Introduction
Blood pressure and ECG monitoring are fundamental cardiac diagnostics and are likely performed daily in your clinics. While all technicians at some point in their training learn the proper techniques for accurately measuring blood pressure and performing electrocardiograms, often times these techniques are forgotten or are not followed closely as they become daily routine. The goal of this lecture is to review the basics and to supply techniques that can help to obtain the most accurate blood pressure and clean, artifact-free ECGs that will allow your clinicians to make accurate treatment decisions for their patients. In addition, the basics and fundamentals of good cardiac auscultation will be reviewed, as it is one of the most important parts of any physical examination.

Blood Pressure Monitoring
Blood pressure in animals can be measured either directly or indirectly. Direct methods involve measuring the pressure via intra-arterial means, most often via an arterial line. Disadvantages of direct measurement are that it is invasive and not practical in most cases. Most often blood pressure is obtained in animals via an indirect method utilizing an oscillometric device (Cardell or Dinamap) or Doppler.

The key to obtaining reliable blood pressure measurements in animals is to follow a standard protocol that is repeated every time blood pressure is assessed. First, measurements should be obtained in a quiet environment in a location that is away from other animals or loud noises. Oftentimes, blood pressure can be obtained in the examination room with the owner present to minimize stress. All patients should be allowed a 5-10 minute acclimation period to allow pets to become adjusted to their new surroundings prior to measurement attempts. It is important to point out that sedation will affect blood pressure measurements and it should be documented if measured in a sedated animal. The second step in blood pressure measurement is assuring proper animal restraint. Animals should be restrained gently and in a comfortable position, this can vary depending upon which artery you are utilizing; however, common restraint positions are left or right lateral recumbency and sternal recumbency. The distance of the base of the heart to the cuff should be no more than 10cm or a correction factor of 0.8mmHg/cm below the heart base should be applied to allow for more accuracy of measurement. When selecting an appropriate cuff, the diameter of the cuff should be approximately 40% of the circumference of the limb or tail in dogs and 30-40% in cats. Cuff size, location of measurement, and animal position should be recorded in the medical record or on special blood pressure forms that can be placed in the medical record. It is also important to record patient’s attitude in the record as to whether they were calm, growling, and/or aggressive as this can affect interpretation if measurements are borderline elevated. The final step in obtaining reliable blood pressure measurements is to take several measurements and average together. At Northwest Veterinary Specialists, the first measurement is typically thrown out, as it tends to be erroneously elevated. A minimum of three pressures should be measured but preferably, depending on patient cooperation, 5-7 measurements are ideal. If consistent measurements are not being obtained (variability of > 20%), additional measurements should be taken at alternate locations.

It is important to be aware of the many factors that can influence blood pressure measurement which include anxiety at the veterinarian (“white-coat hypertension”), age, and dog breed. If anxiety or “white-coat hypertension” is suspected, serial measurements of blood pressure in the hospital environment should be performed prior to initiation of treatment. Several studies have looked at the influence age has on blood pressure and have reported increases of 1.3mmHg and 1.5mmHg/year in dogs and cats, respectively; however, there has been no consistency among these studies and typically this is not taken into consideration. Finally, breed variation in blood pressure has been reported with sighthounds having notably higher pressure by 10-20mmHg. The causes of blood pressure elevation in animals differs among dogs and cats and can occur secondary to underlying systemic illness or can be primary or idiopathic, in that an underlying cause is not determined. In dogs
the causes of secondary hypertension include renal disease, endocrinopathy (Hypothyroidism, Hyperadrenocorticism, and diabetes mellitus), obesity, medications, or adrenal tumor (pheochromocytoma). In cats causes of secondary hypertension are similar as in dogs and most commonly include renal disease, hyperthyroidism, obesity, and adrenal tumor (pheochromocytoma).

While everyone has measured blood pressure many times, it is important to follow a standard protocol to allow for the most accurate blood pressure measurements possible. This will permit your clinicians to make treatment decisions to prevent and lower the risk of future target end organ damage.

