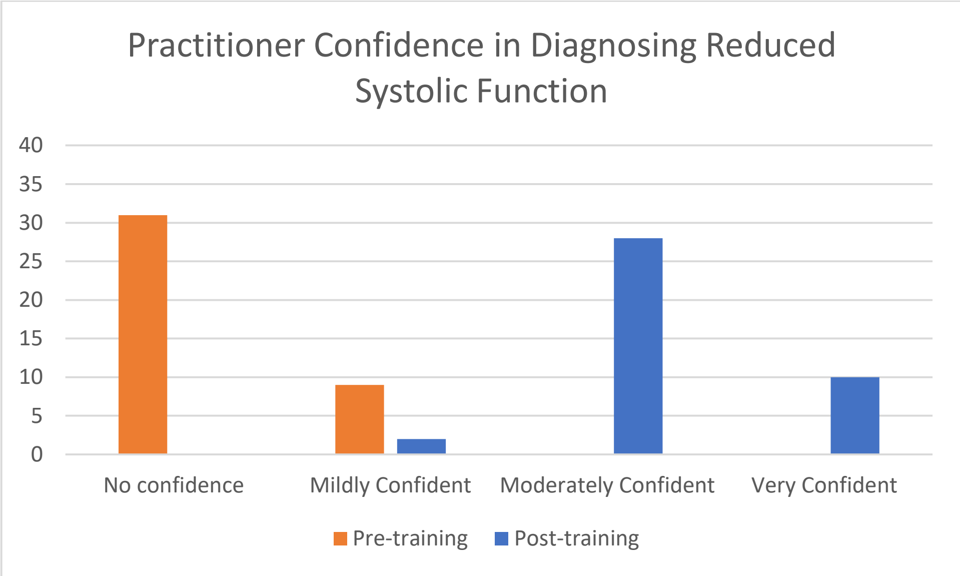


Figure 27 A graphical display of practitioner confidence in diagnosing reduced systolic function pre and post training. Practitioner confidence on the x-axis and number of practitioners on the y-axis.

3.14 Conclusion chapter III

This study has shown that a one hour training course in focused echocardiography can improve the ability of general practitioners to correctly identify cardiac anatomy on echocardiography, detect left atrial enlargement, reduced systolic function and pericardial effusion on echocardiography, practically obtain the views required to make these assessments, and improve their confidence.

Focused echocardiography can give vital information regarding the presence, size, and clinical relevance of a pericardial effusion as a cause of haemodynamic instability which would prompt rapid, life-saving intervention in the form of a pericardiocentesis. Assessment of left atrial size and global ventricular systolic function could alter therapeutic management.

Prior to any training, practitioner scores on the subjective interpretation of echocardiographic video image test were good, 18.9 out of a possible 27 marks (SD 4.39). However, practitioners had limited practical ability to obtain the images required to make the assessment (30% able to obtain a RPSSA 4C and RPSSA LV and 15% able to obtain a RPSSA LA:Ao) and the anatomy scores were low, 4.5 out of a possible 8 marks (SD 2.33). This may suggest why, despite 97% of the general practitioners having access to ultrasound machines, 56.8% were not using them to perform a basic cardiac assessment. Following a short training course, anatomy scores (mean score of 7.3 out of a possible 8 marks (SD 1.12)), practical ability to obtain these images (100% able to obtain a RPSSA 4C and RPSSA LV and 90% RPSSA LA:Ao) and subjective interpretation of echo video loops (mean score of 24.0 out of a possible 27 marks (SD 1.36)) markedly improved.

In relation to the cardiac anatomy test results, the training increased the participant's ability to make the correct diagnosis and reduced the amount of variability in the results. Pre-training scores were significantly higher in practitioners that had been qualified for longer periods of time ($p = 0.011$), however there was no significant difference in scores post training ($p = 0.4519$), suggesting the course brought all practitioners to the same level.

As expected, further training in cardiology (continued professional development [CPD] or completing an internship which rotated through a cardiology discipline) resulted in higher and less variable pre-test scores ($p < 0.001$).
In relation to the interpretation of video images of echocardiography, length of time since graduation did not have any relationship with pre-training ($p= 0.169$) or post-training scores ($p=0.78$), however practitioners who had engaged in further training (CPD or completing an internship) had higher pre-scores ($p = 0.0305$). Again, the post-training scores for those with and without further training were not significantly different ($p = 0.192$).

Post-training, most practitioners correctly subjectively identified a large volume pericardial effusion (95%), severely reduced systolic function (fractional shortening <10%) (97.5%) and left atrial enlargement (LA:Ao >2:1) (95%).

In relation to practical training, following the training session, 100% of practitioners were able to obtain the right parasternal long axis 4 chamber view and right parasternal short axis view of the left ventricle at the level of the papillary muscles and 90% of practitioners were able to obtain a view of the right parasternal short axis view at the level of the left atrium and aorta to a level which was considered essential prior to interpretation. The right parasternal short axis view of the left atrium and aorta is undoubtedly the hardest view to obtain given that the action of fanning the probe is more challenging and there is more lung interference at this level. This may have explained why 10% of practitioners were unable to obtain this view.
In relation to confidence in practically obtaining images, pre-training, the majority of practitioners had no confidence in obtaining any images (62.5%). Following training, the confidence markedly increased to 50% feeling confident and 40% feeling very confident.
Practitioner confidence in detection of pericardial effusion, reduced systolic function and left atrial enlargement improved in all areas following the training. In relation to pericardial effusion, all practitioners felt confident or very confident.

