INTRODUCTION TO ECHOCARDIOGRAPHY
IN SMALL ANIMAL PRACTICE

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INTRODUCTION

Echocardiography in a nutshell

Echocardiographic techniques (or simply “echo”) are mostly used to image two-dimensional slices of the heart (B-mode). Apart from B-mode, conventional echocardiography also employs M-mode and Doppler. Colour Flow Doppler (CFM) is used to image flowing blood. Spectral colour Doppler (Continuous wave Doppler or CW and Pulsed wave Doppler or PW) are used to measure the velocity of flowing blood. Pulsed Doppler transmitted at a higher frequency (high pulsed repetition frequency, HPRF) offers a compromise between CW and LPRF Doppler.

Basic and advanced echocardiography

The usual echocardiogram is also known as a transthoracic echocardiogram, or TTE. In TTE, heart is imaged from outside through the chest wall. The echocardiography probe is placed on the chest wall of the subject and images are obtained. This is a simple, highly accurate test. Another method to perform an echocardiogram is to insert a dedicated endoscope containing an echocardiography transducer into the patient’s oesophagus and record pictures from there. This is known as a transesophageal (trans-oesophageal) echocardiogram or TEE. TEE has the advantage of providing more detailed and more accurate images. This is because the transducer is closer to the heart. Some of the posterior structures of the heart are better imaged with TEE. These include the aorta, the pulmonary artery, the valves of the heart, and the left atrium. TEE requires general anaesthesia and a local anaesthetic lubricant for the oesophagus.

Latest developments in the field of echocardiography includes real time three-dimensional (3-D) imaging, tissue Doppler imaging (TDI), Strain and Strain rate and other specialised techniques.
**B-mode (2-D)**

It allows two-dimensional visualisation of the heart (two-dimensional slices) providing information about its shape, size and spatial relationships of its structures during the cardiac cycle. Overall myocardial contractility is subjectively assessed in real-time B-mode.

![B-mode Image](image1)

**M-mode**

In the M-mode technique ("M" = Mono-dimensional), ultrasonic pulses are propagated along the same axis (stationary crystal that produces a “pencil beam” of sounds) and different parts of the heart are studied by changing the direction of the beam manually. An M-mode echocardiogram is not a "picture" of the heart, but rather a diagram that shows how the positions of its structures change during the course of the cardiac cycle. M-mode does not provide information about the spatial relationships of different parts of the heart to each other.

![M-mode Image](image2)

**Doppler**

Doppler imaging allows evaluation of blood flow patterns, direction, and velocity; thus, it permits documentation and quantification of valvular insufficiency or stenosis and cardiac shunts. With the application of some mathematical formulas, normally performed by the computer software installed in the ultrasound machine, pressure gradients and cardiac output can be estimated.
Doppler echocardiography is based on detection of frequency changes (the Doppler shift) occurring as ultrasound waves reflect off individual blood cells moving either away or toward the transducer. Calculation of blood flow velocity is accurate only when the flow is parallel (or almost parallel) to the angle of the ultrasound beam. Since calculations become increasingly inaccurate as the angle of incidence of the ultrasound beam and the path of blood flow diverges from 0 degrees, measurement of maximal blood flow velocity requires that the ultrasound beam be as close to parallel with the path of blood flow as possible.

**PW**

Pulsed wave (PW) Doppler uses short bursts of ultrasound transmitted to a point (designated the "sample volume" or "gate") distant from the transducer. The advantage of this type of Doppler is that blood flow velocity, direction and spectral characteristics from a specified point in the heart or blood vessel can be interrogated and calculated. The main disadvantage is that the maximum velocity that can be measured is limited because the pulse repetition frequency is limited ("Nyquist" limit) and high velocities appear to wrap around the baseline on the screen ("aliasing"). The Nyquist limit depends on the pulse repetition frequency (PRF), depth and transducer frequency.

![Pulsed Wave Doppler Example](image)

**CW**

Continuous wave (CW) Doppler uses dual crystals so that ultrasound waves can be simultaneously and continuously sent and received. There is no maximum measurable velocity ("Nyquist" limit) with CW so high velocity flows can be measured (up to a certain limit depending on transducer frequency). The disadvantage with CW Doppler is that sampling of blood flow velocity and direction occurs all along the ultrasound beam, not in a specified area.
HPRF

Pulsed Doppler transmitted at a higher frequency (high pulsed repetition frequency or HPRF) represents a compromise between PW and CW by using multiple sample volumes.

CFM

Colour flow mode (CFM) is a form of HPRF, where numerous sample volumes are overlaid on a bi-dimensional echocardiogram along multiple scan lines. The mean frequency shift obtained from these multiple sample volumes is colour-coded for direction and velocity. Several types of mapping are usually available but it is universally agreed that blood flow toward the transducer is coded in red and flow away in blue. Differences in relative velocity of flow can be accentuated, and the presence of multiple velocities and directions of flow (turbulence) can be indicated by different maps, which utilise variations in brightness and colour.
Diagnostic use of echocardiography

In recent years, echocardiography has become indispensable for reaching a specific diagnosis and estimating the severity of various cardiac diseases. However, it is important to remember that echocardiography is only a part of the complete cardiac work-up. Findings on the echocardiogram must be integrated with information obtained from the history and physical examination, cardiac and pulmonary auscultation, blood pressure measurement, and thoracic radiographs. If necessary additional tests may be necessary, such as electrocardiogram (ECG), clinical laboratory tests and/or other appropriate complementary tests in order to determine the accurate diagnosis and optimal therapeutic plan for each individual patient. Technical knowledge and expertise in performing and interpreting the echocardiographic examination are fundamental prerequisites to the valid use of this diagnostic tool.

Echocardiographic evaluations

Echocardiography is generally used to evaluate cardiac chamber size, wall thickness, wall motion, valve configuration and motion. Furthermore, the size and conformation of proximal great vessels (aorta and pulmonary artery) can be assessed during the examination. Using ultrasound, anatomic relationships can be determined and information regarding cardiac function can be derived. Echocardiography represents the most reliable method for detecting pericardial and pleural effusions and identification of mass lesions within and adjacent to the heart. Most examinations can be completed with minimal or no chemical restraint.