**Electrocardiography**
ECG monitoring is important in animals that have abnormal rhythms on auscultation. It is important to know the ins and outs of measuring the ECG, as there are important tips on animal restraint, placement of electrodes, and position of the animal that can help to eliminate artifacts and make it easier for your clinician to interpret. Why is ECG monitoring important? It can help to reliably determine the animals underlying heart rate and heart rhythm. It can also sometimes albeit, more unreliably determine cardiac enlargement patterns, axis shifts, and give indications that there may be fluid accumulation within the thorax or pericardium. ECG leads consist of electrical activity measured between a positive and negative electrode. Electrical activity toward the positive electrode leads to a positive deflection on the surface ECG and similarly, electrical activity toward the negative electrode leads to a negative deflection of the surface ECG. Any movement of electrical activity perpendicular to the positive electrode will result in no baseline deflection on surface ECG. The standard ECG lead systems were created to allow for one to assess the electrical activity of the heart in several dimensions. As you are likely aware the standard leads of measurement are leads I, II, and III which are bipolar leads meaning that they have a positive and negative electrode and leads aVR, aVL, and aVF which are unipolar leads. Depending on your practice, there are also leads called precordial chest leads or V leads (CV5RI, CV6LL, CV6LU, and V10) that can allow for better assessment of chamber enlargement patterns. Often times in veterinary medicine, they are most useful in evaluating P waves when they are not visible or are questionably visible on standard lead assessment. Often times, a single lead, most commonly lead II, is used to assess electrical activity; however, it is important to evaluate more than one lead to most correctly interpret the underlying heart rhythm.

Position and restraint are important features in order to obtain a diagnostic ECG recording. ECGs should be recorded on a non-conductive surface to eliminate electrical interference. In cases in which a metal examination table is used, a towel or padded cover should be used. The standard patient position is right lateral recumbency. The reason for this positioning is that it allows for standardization of the ECG recording. In a normal healthy animal in right lateral recumbency, the recordings from all leads should have a consistent appearance. It is in this position that information can then be obtained about cardiac enlargement patterns and axis deviations. If one is just trying to make a rhythm and heart rate diagnosis, the position of right lateral recumbency is not important. Often times, animals can remain in a standing position as this makes them the most comfortable. ECGs can also be performed in stressed animals when they are sitting or in sternal recumbency. When animals are placed in the standard position of right lateral recumbency, both hands should hold the pelvic and thoracic limbs and the upper and bottom limbs should not touch. The limbs should be maintained in positions perpendicular to the long axis of the body. This is especially important when measuring the electrical axis (which is rarely still assessed in veterinary medicine) as difference in leg position can change the mean electrical axis.

Electrode placement, as is well known, is below the knees in the pelvic limbs and below the elbows on the thoracic limbs. The reason for placement below the joints rather than at the joints is that there is more skin upon which to attach the electrodes and oftentimes it can also reduce motion artifact from shaking. Another trick is to hold the wires in an upright and steady position away from the animal to minimize shaking of the electrode wires. The teeth on the electrode clips can easily be filed with a metal file in an attempt to minimize pinching. There are many little rhymes as to how to remember which electrode is placed on which limb. The most common for the left side is “smoke over fire”: the red (fire) electrode is placed on the left pelvic limb with the black (smoke) electrode placed on the left thoracic limb. For the right limbs, the most common is “snow on grass”: the green
(grass) electrode is placed on the right pelvic limb and the white (snow) electrode is placed on the right thoracic limb. Another helpful way to remember correct placement is that most people read the newspaper in the morning (black and white electrodes are on the right and left thoracic limbs) and Christmas occurs at the end of the year (red and green electrodes are on the right and left pelvic limbs). No matter how you remember, it is important to properly attach electrodes to allow for accurate ECG diagnosis.

Standard recording speeds for ECG are 25mm/sec and 50mm/sec with a sensitivity of 10mm/mV. It is important to make note of the recording speed, sensitivity, and lead assessed on the recording if your ECG machine does not record this information automatically, as it will change the way that your clinicians will measure duration and amplitude of complexes during interpretation.

There are many artifacts that can occur during ECG measurement, some obvious and some maybe not so obvious. In cases where you are trying to determine the presence of P waves (i.e., cases of atrial fibrillation, atrial flutter, atrial standstill), a clean baseline is important. If your ECG recording is not clean, first try to replace the electrode clips in a slightly different location and make sure that they are indeed attached to skin and not to fur, a common problem in our veterinary patients. It is also important to always verify you used a good and adequate amount of conductive medium such as electrode gel, paste, or alcohol. While this appears obvious, in a cardiac arrest situation it is important to remember that gel may be a better medium when attaching ECG leads to the patient, because alcohol can ignite if an electric shock is to be administered in cases of ventricular fibrillation. In animals under anesthesia for surgery in which a Bair Hugger is concurrently used, the most common reason for loss of a clear ECG tracing is drying out of electrodes. If an artifact is still observed after doing the obvious things like replacing leads, checking that they are attached to skin, and making sure they are still damp, make sure that the animal’s legs are pulled apart such that the electrode clips are not touching. Also, depending on your positioning, any touching of the electrodes themselves by your fingertips or hands can also cause significant interference. Cats (who always like to make our lives slightly more interesting) can cause artifact by simple purring, as the vibration is enough to create a little movement in the baseline. It is important to share with your clinician if an animal was purring or growling during the ECG as well as if the animal has any sudden movements or coughs as these artifacts can sometimes look like premature ventricular contractions.