In relation to left atrial enlargement, 90% felt confident or very confident. In relation to reduced systolic function, 95% felt confident or very confident.

To the author’s knowledge, this study is unique in its description of a method to instruct non-cardiologist general veterinary practitioners on the clinical application of focused echocardiography in cardiac emergencies.

3.15 Discussion

The results show that non-cardiologists can, in a relatively short period of time (one hour) learn to perform a basic cardiac ultrasonographic examination that allows them to detect three markers of cardiac disease. They can also learn to correctly interpret these views subjectively in line with measurements made by veterinary cardiologists.

Improvements in test scores, practical ability and confidence in obtaining images was seen in all groups. This suggests that the training session would be beneficial for a variety of general practitioners. The greatest improvement in scores was seen in the complete novice practitioner.

This training was not intended to replace comprehensive echocardiography performed by a board-certified cardiologist. This training takes 3 years to complete and the performance of multiple echocardiograms per day. Rather its aim was to teach practitioners a skill to aid in the triage of patients in an emergency and aid identification of patients who might benefit from a referral echocardiogram. Emphasis was placed on the complementary role this tool could play alongside comprehensive echocardiography.

This skill can be used, alongside the history, physical examination and other diagnostics (including other types focused sonography (TFAST/ Vet BLUE)) to help differentiate cardiac and respiratory causes of dyspnoea and cardiogenic and non-cardiogenic cause of collapse in an emergency. The main goals are to rule in or out pericardial effusion, identify any global systolic dysfunction and assess the left atrium to aortic ratio.

In this study, practitioners performed the focused echocardiogram in 6 minutes with the patient standing. Equipment used was similar to that found in general practices and all examinations were performed in an environment which could be established in practice.

This suggests that the addition of the tool would be of little cost to practices in which ultrasound facilities are already available. The author recommends that all patients presenting with respiratory distress or collapse of unknown aetiology should have a focused echocardiogram.

3.15.1 Limitations

Video images and still images of echocardiography chosen for the training and tests were all of excellent quality. This training was designed as an introduction to focused ultrasound, and may not fully represent the diversity and difficulty that a clinician may face in practice. The ability of a practitioner to assess cardiac disease on pre-recorded images may not reflect the ability of the practitioner in a real emergency situation.

The practical component of the training was performed on healthy, compliant dogs, which may have made obtaining images easier than that from a real patient in heart failure. Undoubtedly an ideal training session would include performing ultrasonography on patients with a variety of chest shapes, demeanours, breed, species, respiratory rate, heart orientation and with or without cardiac disease; however, this was limited by time available.

For the purpose of standardization, all dogs used in the practical weighed between 20-25kg and had similar conformation and no cats were used in the study. These results cannot be extrapolated beyond this species or to extremes of body weight.

All 40 practitioners did not scan the same dog for their assessment, therefore ease of scanning may have varied. However, despite this limitation, the variance was not considered high and this biological variation improved the practical application of this method.

An inherent selection bias may have existed within the study subjects. Practitioners who were keen to learn and attend CPD in their free time or who had an interest in echocardiography were more likely to respond to the regional invitation. The level of engagement as a result of specific interest in cardiology or imaging may have facilitated learning.

3.15.2 Integration of this tool into general practice

This study has shown that focused echocardiography could be used in general veterinary practice to identify pathologic processes that could guide interventions and potentially be life-saving. However, it is important that practitioners have realistic expectations of their ability to image, interpret and understand the limitations of the ultrasound machines used and the limitations of focused echocardiography itself. Inappropriate use or application beyond the defined scope could potentially have adverse effects and abnormal findings on a focused echocardiogram should be referred for a comprehensive echocardiogram if this can be done safely.

Cooperation between referral and general practices on the use of this tool could assist rapid and accurate diagnosis and treatment of patients with cardiac emergencies.

As with any skill, continued competency relies on the individual's ability to implement and re-enforce the skill and follow up on any referral reports so that missed or misinterpreted changes can be noted.

With the ongoing development of the internet, web-based resources are increasingly being used to replace face to face learning. There is the potential that this training could be developed into an online training course, allowing more practitioners to participate, including those with constraints of time and location (Lockwood et al., 2001). The effectiveness of the online training would need to be assessed as thoroughly as the face-to-face training.

3.15.3 Follow up studies

A number of follow-up studies could be developed.

To assess the longevity of the knowledge and practical skill acquisition of the focused echocardiography training course for the individual practitioner. Three months post successful completion of the course, participants could be asked to complete another online test, practical assessment and new questionnaires. This would determine their frequency of use of focused echocardiography and their confidence. The results from this could be used to assess if the positive effects on confidence, knowledge and practical ability to obtain images were sustained.

An alternative approach would be to ask the general practitioners to save all echocardiographic images, diagnoses and decisions obtained from focused echocardiogram for three months following the training. These images could be reviewed and assessed on their diagnostic quality and the practitioner's ability to interpret them. Results could then be used to determine the effectiveness of the training. This would also allow for any disagreement with interpretation to be reported and corrected.

A second study would be to investigate if the training of a practitioner in focused echocardiography expedites the time from the presentation of a patient as a potential cardiac emergency to diagnosis. Practitioners with no previous experience in focused echocardiography would be recruited and trained. The length of time from patient presentation to diagnosis in potential cardiac emergencies, pre and post training, would be recorded to establish improvement.

3.15.4 Future uses of focused echocardiography

In the human medicine literature, there are a number of clinical scenarios where focused ultrasonography has substantial literature support and potential to affect clinical decision making and patient care.