The decision to perform an echocardiographic examination is usually made to:

- Investigate the source and the significance of a cardiac murmur
- Investigate underlying heart disease and the effects of a cardiac arrhythmia
- Identify the presence and significance of myocardial disease
- Identify the presence, significance of pericardial disease
- Investigate unexplained ascites or pleural effusions
- Investigate unexplained recurrent pyrexia (identification of vegetative endocardial lesions)
Limitations

The major limitation of echocardiography is represented by the quality of images that can be obtained in a patient. In some individuals (e.g. obese adult boxers), the thick chest wall and/or increased lung volume during inspiration may reduce a good visualisation of the entire heart, since ultrasounds do not travel well through these structures.

Another problem frequently encountered in veterinary echocardiography is represented by tachypnoea. In fact, the rapid change in the intrathoracic pressure during panting may cause artefacts (e.g. paradoxical motion of the septum) and interfere with Doppler measurements of blood flows.

Sedation

Sedation might significantly affect the correct measurement of ventricular contractility and cardiac output. However, most sedation protocols, with the exception of those using alpha-2 agonist like medetomidine (Domitor®), do not seem to alter significantly echo measurements. Most examinations can be performed without sedation, although, occasionally, there might be patients (especially cats) that do not tolerate any forms of manual restraint and chemical sedation may become necessary.

Examples of protocols used for sedation in dogs and cats:

<table>
<thead>
<tr>
<th>Dogs</th>
<th>Cats</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACP (0.02 mg/Kg) + Butorphanol (0.1 mg/Kg) [30 min before, lasts for a few hours]</td>
<td>Ketamine (10 mg/Kg) + Midazolam (0.25 mg/Kg) [10 min before, lasts for approx 30-45 min]</td>
</tr>
<tr>
<td>ACP (0.02 mg/Kg) + Buprenorphine (0.01 mg/Kg) [30 min before, lasts for a few hours]</td>
<td>ACP (0.05-0.1 mg/Kg) + Butorphanol (0.25 mg/Kg) [30 min before, lasts for a few hours]</td>
</tr>
<tr>
<td></td>
<td>ACP (0.05-0.1 mg/Kg) + Buprenorphine (0.02 mg/Kg) [30 min before, lasts for a few hours]</td>
</tr>
</tbody>
</table>
Patient preparation
Air-free contact between the transducer and body wall is necessary. This can be better achieved if hair is clipped from the axillae, before coupling gel is applied. However, some owners do not want their animals to be clipped (e.g. cat or dog show in few days) and in this case the hair can be thoroughly soaked with spirit or liquid soap before applying the ultrasound gel. Satisfactory imaging without hair clipping can also be obtained in shorthaired dogs and cats (e.g. greyhounds, DSH).

Most ultrasonographers use a scanning table with a cut-off section and images are obtained by scanning the patient in lateral recumbency from beneath the table. This method allows a better imaging of the heart because the organ drops toward the thoracic wall, reducing the problem of lung interference on echocardiographic images. In some occasions, animal will not tolerate a recumbent position (e.g. patients with dyspnoea) and the examination can be performed in standing position.

ECG monitoring
Cardiac ultrasound machines provide a single lead ECG monitor for timing reference. The crocodile clips should be attached to the patient as when recording a standard ECG and a good trace should be displayed on the screen before commencing the ultrasound examination. The most common technique for connecting ECG electrodes to a dog or cat involves the use of crocodile (alligator) clips attached to the skin of the patient, just above or below the elbows (forelimbs) or just above or below the patella (hindlimbs). If the fur is long enough, the electrodes can be clipped to the hair of the patient, rather than skin, providing electrical contact with a generous amount of ultrasound gel. Self-adhesive disposable electrodes attached to the paws can also be used.

Transducer selection
Mechanical
Old ultrasound systems used simple mechanically steered transducers. This involved a single piezoelectric (PZT) element which was mechanically steered through an arc to generate sector.
Phased-array (Digital)
Current generation of ultrasound systems use phased array transducer systems. A phased array consists of multiple PZT elements, generally arranged parallel to each other. The beam generated by the array of PZT elements is electronically steered through sequential activation of each element to generate a scanning sector.

Frequency
High-frequency transducers (7.5-10.0 MHz) should be chosen for scanning cats and small dogs (<10 Kg). Because of their short wavelength, high-frequency transducers allow a better resolution of the cardiac structures but less depth penetration. Low-frequency transducers (5.0 MHz), with longer wavelength, allow ultrasound to penetrate deeper at the expense of resolution and can be used in medium-sized dogs (up to 30-35 Kg). Larger dogs may require a 2.5-3.5 MHz transducer.

Features of an ultrasound machine suitable for echocardiography
- Sector scanner or small head phase arrayed transducers
- Wide range of frequency (from 7.5 to 3.5 MHz) (ideally from 10 to 2.0 MHz)
- Wide sector angle
- M-mode function (ideally with sweep speed control)
- Doppler (CW + PW and possibly HPRF)
- Colour Doppler
- ECG timing
- Software package for cardiology
• Capacity to switch quickly from B-mode to M-mode to Doppler (fast image update)
• Easy gain setting
• Freeze frame
• Cine-loop facility
• Digital archiving (or -at least- availability of a digital image acquisition device or printer and/or high quality video-recorder)

**Ultrasound Machine Settings**

The adjustment of the various controls on the ultrasound machine for beam strength, focus and post processing also affect the quality of images obtained.

Depth control adjusts the field of view. It should be adjusted until the image fills the field.

**Gain (or power or transmit)**

Gain controls the output power of the transducer. The entire sector is affected by this control. If too high, it may produce a white and distorted image. If too low, produces a weak and dark picture.

**Time-gain compensation (TGC)**

TGC controls the gain settings at different depths. It is usually adjusted by levers and the gain can be increased by sliding the lever (1) to the right, and vice-versa for reducing the power.

Some machines provide automatic adjustments (2) (Image below)
Compress
It adjusts the dynamic range of the displayed image. Decreasing compress reduces the dynamic range, eliminating weaker signals and increasing contrast.

Sector width
It can be adjusted from 30-45 degree to 90-120 degree, depending on the ultrasound machine.

Sector depth allows penetration of ultrasounds at different depths (cm), depending on the frequency of ultrasound transducer. Low frequency transducers allow deeper penetration, and vice-versa.

Adjusting depth and width together
The aim is to use the lowest depth and narrower angle in order to fulfil the screen with the cardiac structure to examine. A smaller sector size containing the cardiac structure allows a faster frame rate, improving image quality.

Focus
It allows focus the picture at different depths.

Cursor
It is a line that can be placed and move along the sector to direct M-mode and Doppler measurements. Direction of the cursor can be modified by using a track ball or a joystick.