Basics of Auscultation
Auscultation is one of the most important parts of any physical examination. Like most things, auscultation of the heart should be performed in a standardized manner to obtain the most complete information regarding cardiac abnormalities. While it is one of the most basic things that you will do as a veterinary technician, there are several tips that will help you to get the most out of your auscultation.

As a helpful hint, not all stethoscopes are created equal! It is important to know this, as the better stethoscope you have, the better chance you have of hearing abnormalities. In general most stethoscopes are comprised of a bell and diaphragm. The bell of the stethoscope is used when trying to determine low-pitched, more rumbling sounds. The diaphragm is best at determining high-pitched, higher frequency sounds. When listening to animals, it is important to approach auscultation in a systematic way. This first involves palpation of the chest wall in order to feel the precordial thrill. This is typically palpated on the left side of the chest between the 4th and 5th intercostal spaces and corresponds to tensing of the myocardium during systole. It is appreciated in normal animals on the left side due to the increased muscle mass of the left ventricle as compared to the right. Thoracic wall palpation will also better help you to classify murmur grade if a palpable thrill or vibration can be appreciated. Following thoracic palpation, auscultation can begin at the point of the apical thrust, which typically coincides with the left ventricular apex in the region of the mitral valve. The stethoscope should then be moved cranially to the left axillary region, the area of the pulmonary valve, and then slightly caudal and dorsal to allow for auscultation of the aortic valve. In cats and small dogs, as well as some large dogs, it can be difficult when ausculting the area of the heart base to distinguish between the aortic and pulmonary valves. All valve regions should be ausculted using the bell and diaphragm portion of the stethoscope in order to pick-up both low and high frequency sounds.
After this is complete, auscultation of the right side is performed at the level of the apical thrust on the opposite side of the chest. This will allow for auscultation of the tricuspid valve, located at the right apex.

In most animals, cardiac auscultation reveals 2 prominent heart sounds referred to as the "lubb dub". The first heart sound ausculted, also known as S1 or the “lubb”, is the sound associated with the closure of the atrioventricular valves (tricuspid and mitral valves). The S1 occurs at the onset of ventricular contraction in systole and has a high pitch so is often appreciated with the diaphragm. The second heart sound ausculted, also known as S2 or the “dub”, is the sound associated with the closure of the semilunar valves (aortic and pulmonary valves). The S2 occurs at the end of ventricular contraction into early diastole and is often high-pitched and appreciated with the diaphragm of the stethoscope. In some animals, additional heart sounds can be ausculted including an S3 or third heart sound that coincides with rapid filling of the ventricles in early diastole. It is often a lower-pitched sound ausculted best with the bell. S4 or the 4th heart sound corresponds to the remaining ventricular filling in diastole associated with atrial contraction.

In addition to normal or abnormal heart sounds, auscultation will allow you to determine if the animal has a cardiac murmur. Cardiac murmurs refer to turbulent blood flow occurring somewhere within the heart. The most common reasons for murmur auscultation include narrowing at the level of the valves (stenoses) or backwards blood flow (regurgitation) at the level of the valves. Cardiac murmurs are classified by location, timing (systole, diastole, or continuous), and grade (I-VI). The most typical grading scale for heart murmurs is on a scale of I through VI. A grade I murmur is one that is very focal and faint, typically heard best in a very quiet room when the listener is “tuned-in”. A grade II murmur is one that is still quiet and very focal. It often takes several seconds to find and is softer than the normal S1 and S2 heart sounds (“lubb dub”). A grade III murmur is moderately loud and audible immediately after placing your stethoscope on the chest. It can sometimes radiate and be heard at other areas of the chest and is equal intensity to the underlying “lubb dub”. A grade IV is very loud and again audible immediately after placing the stethoscope on the chest. It radiates to the left heart base and often to the right thorax and is louder in intensity than the traditional “lubb dub”. A grade V murmur is the same as a grade IV in terms of characteristics; however, there is a palpable thrill. Often times, the palpable thrill will be appreciated prior to auscultation when the thorax is palpated. Thrills can vary in intensity from a very subtle vibration to something that is easily appreciated. When palpating for thrills, the ball of your hand is often more sensitive than your fingertips. Finally, a grade VI murmur is one that can be appreciated with the stethoscope off the chest wall.

Conclusions
While blood pressure monitoring, cardiac auscultation, and recording electrocardiograms are part of your daily routine, these small tips and techniques to be learned or reviewed will help you obtain the most accurate measurements and recordings.