For example, in patients who suffer a cardiac arrest, the goal of the focused echocardiogram in this situation is to improve the outcome of cardiopulmonary resuscitation. This is by enabling the identification of organized cardiac contractility to help the clinician distinguish between asystole, pulseless electrical activity (PEA), and pseudo-PEA, to determine a cardiac cause of the cardiac arrest, and to guide lifesaving procedures at the bedside. (Bocka, Overton and Hauser, 1988; Mayron et al., 1988; Salen et al., 2005; Soar et al., 2005; Breitkreutz, Walcher and Seeger, 2007). Another use is in determining intravascular volume status using left ventricular size, ventricular function, and inferior vena cava size and respiratory change, and focused echocardiography can be used to identify the severely hypovolaemic patient (Brennan et al., 2007). Both of the above could be transferred for use in veterinary medicine in the future.

Myxomatous mitral valve disease (MMVD) is the leading cause of heart disease in dogs (Ljungvall and Haggstrom, 2017). The disease has a long pre-clinical period.
Recently published veterinary literature has shown that administration of pimobendan to dogs with MMVD and echocardiographic and radiographic evidence of cardiomegaly results in prolongation of the preclinical period. Prolongation of the preclinical period by approximately 15 months represents a substantial clinical benefit (Boswood *et al.*, 2016).

This study has shown that practitioners who completed a training course in focused echocardiography were able to correctly identify normal left atrial size, a mildly enlarged left atrium and severely enlarged left atrium an average 88% of the time.

Therefore, the author suggests that the addition of the focused echocardiogram to general practice could aid earlier detection of patients who might benefit from a referral echocardiogram and subsequently treatment with pimobendan i.e. dogs with a grade 3/6 or greater, left apical heart murmur and cardiomegaly. This training was aimed at general practitioners, however it could be incorporated into a final year veterinary student curriculum.

Focused ultrasonography can be performed with both static and portable machines, however, the size, complexity and cost of static machines exceeds the requirements needed for focused echo and removes the advantage of the smaller machine size. In human medicine, most reports that evaluate the focused echocardiogram use hand carried platforms; however pocket instruments have also shown promise (Spencer et al., 2013).

Miniaturization of the equipment has improved their function at the bedside and it may be that in the future hand-held machines are used in the veterinary consulting room.

Conclusion

This research aimed to investigate possible skills gaps in relation to the detection of cardiovascular disease in general veterinary practice and to identify methods to reduce these skill gaps, with particular emphasis on the detection of myxomatous mitral valve disease (MMVD).

The research performed identified a limited standard of record keeping for important cardiovascular parameters in general veterinary practices. Whilst it was difficult to ascertain whether the absence of recorded parameters was due to lack of assessment of the parameter, lack of practitioner knowledge or ability to interpret findings or poor record keeping itself, the absence of recorded parameters is a significant gap. The impact of poor record keeping can increase the workload on staff, undermine patient care and put practitioners at risk of legal and professional complications.

In relation to the detection of myxomatous mitral valve disease, poor record keeping may prevent identification of new heart murmurs, identification of an increase in the intensity of a heart murmur (which may suggest progression of heart disease) and identification of an increase in heart rate (which may prevent the identification of patients in early stages of heart failure or patients who might benefit from further cardiovascular investigation). The author suggests that methods should be put in place to address the poor standard of record keeping. These could include practitioners attending continued professional development highlighting the importance of the cardiovascular physical examination and refreshing practitioners on how to perform a cardiovascular specific clinical examination and how to interpret findings, the use of computer software ensuring vital parameters are recorded and the introduction of frequent auditing of clinical records to ensure a high standard of record keeping.

When investigating general practitioner ability to correctly interpret heart murmurs, results from the research performed suggests that practitioners can accurately interpret murmurs. General practice and the referral consensus opinion had a substantial agreement on murmur grade, a perfect agreement on murmur timing and a moderate agreement on the side of maximum intensity of murmur. In relation to MMVD, this would suggest that practitioners would be able to accurately grade a heart murmur and therefore correctly select patients who would benefit from further investigation to confirm the cause of the murmur as MMVD and determine which stage of the MMVD.

General practitioners were found to be accurate in their detection of thoracic radiographic changes associated with MMVD and identification of patients without disease, however a skill gap was identified in their detection of patients with mild cardiomegaly and mild left atrial enlargement. This suggests that patients in the early stages of cardiac remodelling due to MMVD and those who might benefit greatly from the positive effects of medication may go undiagnosed. The author suggests that practitioners may benefit from CPD highlighting how to identify mild changes associated with MMVD on thoracic radiographs.

The final part of this thesis investigated the current frequency of use of echocardiography in participating general veterinary practices across Glasgow. This was found to be 41% despite 97% of practices having an ultrasound machine available. This is a significant skill gap. The introduction of the novel tool of focused echocardiography to general veterinary practitioners was then assessed. Following a one-hour training course in focused echocardiography, practitioners were found to significantly improve their ability to correctly identify cardiac anatomy on echocardiography, detect left atrial enlargement, reduced systolic function and pericardial effusion, practically obtain the views required to make these assessments, and improve their confidence in both image interpretation and practical acquisition.

This skill could provide a complementary diagnostic tool, aid triage of patients in an emergency setting and aid identification of patients with cardiac disease who might benefit from cardiac medications and/or a referral echocardiogram.