M-mode sweep speed allows to compress or stretch the M-mode image. Typical sweep speeds are 25, 50, 100 mm/s and they can be chosen according to the heart rate (e.g. highest speed for high heart rate in cats).

Gate is a marker on the cursor line that corresponds to the sampling site (Doppler mode) and can be moved along the line with the trackball. Gate-size is adjustable to more or less volume.
Angle correction is present in some ultrasound machines. It is a separate cursor that can correct for angle when the Doppler line is not perfectly aligned (parallel) to the blood flow. The computer will take the angle into account when calculating the blood flow velocity.

Baseline corresponds to zero velocity and can be moved up and down on the screen.

Scale allows the adjustment of the height of the flow displayed on the screen depending on its velocity.

Doppler gain can be adjusted similarly to other gain controls. Increasing the Doppler gain will increase the strength of the returning signal but it will also increase background noise and artefacts.

Doppler filter decreases the amount of low-frequency noise produced by slow-moving structures like myocardial wall. However, if turned too high, it may eliminate the beginning and the end of a flow because these are the slowest flow velocities.

Doppler sweep speed is similar to the control used in the M-mode displays.

Control panel of a ultrasound machine commonly used in small animal cardiology (Esaote MyLab30)
The echocardiographic examination

A complete, standardised echocardiographic examination should be performed on all patients so that no diagnostic information is missed. Air-filled structures such as the lung and bone are excellent reflectors of ultrasound and prevent transmission of the ultrasound beam to the deeper structures. Therefore, the intercostal spaces in the axillary region at the cardiac level are used as cardiac windows. The ultrasound transducer must be positioned so that the ultrasound beam is perpendicular to the intracardiac structures for optimal image quality while the ultrasound beam must be as parallel as possible to flow disturbances to accurately quantify the flow abnormality with Doppler echocardiography. Correct placement of the ultrasound cursor within a particular view is essential for obtaining accurate and reproducible measurements. Equipment settings also affect the quality of images obtained. The echocardiographer should become familiar with some artefacts, which can mimic a cardiac abnormality, such as echo "drop-out" at the level of the fossa ovale (interatrial septum) or high interventricular septum. Visualisation of a suspected defect in more than one plane reduces the risk of over interpretation of an artefact.
ECHOCARDIOGRAPHIC VIEWS

The transducer needs to be located in the correct position and then angled and rotated to different degrees to obtain the standardised image planes. Standard echocardiograms views are as follows:

**RIGHT SIDE**

- right parasternal long-axis view (four chamber)
- right parasternal long-axis view (five chamber)
- right parasternal short-axis view (left ventricle)
- right parasternal short-axis view (papillary muscles)
- right parasternal short-axis view (chordae tendineae)
- right parasternal short-axis view (mitral valve)
- right parasternal short-axis view (heart base – aorta)
- right parasternal short-axis view (heart base – pulmonary artery)

**LEFT SIDE**

- left caudal parasternal apical images (four chamber)
- left caudal parasternal apical images (five chamber)
- left cranial parasternal position (left ventricle-aorta)
- left cranial parasternal position (pulmonary valve)

**SUBCOSTAL POSITION**

- trans-diaphragmatic view of the aorta for accurate measurements of LVOT velocity
Images from June Boon Manual of Veterinary Echocardiography, Williams & Wilkins 1998

RIGHT PARASTERNAL VIEWS

Long axis, four chambers

Long axis (five chambers)

Short axis (papillary muscle level)

Short axis (mitral valve level)

Short axis (heart base)

Short axis (level pulmonary artery)
LEFT PARASTERNAL VIEWS

Long axis four chambers

Long axis five chambers

LEFT CRANIAL

Long axis (aortic evaluation)

Oblique view (pulmonary artery evaluation)
INTERPRETATION OF AN ECHOCARDIOGRAM

**B-mode**

Observe and Examine:

- Overall shape of ventricles and atria. Cardiac chambers tend to dilate as a consequence of volume overload (CHF or fluid over-infusion) and the septa may bow away from the enlarged chamber.
- Myocardial texture (echogenicity may increase with myocardial fibrosis).
- Endocardial appearance (echogenicity may increase with endocardial fibrosis)
- Pericardial appearance (hypo-echogenic area with pericardial effusion)
- Valve conformation and echogenicity
- Valve motion. Opening and closing.
- Possible presence of cardiac masses or thrombi
- Possible presence of VSD or ASD

**M-mode**

The standard M-mode views utilised in veterinary medicine include the left ventricle (at the level of the chordae tendineae), the mitral valve and the aortic root (aorta/ left atrial appendage) view. The most useful and commonly used parameters are:

- LVDd: left ventricular end-diastolic dimension
- LVDs: left ventricular end-systolic dimension
- FS: fractional shortening \([\text{LVDd-LVDs} / \text{LVDd} \times 100]\)
- IVSd: interventricular septum end-diastolic
- IVSs: interventricular septum end-systolic
- LVWd: left ventricular wall end-diastolic
- LVWs: left ventricular wall end-systolic
- EPSS: E-point to septal separation:
- LA: left atrium
- Ao: aorta
- E:A mitral E:A diastolic points
Published normal ranges for measurements are available for the dog and cat (see tables below).

<p>| Normal M-mode average values and prediction intervals for DOGS of varying weights |</p>
<table>
<thead>
<tr>
<th>(Cornell, J Vet Intern Med 2004;18:311)</th>
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<tr>
<td><strong>Body Wt</strong></td>
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<td>60</td>
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<td>70</td>
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**NORMAL ECHOCARDIOGRAPHIC VALUES IN CATS** (different bibliographic sources)