In relation to general practitioner detection of MMVD, following the training course, the mean accuracy of identification of normal left atrial size, a mildly enlarged left atrium and severely enlarged left atrium was 88%. Post training, 95% of practitioners were able to correctly identify a severely enlarged left atrium.

The author suggests that the addition of the focused echocardiogram to general practice could aid earlier detection of patients in stage B2 MMVD or greater by detection of left atrial enlargement. These patients could then benefit from a referral echocardiogram and potentially from medical treatment.

Conflicts of interest

The author was sponsored by Boehringer Ingelheim for other studies.

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Supplementary Material

Supplementary material.1 Thoracic radiograph questionnaire no.1. Given prior to any assessment

Thoracic Radiograph Interpretation Questionnaire

Please answer all questions with what you would really do in practice. This is not an assessment for the correct answer, its aim is to give an impression of what is done in practice.

Name: ____

Year of Graduation: __________________________________

Have you attended any further training on thoracic radiograph interpretation (CPD/rotating internship with an imaging rotation/other) since graduation?

- ☐ Yes
- ☐ No

How confident do you feel with interpretation of cardiomegaly on thoracic radiographs?

- ☐ No confidence
- ☐ Mildly confident
- ☐ Moderately confident
- ☐ Very confident

How many radiographs would you typically take in practice when assessing for cardiomegaly?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4

Which of these radiographs would you normally take in practice when assessing for cardiomegaly? (Can tick as many answers as you like)

- ☐ Right lateral
- ☐ Dorsoventral
- ☐ Left lateral
- ☐ ventrodorsal

Supplementary material.2 Thoracic radiograph questionnaire.2. Given post assessments.

Thoracic Radiograph Interpretation Questionnaire 2

How would you typically take a radiograph to assess for cardiomegaly?

- ☐ Patient sedated
- ☐ Patient held, no sedation
- ☐ Patient restrained with sandbags, no sedation
- ☐ Patient anaesthetized

Which of these (if any) do you take into consideration when assessing for cardiomegaly (tick as many as you like) ?

- ☐ Body condition score
- ☐ Breed
- ☐ Phase of respiration
- ☐ Positioning of radiograph
- ☐ Haematology
- ☐ Side of recumbency
- ☐ If the patient is anaesthetised
- ☐ Presence of abnormal skeletal pathology
- ☐ Heart rate

How do you TYPICALLY assess for generalised cardiomegaly in practice?

- ☐ Decrease in distance between heart and diaphragm
- ☐ Dorsal displacement of the trachea
- ☐ Vertebral heart score measurement
- ☐ An increase in the number of intercostal spaces covered by the cardiac silhouette
- ☐ Cardiac width exceeding 2/3rds of the width of the thoracic cavity
- ☐ Height exceeding 2/3rds of the height of the thoracic cavity on lateral view
- ☐ Round silhouette
- ☐ Straight caudal margin of the heart
- ☐ General impression of increase in size
- ☐ Reversed D shape
- ☐ Other ……………………………………

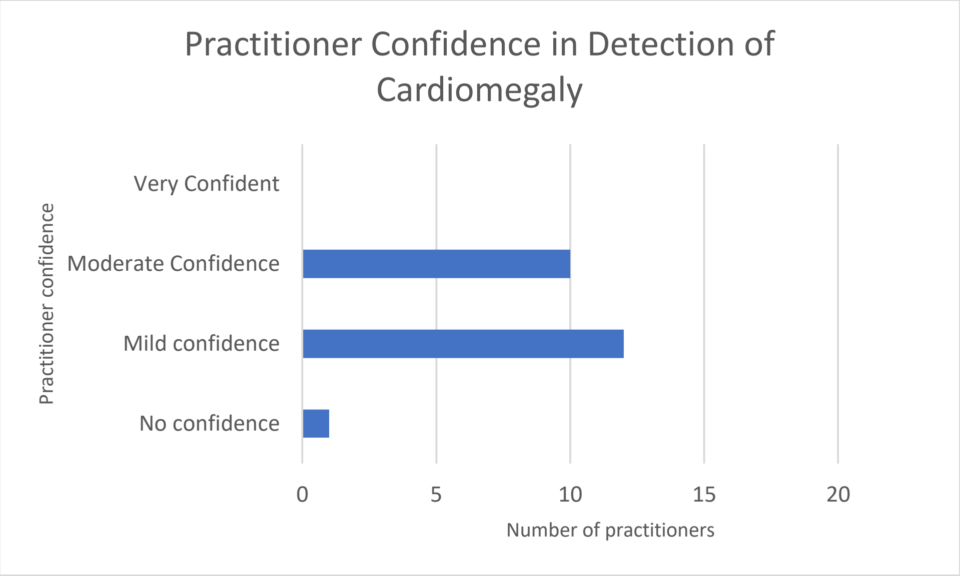
When using the radiographs provided in the quiz, how did you SUBJECTIVELY assess for left atrial enlargement?

- ☐ Left auricular bulge
- ☐ Dorsal deviation and compression of left main stem bronchus
- ☐ Dorso caudal bulging of soft tissue opacity on lateral view ('tenting')
- ☐ Cowboy sign
- ☐ Other ……………………………………………

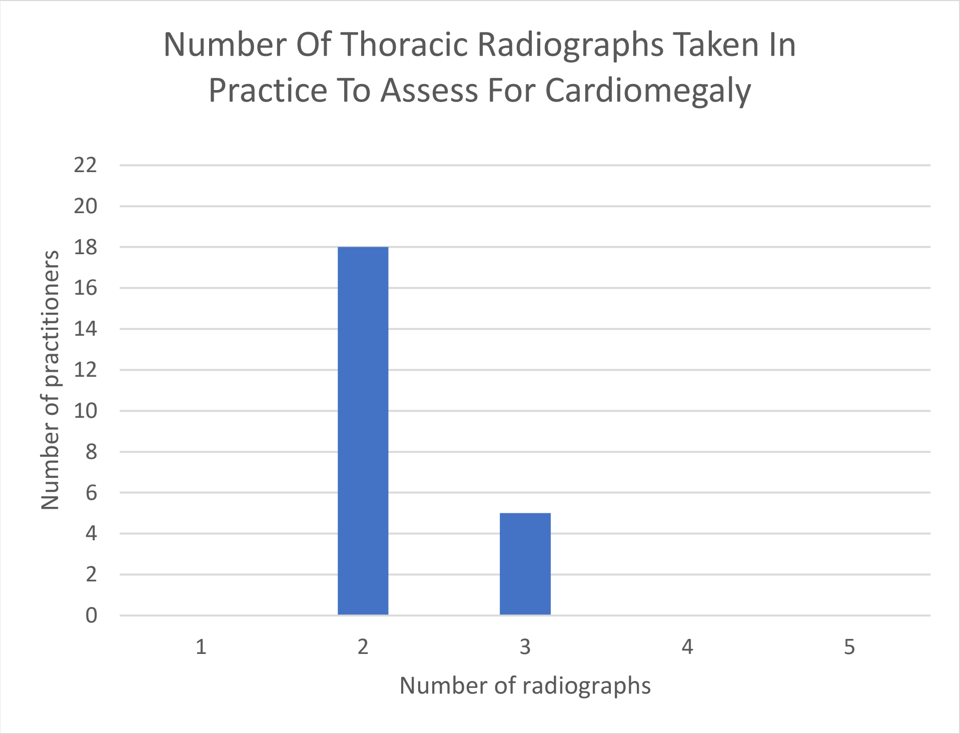
What would you use as the upper limit of a normal vertebral heart score (VHS) for a Cavalier King Charles Spaniel?

………………………………………………………………………………………

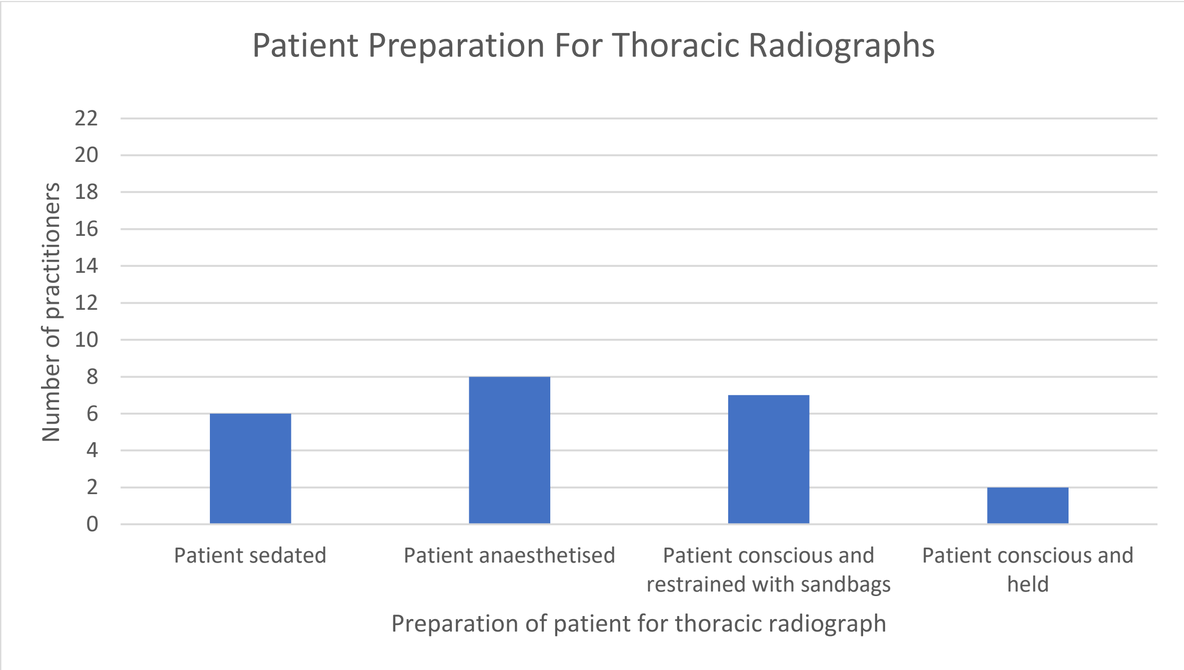
Supplementary material. 3 A graphical display of practitioner confidence in detection of cardiomegaly on thoracic radiographs. Confidence range from none to mild, moderate and very confident. Total number of practitioners = 23.