<table>
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<tbody>
<tr>
<td></td>
<td>(n=11)</td>
<td>(n=25)</td>
<td>(n=30)</td>
<td>(N/A)**</td>
<td>(n=30)+</td>
<td>(n=26)+</td>
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<tr>
<td>LVEDD (cm)</td>
<td>1.5 ± 0.21±</td>
<td>1.48 ± 0.26±</td>
<td>1.59 ± 0.19±</td>
<td>1.10 - 1.60±</td>
<td>1.40 ± 0.13±</td>
<td>0.28 ± 0.17±</td>
</tr>
<tr>
<td>LVESD (cm)</td>
<td>0.69 ± 0.22±</td>
<td>0.88 ± 0.24±</td>
<td>0.80 ± 0.14±</td>
<td>0.60 - 1.00</td>
<td>0.81 ± 0.16</td>
<td>0.83 ± 0.15±</td>
</tr>
<tr>
<td>Ao (cm)</td>
<td>0.95 ± 0.15±</td>
<td>0.75 ± 0.18±</td>
<td>0.95 ± 0.11±</td>
<td>0.65 - 1.10</td>
<td>0.94 ± 0.11</td>
<td>0.94 ± 0.14±</td>
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<tr>
<td>LA (cm)</td>
<td>1.21 ± 0.18±</td>
<td>0.74 ± 0.17±</td>
<td>1.23 ± 0.14±</td>
<td>0.85 - 1.25</td>
<td>1.03 ± 0.14</td>
<td>0.98 ± 0.17±</td>
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<tr>
<td>LA/Ao (cm)</td>
<td>1.29 ± 0.23±</td>
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<td>1.30 ± 0.17±</td>
<td>0.80 - 1.30</td>
<td>1.10 ± 0.18</td>
<td>1.09 ± 0.27±</td>
</tr>
<tr>
<td>IVSed (cm)</td>
<td>0.50 ± 0.07±</td>
<td>0.45 ± 0.09±</td>
<td>0.31 ± 0.04±</td>
<td>0.25 - 0.50</td>
<td>0.36 ± 0.08</td>
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<tr>
<td>IVSes (cm)</td>
<td>0.76 ± 0.12±</td>
<td>--</td>
<td>0.58 ± 0.06±</td>
<td>0.50 - 0.98</td>
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<tr>
<td>LVWED (cm)</td>
<td>0.46 ± 0.05±</td>
<td>0.37 ± 0.08±</td>
<td>0.33 ± 0.06±</td>
<td>0.25 - 0.50</td>
<td>0.35 ± 0.08</td>
<td>0.31 ± 0.11±</td>
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<tr>
<td>LVWES (cm)</td>
<td>0.78 ± 0.10±</td>
<td>--</td>
<td>0.68 ± 0.07±</td>
<td>0.40 - 0.90</td>
<td>--</td>
<td>0.55 ± 0.88±</td>
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<tr>
<td>RVED (cm)</td>
<td>0.54 ± 0.10±</td>
<td>--</td>
<td>0.60 ± 0.15±</td>
<td>--</td>
<td>0.50 ± 0.21</td>
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<tr>
<td>LVID (cm)</td>
<td>0.50 ± 0.07±</td>
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<td>--</td>
<td>--</td>
<td>0.32 ± 0.11</td>
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<tr>
<td>EPSS (cm)</td>
<td>0.04 ± 0.07±</td>
<td>--</td>
<td>0.02 ± 0.09±</td>
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<tr>
<td>AA (cm)</td>
<td>0.36 ± 0.10±</td>
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</tr>
<tr>
<td>MVEFS (mm/sec)</td>
<td>54.4 ± 13.4</td>
<td>--</td>
<td>87.2 ± 25.9</td>
<td>--</td>
<td>83.78 ± 23.81</td>
<td>--</td>
</tr>
<tr>
<td>FS (%)</td>
<td>55.0 ± 10.2</td>
<td>41.0 ± 7.3</td>
<td>49.8 ± 5.3</td>
<td>29 - 35</td>
<td>42.7 ± 8.1</td>
<td>34.5 ± 12.6</td>
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<tr>
<td>LVWT (%)</td>
<td>39.5 ± 7.6</td>
<td>--</td>
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</tr>
<tr>
<td>IVST (%)</td>
<td>33.5 ± 8.2</td>
<td>--</td>
<td>--</td>
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<td>--</td>
</tr>
<tr>
<td>HR (beats/min)</td>
<td>182 ± 22</td>
<td>167 ± 29</td>
<td>194 ± 23</td>
<td>--</td>
<td>255 ± 36</td>
<td>--</td>
</tr>
</tbody>
</table>

* LVEDD = left ventricular end-diastolic dimension; LVESD = left ventricular end-systolic dimension; Ao = aorta; LA = left atrium; LA/Ao = left atrium to aorta ratio; IVSED = Interventricular septum end-diastolic; IVSES = Interventricular septum end-systolic; LVWED = left ventricular wall end-diastolic; LVWES = left ventricular wall end-systolic; RVED = right ventricular end-diastolic dimension; LVID = left ventricular wall amplitude; EPSS = E-point to septal separation; AA = aortic amplitude; MVEFS = mitral valve E-F slope; FS = left ventricular fractional shortening; LVWT = left ventricular wall thickening; IVST = interventricular septum thickening; HR = heart rate.

** N/A = not available
† Cats anaesthetised with ketamine
‡ Mean ± SD.
§ Normal range.
ECHOCARDIOGRAPHIC MEASUREMENTS

Leading edge to leading edge principle

Conventional M-mode measurements should use the leading edge to leading edge technique. The measurement starts at the top (or leading edge) of the line that makes up a cardiac structure.
LV M-mode measurement

Measurements of left ventricular dimensions are traditionally performed on M-mode images obtained in right parasternal short axis view at the level of the papillary muscles, just below the chordate tendineae. The cursor should be positioned in a way that produces a virtual dissection of the ventricle in two equal parts (picture below, left side). The obtained M-mode echocardiogram (picture below, left side) will display the following structures (from top to bottom):

- RV (right ventricular) lumen
- IVS (interventricular septum)
- LV (left ventricular) lumen
- LVFW (left ventricular free wall)
- Pericardium (bright line)

Diastolic measurements should be taken at the point of maximal LV dilation (end-diastole) and at the point of minimal LV lumen (end-systole). If ECG trace is available, diastolic measurements should be taken at the level of the Q wave deflection. Systolic measurements should be taken at the end of the T wave.
LV B-mode measurement

In cats with hypertrophic cardiomyopathy (HCM) the hypertrophied papillary muscles can enter the field of view of the M-mode. This may cause the investigator to underestimate end-systolic diameter and over-estimate myocardial thickness.

In such cases, in particular, and in all cases, in general, measurements of LV dimensions can also be obtained in B-mode (again, right parasternal short axis view at the level of the papillary muscles, just below the chordate tendineae).

The end of diastole is seen when the ventricle is largest and the end of systole is the time when the ventricle is smallest.
**Left atrial and aorta size**

Left atrial and aortic dimension can be obtained in different views. However, one of the most popular systems utilises the right parasternal short-axis view of the heart base.

**Ao**: internal short-axis diameter of the aorta along the commissurae between the non-coronary and right coronary aortic valve cusps on the 1st frame after aortic valve closure.

**LA**: internal short-axis diameter of the left atrium in the same frame in a line extending from and parallel to the commissurae between the non-coronary and left coronary aortic valve cusps to the distant margin of the left atrium.

In images where a pulmonary vein was seen entering the left atrium at this caudo-lateral location, the edge of the left atrium is approximated by extending the visible edges of the left atrium in a curved fashion.
**Doppler measurements**

The following images indicates some conventional cursor alignments for accurate Doppler measurements of blood flows. For further information on echocardiographic Doppler measurements please refer to dedicated textbooks (e.g. June Boon, Veterinary echocardiography, Wiley-Blackwell; 2 edition, 2011)

Right ventricular outflow tract (RVOT) or Pulmonic flow (Systolic flow)

*(From the right parasternal short-axis view of the heart base)*

![Diagram of RVOT and Doppler waveforms](image1)

Left ventricular outflow tract (LVOT) or Aortic flow (Systolic flow)

*(From the left parasternal long-axis, 5-chamber view)*

![Diagram of LVOT and Doppler waveforms](image2)
Mitral Valve Inflow (Diastolic flow)

*(From the left parasternal long-axis, 4 or 5-chamber view)*

Tricuspid Valve Inflow (Diastolic flow)

*(From the left parasternal long-axis, 4 or 5-chamber view)*
SPECIFIC CARDIAC CONDITIONS

Myocardial Diseases

Echocardiography allows a rapid, non-invasive identification of myocardial disease and differentiation between different cardiomyopathies. Image quality and resolution are important for identifying cardiac wall edges, so that septal and ventricular measurements can be accurately made. This is especially important in cats because of their small size. In general, it is easier to measure wall thickness and chamber dimensions using M-mode images; however, the location and level of the M-mode beam is optimally determined using B-Mode echocardiography, especially when the alignment of the cursor is difficult because of hypertrophy of the papillary muscle (e.g. hypertrophic cardiomyopathy - HCM).

Dilated cardiomyopathy (DCM) is characterised by dilation (eccentric hypertrophy) of the left and, typically the right heart chambers. Systolic wall and septal motion is poor, causing the left ventricular dimensions (systolic and diastolic) to be increased, causing reduction of the fractional shortening. Other indices of myocardial function are reduced (e.g. low aortic and pulmonic velocity). Increased mitral valve E point to septal separation and reduced aortic root motion are common, while left ventricular freewall and septal thickness are normal or decreased.

HCM is characterised by increased septal and left ventricular freewall thickness. In cats, a diastolic thickness of these structures greater than 6 mm indicates hypertrophy. Thickened papillary muscles and reduced left ventricular lumen size are also common. In patients with HCM, the fractional shortening is normal to increased and the left atrium is often markedly enlarged. In the obstructive form of HCM (HOCM) septal thickness may be greater than the freewall thickness (asymmetric septal hypertrophy) and systolic narrowing of the left ventricular outflow region from the bulging, hypertrophied septum and SAM may be seen on B-Mode imaging or M-mode imaging. A thrombus is occasionally visualised within the left atrium or auricle in cats with cardiomyopathy.

Restrictive cardiomyopathy (RCM) also occurs in cats. Ventricular and septal myocardial thickness is normal or slightly increased. Left atrial size tends to be greatly increased in cases of restrictive cardiomyopathy than in those affected by HCM, and often RCM is accompanied
by a bi-atrial dilation. If present, endomyocardial fibrosis can enhance the brightness of the endocardial surface.

**Valvular insufficiency**

Mitral or tricuspid valve insufficiency results in progressive dilation of the affected side of the heart. Massive atrial enlargement may develop in patients with chronic valvular regurgitation. Ventricular motion throughout the cardiac cycle is accentuated, especially in mitral insufficiency. The diastolic left (and/or right) ventricular dimension is increased but systolic dimension is normal until the myocardium itself begins to fail. Therefore, prior to myocardial failure, there is exaggerated septal motion, normal E point-septal separation, and increased fractional shortening. Calculation of the end systolic volume index may also be helpful in assessing myocardial function. With severe tricuspid regurgitation, paradoxical septal motion may occur.

The most common form of mitral insufficiency is caused by a myxomatous degeneration (endocardiosis) of the mitral leaflets. Affected valve cusps are thicker than normal and may take on a “golf club” appearance at their edges. Bacterial endocarditis tends to cause rough and irregular vegetative valve lesions. However, it is not easy to distinguish between these valve lesions with ultrasound alone. Rupture of a chorda tendineae causes part of the valve leaflet to have a flailed or paradoxical motion, parachuting into the left atrium in systole. Sometimes the broken chordae itself can be seen.

Aortic valve insufficiency, whether resulting from infectious endocarditis or congenital malformation, also leads to left ventricular and possibly, left atrial dilation. Evidence of a vegetative lesion or rapid diastolic fluttering (as blood flows back into the ventricle in diastole) may be seen while imaging the aortic valve. A flailed aortic leaflet will prolapse into the ventricular outflow tract during diastole. Also, the regurgitant jet of blood during diastole may cause the open anterior mitral leaflet to flutter.

**Pericardial diseases**

Pericardial effusion can be readily detected using echocardiography. Since fluid is hypo-echogenic, pericardial effusion appears as an echo-free space between the bright parietal pericardium and the epicardium. Pericardial effusion must be differentiated from pleural
effusion on echocardiography. Evidence of collapsed lung lobes or pleural folds may appear in patients with pleural effusion. Very large amounts of pericardial fluid allow the heart to swing wildly within the pericardial sac. In addition, pericardial effusion of sufficient volume (pressure) to cause cardiac tamponade results in diastolic compression or collapse of the cardiac chambers, especially the right atrium and ventricle. A soft tissue density mass may be identified in cases of neoplastic pericardial effusion. The usual locations are the right auricle (haemangiosarcoma) and around the ascending aorta (chemodectoma). Tumours of the pericardium itself or the myocardium may also be a cause of pericardial effusion. Sometimes, intracardiac masses occur and are not associated with pericardial effusion.