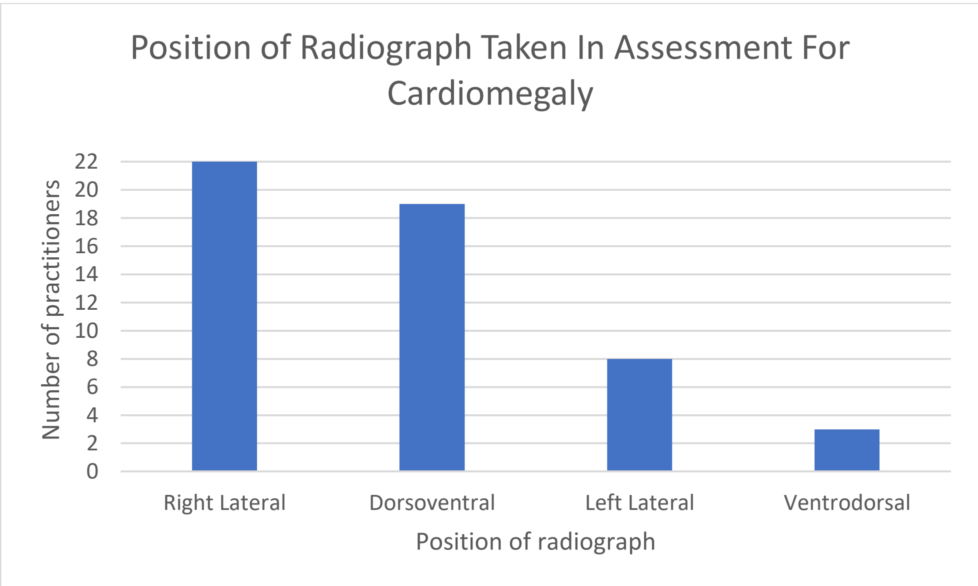
Supplementary material. 4 A graphical display of number of thoracic radiographs taken in practice to assess for cardiomegaly.



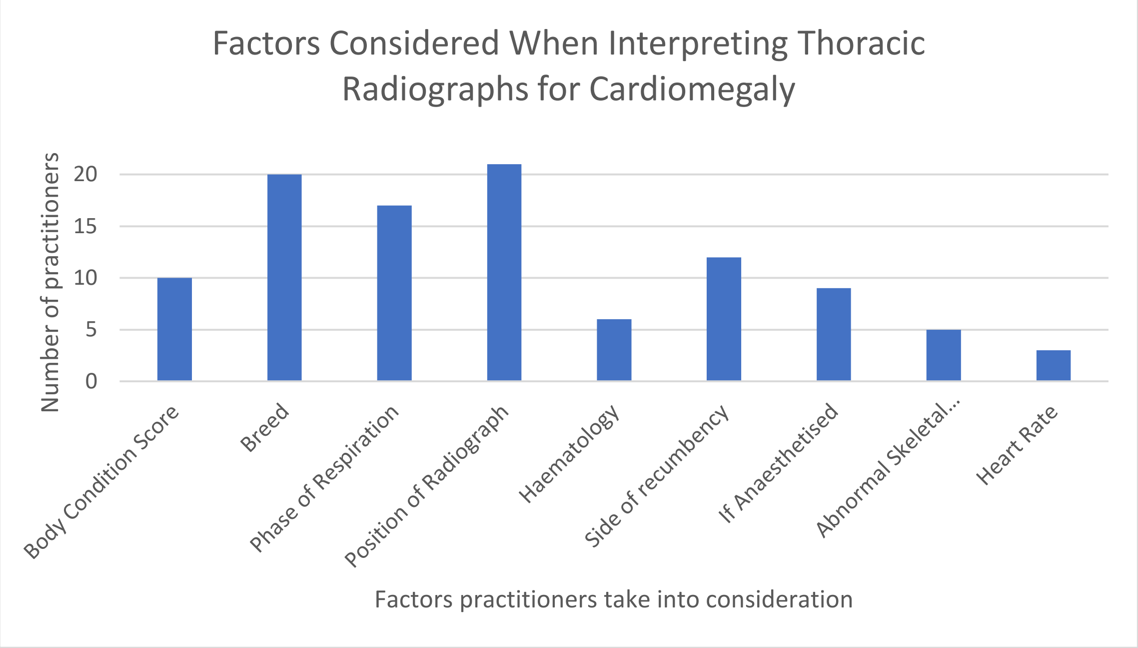
Supplementary material. 5 A graphical display of how patients are typically prepared for thoracic radiographs in general practice. This included the patient being sedated, anaesthetised, conscious and restrained with sandbags and conscious and held.



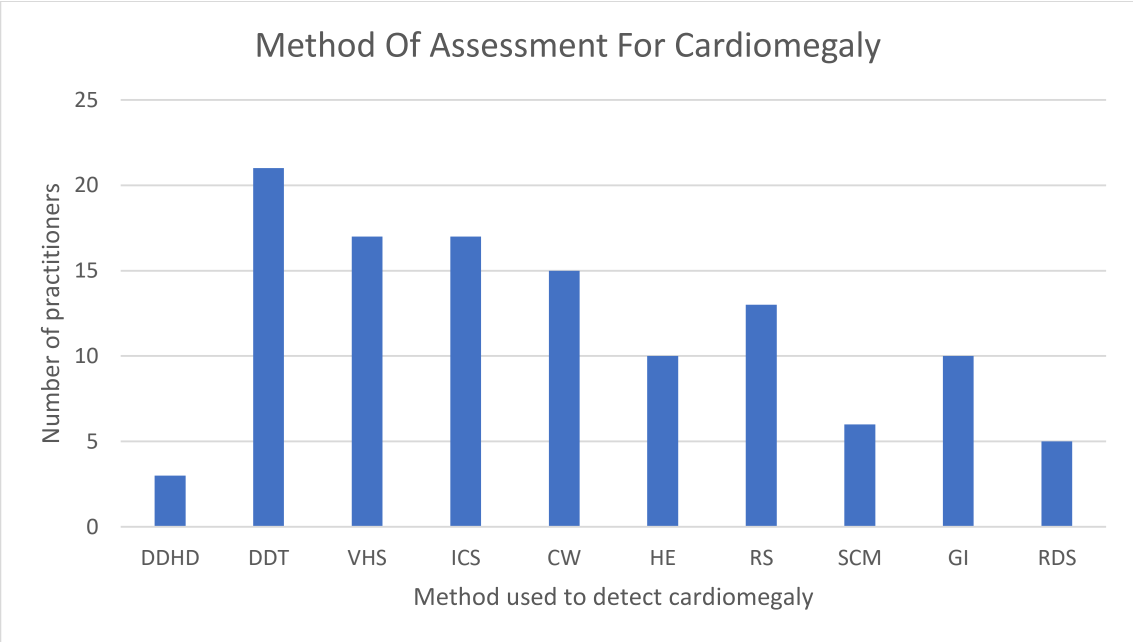
Supplementary material. 6 A graphical display of position of radiograph typically taken in general practice to assess for cardiomegaly. Positions include: right lateral radiograph, dorsoventral radiograph, left lateral radiograph, ventrodorsal radiograph.