_Ventricular outflow obstruction_

Both aortic and pulmonic stenosis cause pressure overload on the affected ventricle (left and right respectively). The response of the myocardium to this stress is muscular hypertrophy. With pulmonic stenosis the right ventricular wall is thicker than normal and may exceed the left ventricular wall thickness in severe cases. RV papillary muscles are also prominent. High pressures in the right ventricle tend to push the interventricular septum to left, causing the left ventricular lumen to appear oval rather than round on short axis view. Dilation of the right ventricle and atrium, and thickening of the right atrial wall may also be seen. Narrowing at the level of the pulmonic valve with evidence of thickening or asymmetry of the valve leaflets, and dilation of the main pulmonary trunk are also common finding. The pulmonic valve may appear to "dome" toward the pulmonary artery in systole with valvular stenosis. Valvular stenosis the aortic valve is rare in dogs and cats; instead, a subvalvular fibrous ring causing outflow obstruction is more common (sub-aortic stenosis or SAS). In mild sub-aortic stenosis, there may be no definitive changes on the echocardiogram. With moderate to severe disease, a ridge of tissue below the aortic valve may be evident. Premature closure of the aortic valve and systolic anterior motion of the anterior mitral leaflet are sometimes seen with severe disease. The left ventricular wall is thicker than normal and dilation of the ascending aorta (wider than the area of the sinuses of Valsalva) may be visualised. Left atrial enlargement and hypertrophy may also be seen. Doppler echocardiography is helpful for quantitative as well as qualitative assessment of ventricular outflow obstructions.

_Cardiac shunts_
Communications between the left and right sides of the circulation cause volume overload, with subsequent dilation of the affected cardiac chambers. Intracardiac shunts include ventricular and atrial septal defects; the most common extracardiac shunt is patent ductus arteriosus (PDA).

Ventricular septal defects (VSD) occur high, in the membranous portion of the septum. Larger defects may be visualised in a plane optimised for viewing the left ventricular outflow tract. The defect is usually located just below the aortic valve, with the septal tricuspid leaflet to the right of the defect. Sometimes echo "drop-out" occurs at the thin membranous septum mimicking a ventricular septal defect. Suspected defects should be examined in more than one echo plane. Unless the ventricular septal defect is quite large, causing both ventricles to act as a common chamber, the usual pathophysiology is that of a volume overload to the left heart. Consequently, dilation of the left ventricle and atrium occurs with significant shunts.

Atrial septal defects (ASD) usually cause volume overload of the right atrium and ventricle; because left heart pressures are normally higher, blood moves across the shunt from left to right atrium. The thinner region of the fossa ovalis in the atrial septum can be confused with a septal defect, since echo drop out can also occur here. Doppler (and colour-Doppler) echocardiography often allows identification of smaller intracardiac shunts that cannot be visualised with B-Mode imaging.

Patent ductus arteriosus (PDA) creates a volume overload on the left heart, with left atrial and ventricular dilation. Fractional shortening may be normal to decreased, and E point-septal separation is often increased. The actual shunt is difficult to visualise, as it is located between the descending aorta and the pulmonary artery. In some animals, the ductus can be seen using the cranial left parasternal position. Doppler imaging allows identification of this defect, with its turbulent blood flow pattern in the pulmonary artery throughout systole and diastole.

*Atrioventricular valve dysplasia*

Malformation and insufficiency of the mitral or tricuspid valve results in dilation of the associated cardiac chambers, just as it does with acquired valve insufficiency. Often, chamber dilation is marked. Abnormally formed papillary muscles and/or chordae tendineae as well as incomplete closure of the valve may be visualised on B-Mode imaging.
Complex malformations

Tetralogy of Fallot is characterised by a large ventricular septal defect and some degree of pulmonic stenosis with a dextro-positioned aortic root overriding the ventricular septum. Secondary to these malformations, right ventricular hypertrophy and right to left shunting of blood across the ventricular septal defect occur. The septal defect, right ventricular hypertrophy, and overriding aorta can usually be appreciated on a B-Mode echocardiogram. Use of an echo contrast study should demonstrate blood flow from the right ventricle into the aorta. Other complex and unusual defects may also be identified using ultrasound.

Dirofilariasis (Heartworm disease or HWD)

Many cases of HWD evidence no echocardiographic abnormalities; therefore, echocardiography is not a sensitive tool for diagnosing this disease in dogs. However, severe heartworm disease will cause right ventricular enlargement and hypertrophy, with dilation of the main pulmonary artery. The interventricular septum tends to become "flattened" toward the left ventricle because of the high right ventricular pressures required to eject blood in the face of pulmonary hypertension. Paradoxical septal motion may be observed on M-mode. Worms rarely identifiable in the main pulmonary artery appear as bright dots and closely parallel lines on B-Mode images. With “caval syndrome”, masses of worms can be imaged in the right atrium and ventricle as well as the caudal cava. The intracardiac worm mass tends to move into the ventricle in diastole and back to the atrium in systole. Left heart size is diminished from impaired filling.
COMMON ECHOCARDIOGRAPHIC MISINTERPRETATIONS

There are various mistakes that can derive from an inappropriate understanding of echocardiographic principles. It is not the intention of this course to address the use and misuse of echocardiography in small animal practice. However, I have listed below some of the common echocardiographic misinterpretations that may affect the clinical assessment and clinical management of a cardiac patients.

Fractional shortening
Left ventricular fractional shortening (FS) is dependent on left ventricular preload and afterload, as well as contractility. Contractility may therefore not be accurately described by FS. Furthermore FS is calculated on a mono-dimensional system (M-mode) which interrogates only a specific point of the myocardium. Therefore, FS does not provide a global assessment of myocardial contractility. Measurements of loading conditions and load-independent indexes, which more directly reflect contractility, allow a more accurate determination of myocardial status and may lead to better clinical management.

Colour mapping setting
The Nyquist frequency is the maximum frequency that can be sampled without aliasing. If the scale is set too low (ie < 1.0 m/s), together with a low filter, there is a high chance to obtain aliasing even with normal blood flows and interpret such flows as turbulent. For example, the severity of a mitral regurgitation assessed purely on colour mapping also depends on these settings.

Athletic heart
Repeated exercise, in particular endurance type, induces structural changes in the heart. This is primarily determined by an increased venous return (haemodynamic loading) caused by the respiratory and abdominal bellows, as well as the pumping function of the contracting muscle. On echocardiography, the athletic heart presents features similar to those observed in dilated cardiomyopathy (increased end diastolic and end systolic diameters and reduced FS). However, left atrial size remains within normal and the clinical features are not
consistent with a myocardial disease (lack of exercise intolerance, normal blood pressure, respiratory sinus arrhythmia, etc).

_Echocardiography cannot replace thoracic radiographs_

Echocardiography is never a substitute for thoracic radiographs and or bronchoscopy/airway cytology/culture. Thoracic radiography should always be the first clinician’s choice to confirm the presence of congestive heart failure.

_Relative stenosis_

An increased velocity in the outflow tract is not sufficient to make a diagnosis of valvular stenosis. For example, a large ASD can cause haemodynamic load of the right side with increased velocity of the pulmonary flow. Similarly, in the presence of left-to-right shunting PDA, the left cardiac chambers are overloaded, which often results in increased aortic velocity.

_Arrhythmias_

Supraventricular and ventricular arrhythmias can be accompanied by significant haemodynamic disturbances that can change the cardiac structure and affect the overall myocardial performance. It is important that such electrical abnormalities are correctly recognised during the examination in order to provide a correct interpretation of the echocardiographic findings.
Underestimation of pressure gradients

Doppler measurements are subject to errors depending on the alignment of the cursor in relation to the blood flow. An angle higher than 20° is not acceptable for accurate measurements since it underestimates significantly the speed of the blood cells according to the Doppler shift equation:

\[
\text{measured velocity} = \text{real velocity} \times \cos(\theta) \quad \text{[where } \theta \text{ is the angle between blood flow direction and cursor]} 
\]
Novel echocardiographic techniques

Echocardiography is a diagnostic discipline in continuous expansion and new technologies are becoming available to improve the diagnostic and prognostic value of this exam. I have listed some novel echocardiographic methods that are becoming widely available in veterinary practice.

Contrast echocardiography
Agitated saline solution administered via intravenous injection provides air microbubble contrast in the right heart. The air microbubbles are short-lived and diffuse into the lungs when traversing the pulmonary circulation. Therefore the microbubbles enter the left heart only in the presence of a right to left intracardiac or extracardiac (pulmonary arteriovenous) shunt. Saline microbubbles are therefore helpful in examining the right heart and identifying shunts. Transpulmonary passage of contrast agents allow left heart evaluation, an ideal contrast microbubble must be small and durable enough to traverse the pulmonary circulation to pass into the left heart from an intravenous injection. Improvements in contrast agents have resulted from the exploitation of knowledge concerning both the mechanisms of echogenicity and the impediments to transpulmonary passage. Intravenously administered micro-bubbles to traverse the myocardial microcirculation can be used to outline the myocardial structure, motion and perfusion, as well as to assess the velocity of the pulmonary circulation.

Pulsed Tissue Doppler
Tissue Doppler is an ultrasound tool representing a useful completion of standard Doppler echocardiographic examination. The placement of pulsed tissue Doppler sample volume at the level of the different sites of the mitral annulus allows to obtain information on left ventricular global longitudinal (systolic and diastolic) function, whereas the sampling of tricuspid lateral annulus gives similar information on the right ventricular chamber. Myocardial early diastolic velocity (Em) is a marker of ventricular diastolic relaxation and the ratio obtainable between transmitial (or transtricuspid) E velocity and annular Em (E/Em ratio) is an accurate index of the level of filling pressure of the assessed ventricular chamber. Myocardial systolic velocity (Sm) as well as the frequency of acceleration of presystolic velocity, occurring during isovolumic contraction time, are indexes of systolic performance and their reduction is evident in several cardiac pathologies.

Strain and strain rate
Strain and strain rate (SR) are measures of deformation that are basic descriptors of both the nature and the function of cardiac tissue. These properties can be measured using either Doppler or B-Mode
ultrasound techniques. Speckle tracking is becoming the most popular technique for strain
assessment. It is based on the interference of the reflected ultrasound giving rise to an irregular
speckled pattern. The random distribution of the speckles ensures that each region of the
myocardium has a unique pattern (fingerprint) The speckles follow the motion of the myocardium so
when the myocardium moves from one frame to the next, the position of this fingerprint will shift
slightly, remaining fairly constant. Thus, if a region (kernel) is defined in one frame, a search
algorithm will be able to recognise the lie sized and -shaped area with the most similar speckle
pattern in the next frame, within a defined search area and find the new position of the kernel.
Although these measurements are feasible in routine clinical echocardiography, their acquisition and
analysis nonetheless presents a number of technical challenges and complexities. Although the
evidence base is limited, SR imaging seems to be feasible and effective for the assessment of
myocardial function.

Brief notes on echocardiography report

The echocardiography report should contain all of the following information:

1. All Patient’s details
2. Owner’s details
3. Examination date
4. Examination ID
5. Operator name or ID
6. B-mode measurements of the major anatomical structures
7. M-mode measurements of the left ventricle and mitral valve (left atrium M-mode is less
commonly performed)
8. Doppler measurements of the major blood inflows and outflows
9. Measurements of all abnormalities detected (i.e. masses, intracardiac communications,
shunts, etc)
10. Relevant pictures
11. Comments on cardiac anatomy (cardiac structure)
12. Comments on cardiac physiology (cardiac function)
13. Comments on ECG recording
14. Comments on abnormal findings with clinical recommendations
An example of echocardiographic report is shown on the next page.
HEALTH & SAFETY and principles of ERGONOMICS

Very rarely, health issues related to prolonged use of ultrasound machine in veterinary practice are mentioned at practical courses. However, health issues related to the use of this technology are as important as those reported for prolonged use of computer desktops or laptops. The following notes are adapted from the Health & Safety guidelines for computer users published by the Open University (https://msds.open.ac.uk/your-record/health.htm).

Advice on using your ultrasound machine

The use of visual display units (VDU) and other display screen equipment (DSE) has been related to various symptoms to do with sight and working posture. These symptoms are often perceived as fatigue of some kind. Applying simple ergonomic principles to the layout of your work area and how you study can readily prevent them.

Try to position the monitor to minimize glare and reflections on the screen. Suitable lighting is important: remember that glare can occur either directly or by reflection from the screen. Glare from windows can usually be eliminated by curtains or blinds, or by facing the screen in a different direction. It might be a good idea to make adjustments from time to time during the day, as light changes. You should have general lighting, by artificial or natural light or both, that illuminates the whole room adequately.

Eyes and eyesight

There is no evidence that working with DSE is harmful to the eyes, nor that it makes visual problems worse, although a few people who have difficulties with their sight may become more aware of them. But working at a screen for a long time without a break can have effects similar to reading or writing uninterruptedly, and may make your eyes feel 'tired' or sore. You might find that it helps to look away from the screen from time to time and focus your eyes on a distant object.