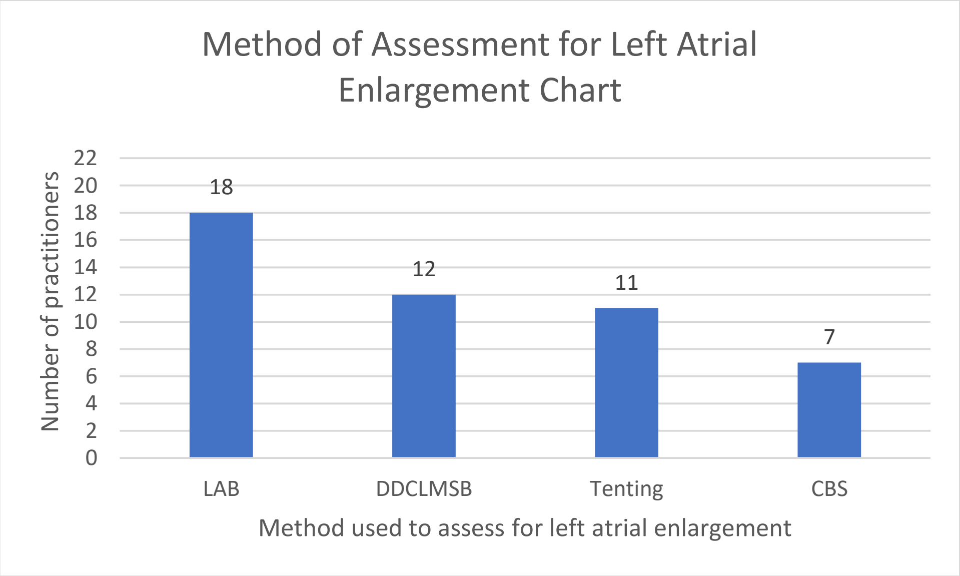
Supplementary material. 7 A graphical display of the factors practitioners consider when interpreting thoracic radiographs.



Supplementary material. 8 A graphical display of method used to detect cardiomegaly in general practice. DDHD = decrease in distance between heart and diaphragm, DDT = dorsal displacement of the trachea, VHS = vertebral heart score, ICS = increase in the number of intercostal spaces covered by the cardiac silhouette, CW = cardiac width exceeding 2/3rds of the width of the thoracic cavity, HE = cardiac height exceeding 2/3rds of the height of the thoracic cavity on lateral view, RS = rounded cardiac silhouette, SCM = straight caudal margin of the heart, GI = overall general impression of increase in size (GI) and RDS = reversed D shape on the DV view.



Supplementary material. 9 A graphical representation of method used to assess for left atrial enlargement in general practice. Left auricular bulge on the DV view = LAB, dorsal deviation and compression of left main stem bronchus = DDCLMSB, dorso-caudal bulging of soft tissue opacity on lateral view = 'tenting' and 'cowboy sign' on the DV view = CBS.



Supplementary material. 10 Questionnaire completed by practitioners prior to focused echocardiography training.

Questionnaire- Focused Echo
PRE-training
Please fill in all the spaces provided and tick one correct answer

Name: ____________________

Place of graduation ____________________

Year of graduation ____________________

Were you taught echocardiography (heart scan) at university?
- ☐ Yes
- ☐ No

Have you received any echocardiography (heart scan) training post qualification?
- ☐ Yes
- ☐ No

If yes
- ☐ CPD
- ☐ Certificate in cardiology
- ☐ Rotating internship including cardiology rotation
- ☐ Other ____________________

Do you have an ultrasound machine in your practice?
- ☐ Yes
- ☐ No

If yes,
Make of ultrasound machine ____________________
(don't worry if can't remember)

Is it portable or static
- ☐ Portable
- ☐ Static

How often would you use your ultrasound machine for performing a focused echocardiogram in the past 3 months?
- ☐ Never
- ☐ <5 times
- ☐ 5-10 times
- ☐ 10-20 times
- ☐ 20+

How would you feel if you were asked to obtain some standard right sided echocardiographic views?

- ☐ I would not know where to start
- ☐ I would feel mildly confident
- ☐ I would feel moderately confident
- ☐ I would feel very confident

How confident do you feel in diagnosing any of the following using focused echocardiogram?

Pericardial effusion
- ☐ Very confident
- ☐ Moderately confident
- ☐ Mildly confident
- ☐ No confidence

Cardiac tamponade
- ☐ Very confident
- ☐ Moderately confident
- ☐ Mildly
- ☐ No confidence

Left atrial enlargement
- ☐ Very confident
- ☐ Moderately confident
- ☐ Mildly confident
- ☐ No confidence

Assessment of systolic function
- ☐ Very confident
- ☐ Moderately confident
- ☐ Mildly confident
- ☐ No confidence

Supplementary material. 11 Assessment form completed for the pre-training echocardiography practical assessment

Pre- training practical assessment:

Vet name____

Vet number____

1. 'Please obtain a right parasternal long axis 4 chamber view'

Left atrium	Not visible	Visible but base cut off	Visible in entirety

Left ventricle	Not visible	Visible, but apex cut off	Visible in entirety, but foreshortened	Visible in entirety and no foreshortening

Septum	Not visible	Tipped up/down	Horizontal across screen

- Unsatisfactory image
- Satisfactory image
- Excellent image

2. 'Please obtain a right parasternal short axis view of the left ventricle'

Right ventricle	Not visible	Visible, but not crescent shaped	Crescent shaped

Left ventricle	Not visible	Visible, but not symmetrical	Round + symmetrical papillary muscles

- Unsatisfactory image
- Satisfactory image
- Excellent image

3. 'Please obtain a right parasternal short axis view of the left atrium and aorta'

Aorta	Not visible	Circular	Circular and all 3 cusps seen.

Left atrium	Not visible	Visible	Visible including intra-atrial septum

- Unsatisfactory image
- Satisfactory image
- Excellent image

Supplementary material.12 Assessment form completed for the post-training echocardiography practical assessment

Post- training practical assessment:

Vet name____

Vet number____

1. 'Please obtain a right parasternal long axis 4 chamber view'

Left atrium	Not visible	Visible but base cut off	Visible in entirety

Left ventricle	Not visible	Visible, but apex cut off	Visible in entirety, but foreshortened	Visible in entirety and no foreshortening

Septum	Not visible	Tipped up/down	Horizontal across screen

- ☐ Unsatisfactory image
- ☐ Satisfactory image
- ☐ Excellent image

2. 'Please obtain a right parasternal short axis view of the left ventricle'

Right ventricle	Not visible	Visible, but not crescent shaped	Crescent shaped

Left ventricle	Not visible	Visible, but not symmetrical	Round + symmetrical papillary muscles

- ☐ Unsatisfactory image
- ☐ Satisfactory image
- ☐ Excellent image

3. 'Please obtain a right parasternal short axis view of the left atrium and aorta'

Aorta	Not visible	Circular	Circular and all 3 cusps seen.

Left atrium	Not visible	Visible	Visible including intra-atrial septum

- ☐ Unsatisfactory image
- ☐ Satisfactory image
- ☐ Excellent image

Supplementary material. 13 Questionnaire completed by practitioners post focused echocardiography training

Questionnaire- Focused Echo

POST-training

Please fill in all the spaces provided and tick one correct answer

Name: ________________________________

How would you feel if you were asked to obtain some standard right views of the heart using echocardiography?

- ☐ I would not know where to start
- ☐ Mildly confident
- ☐ Moderately confident
- ☐ Very confident

How confident do you feel in diagnosing any of the following using focused echocardiogram?

Pericardial effusion

- ☐ Very confident
- ☐ Moderately confident
- ☐ Mild confidence
- ☐ No confidence

Cardiac tamponade

- ☐ Very confident
- ☐ Moderately confident
- ☐ Mild confidence
- ☐ No confidence

Left atrial enlargement

- ☐ Very confident
- ☐ Moderately confident
- ☐ Mild confidence
- ☐ No confidence

Assessment of systolic function

- ☐ Very confident
- ☐ Moderately confident
- ☐ Mild confidence
- ☐ No confidence

Supplementary material.14 Table of the availability of ultrasound to general practitioners

General practitioners	Ultrasound Machine Available		No ultrasound machine available
40	39 (97.5 %)		1 (2.5%)
	Portable 33 (84.6%)	Static 6 (15.4%)	

Supplementary material.15 Table of the frequency of use of echocardiography in general practice

Practitioners with ultrasound available	Using ultrasound machine for echo				Not using ultrasound machine for echo
39	16 (41.0%)				23 (59.0%)
	<5 11 (28.2%)	5-10 3 (7.7%)	10-20 1 (2.6%)	>20 1 (2.6%)	

Supplementary material.16 Table of echocardiography anatomy test results pre and post training course in focused echocardiography

	Mean pre-training test result/8	Mean post training test result/8
Anatomy test	4.5	7.3

Supplementary material.17 Video image echocardiography test results pre and post training

	Mean Pre-training tests results/27	Mean Post-training test results/27
Video loops of echocardiography test	18.9	24

Supplementary material.18 Pre and post training scores of practitioner ability to practically acquire echocardiographic views

	RPSLA 4C		RPSSA LV		RPSSA LA:Ao	
	Pre	Post	Pre	Post	Pre	Post
Number of practitioners able to obtain a diagnostic quality image	12 30%	40 100%	12 30%	40 100%	6 15%	36 90%

Supplementary material.19 Pre and post training practitioner confidence in practically obtaining echocardiographic views

Pre-training				Post-training			
No confidence	Mildly confident	Moderately confident	Very confident	No confidence	Mildly confident	Moderately confident	Very confident
25 (62.5%)	13 (32.5%)	2 (5.0%)	0	0	4 (10.0%)	20 (50.0%)	16 (40%)