Making yourself comfortable

As for any task that means working in one position for some time, it's important to make yourself as comfortable as possible when you use your ultrasound machine. Place the monitor in front of you and at a comfortable viewing distance. Keep your body straight, facing the screen, with your shoulders relaxed and your right arm reaching the patient and the left hand on the ultrasound keyboard. The right forearm should rest on the table and the ultrasound transducer should be held...
gently with the fingertips. If you are concerned about the probe dropping to the floor, try to position the probe cable around your neck or use a soft tie connected to the probe and secured around your wrist. If the ultrasound machine is positioned on a wheel-cart, release the breaks and adjust the cart according to your body position. Try to sit on a stool with adjustable height in order to be in the most comfortable position. Try also to position the top of the monitor display slightly below eye level when you are working. Before starting work you should:

Adjust the positions of the screen and cart to achieve the most comfortable arrangement. Make sure that you have space to move your arm and reach the bottle of gel; rest your left wrist in front of the keyboard when not typing. Place a clean towel in a reachable position to wipe excess of ultrasound gel from your fingers before touching the keyboard or control buttons.

Adjust the position of your stool to give you a comfortable viewing distance and posture. The screen should probably be somewhere between eighteen and thirty inches away from you, whatever suits you best.

Good keyboard and US-probe holding technique is important. Keep your upper body as relaxed as possible and don't over stretch your wrists and fingers. As a general guide, your forearms should be roughly horizontal and your elbows level with the keyboard or the probe.

Your feet should reach the floor. If your feet don't reach the floor when you're sitting in a good position, try a footrest.

*Take a break!*

Whenever you can, try to arrange your study to consist of a combination of work on and away from the screen, to prevent fatigue and to vary visual and mental demands. Long spells of intensive screen work should be broken up by periods of non-intensive work of a different kind.

The nature of your study and the combination of media you're using will determine the length of break you need to prevent fatigue, but as a general rule:

You should take breaks before the onset of fatigue, not in order to recuperate. The timing of the break is more important than its length.

Short, frequent breaks are more satisfactory than occasional, longer breaks. A break of thirty seconds to two minutes after twenty or thirty minutes of continuous work with the screen and keyboard is likely to be more effective than a fifteen-minute break every two hours.
If possible, you should take your breaks away from the screen, and avoid activities that require actions similar to your work (for example working at your computer).

**YES!** Upright position, facing the screen at eye level

**NO!** Neck flexion and extension.

**NO!** Twisting of the neck

**Tension headaches**

A tension headache is a condition involving pain or discomfort in the head, scalp, or neck, usually associated with muscle tightness in these areas.

Tension headaches occur when neck and scalp muscles become tense, or contract. The muscle contractions can be a response to stress, depression, a head injury, or anxiety.

Any activity that causes the head to be held in one position for a long time without moving can cause a headache. Sleeping in a cold room or sleeping with the neck in an abnormal position may also trigger a tension headache.

Recognise the signs of fatigue!
Headaches may result from several things that occur with VDU work, such as:

- screen glare;
- poor image quality;
- a need for different spectacles;
- stress from the pace of work;
- anxiety about new technology;
- reading the screen for long periods without a break;
- poor posture; or
- a combination of these

**Solutions**

- Exercise Regularly
- Manage Stress
- Live a Healthy Lifestyle
- Follow regular eating and sleeping schedules.
- Avoid excess caffeine and other diet triggers.
- Stay well hydrated.
- Stay physically active.
- Take Rests
- Schedule mini-breaks every 20 to 30 minutes to avoid repetition and static positions.
- Follow Ergonomics Principles (see above)
- Stretch after each ultrasound examination
GET ACTIVE AT WORK

Shoulder Shrugs
- Raise shoulders towards ears
- Hold
- Relax downward to a normal position

Upper Back Stretch
- Interlace fingers behind head with elbows out
- Pull shoulder blades together
- Hold 5 seconds, then relax

Neck Tilts
- Keep shoulders relaxed and arms hanging loosely
- Tilt head sideways, first to one side, then the other
- Hold 5 seconds on each side

Wrist/Forearm Stretch
- Place hands palm to palm
- Move hands downward, keeping palms together and elbows even
- Hold 5-8 seconds

Hand/Finger Stretch
- Separate and straighten fingers
- Hold 10 Seconds
- Bend fingers at knuckle and hold 10 seconds
- Separate and straighten again

Back and Hip Stretch
- Bend left leg over right leg and look over left shoulder
- Place right hand on left thigh and apply pressure
- Repeat for right side

Back Stretch
- Lean forward
- Keep head down and neck relaxed
- Hold 10-20 seconds
- Use hands to push yourself back up

Side Stretch
- Hold left elbow with right hand
- Gently pull your elbow behind your head to feel stretch in shoulder or back of upper arm
- Hold 10 seconds
- Don’t over stretch or hold breath
- Repeat on right side

Upper Body Stretch
- Interlace fingers, turn palms upward and straighten arms above head
- Elongate arms to stretch through upper sides of your rib cage
- Hold 10-15 seconds
- Breathe deeply

Hamstring Stretch
- Sitting, hold onto upper left leg just above and behind the knee
- Gently pull bent knee toward chest
- Hold 15-20 seconds
- Repeat on right leg

Neck Stretch
- Sit or stand with arms hanging loosely
- Gently tilt head forward
- Keep shoulders relaxed and downward
- Hold 5 seconds

THIS IS A GUIDE ONLY!
If you feel: - Pain - Discomfort - Numbness - Tenderness - Tingling - Chumsiness - Loss of Strength & Flexibility
STOP EXERCISING AND CONTACT A HEALTH PROFESSIONAL

From: http://karim-ouda.blogspot.it/2012/04/computer-related-health-problems-and.html
Abbreviations

B-mode Bi-dimensional echocardiography
M-mode Mono-dimensional echocardiography
CFM Colour-flow Doppler
CW Continuous flow Doppler
PW Pulsed wave Doppler
HPRF High pulsed repetition frequency
TTE Trans-thoracic echocardiography
TEE Trans-esophageal (oesophageal) echocardiography
TDI Tissue Doppler imaging
3-D Three-dimensional imaging
Ao Aorta
LA Left atrium
RA Right atrium
LV Left ventricle
RV Right ventricle
LVOT Left ventricular outflow tract
RVOT Right ventricular outflow tract
PV Pulmonic valve
MV Mitral Valve
TV  Tricuspid valve

AV  Aortic valve

PM  Papillary muscles

IVS  Interventricular septum

LVFW  Left ventricular free wall

LVD  Left ventricular diameter

LVDd  Left ventricular end-diastolic dimension

LVDs  Left ventricular end-systolic dimension

FS  Fractional shortening ([LVDd-LVDs] / LVDd x 100)

IVSd  Interventricular septum end-diastolic

IVSs  Interventricular septum end-systolic

LVWd  Left ventricular wall end-diastolic

LVWs  Left ventricular wall end-systolic

EPSS  E-point to septal separation: