

Advances of Echocardiography in Equines Practice - A Review

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Abstract

Echocardiography has become routinely procedure used in the diagnosis, management, and follow-up of patients with any suspected or known heart diseases. It is one of the most widely used diagnostic modality in cardiology. It can provide a wealth of helpful information, including the size and shape of the heart, pumping capacity, and the location and extent of any tissue damage of heart. An Echocardiogram on other hand gives physician's estimates of heart function such as a calculation of the cardiac output, ejection fraction, and diastolic function. It also helps to evaluate cardiac defects such as, atrial septal defects, AV valve stenoses, coronary artery defects, occult DCM, coronary artery disease, feline heartworm disease, persistent left cranial vena cava, canine hypertrophic cardiomyopathy and feline diastolic dysfunction may be identified. This Review details principle, uses, technique, types and limitations of Echocardiography in equines.

Keywords: Heart; Horse; Ultrasound; Echo

Introduction

Echocardiography is ultrasonography of heart. Equine echocardiography uses ultrasound technology to display images of a horse's heart. Echocardiography has emerged to become a standard diagnostic procedure in equine cardiology. Development of M-mode echocardiography and introduction of 2D real-time echocardiography allowed evaluation of internal cardiac structure, size and function in horses. Development of Doppler echocardiography leads to the ability to assess blood flow characteristics in the equine heart. Echocardiography is essential for diagnosing cardiac diseases in horses as well as in other species [1]. The aim of this presentation is to give an overview on the general principles of equine echocardiography, indications for an echocardiographic examination, its clinical relevance, and current limitations of equine echocardiography [2]. Echocardiography provides a substantial amount of structural and functional information about the heart. Still frames provide anatomical detail. Dynamic images tell us about physiological function. The quality of an echo is highly operator dependent and proportional to experience and skill, therefore the value of information derived depends heavily upon who has performed it. Moreover, any deviation from the normal procedure or protocol, leading to various complications, would attract legal liability both at personal as well as institutional level.

The idea of compiling this article was a typical case of Horse which was presented to our clinics with Unthriftness, Jugular pulsation, faster respirations on work, Sudden falling while pulling Tonga, Crossed legs (Figure 1), dehydrated and loss of condition. The animal was put to ECG at Clinical complex revealing heart ventricular enlargement.

Principles of Equine Echocardiography

Sedation may or may not be required prior to Echocardiography in animals. The horse should not be sedated unless his behavior is uncooperative. Sedation can manipulate dimension and blood flow results, leaving only the structural data to be legitimate. Second, the horse's size, anatomical build of the thorax and the type of echocardiography equipment used can affect image results [3]. Four views of the heart are taken-a long and short view from both the right and left pasternal areas. While structural information is still valid in a sedated horse, some cardiac dimensions (e.g. endsystolic left ventricular diameter, interventricular septal thickness, and free wall thickness) and

indices of cardiac function (e.g. fractional shortening and fractional area change) will be altered [4,5].

Imaging modes used in echocardiography

Real time two-dimensional (2D) or B-mode ("brightness" mode), M-mode (motion mode), color flow Doppler, pulsed-wave (PW) Doppler, and continuous-wave (CW) Doppler are some of the possible modes that are employed for the procedure. M-mode and 2D equine echocardiography allow users to see the heart structure and function [6]. The structures nearest to the transducer are displayed at the top of the screen, the dorsal (in the long axis views) and cranial (in the short-axis views) structures of the heart, respectively, are displayed to



Figure 1: Animal presented to clinics with crossed leg appearance.

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the right side of the screen Doppler ultrasonography works similarly to Doppler weather radar by showing direction, volume, and speed of fluid movement [7].

There are 3 types of echocardiography used clinically: M-mode, two-dimensional (2-D, B-mode or real time) and Doppler echocardiography. The different types of echocardiography are routinely used in each echocardiographic examination and the findings from one type of echocardiographic examination compliments those from the other portions of the examination. Simultaneous electrocardiography should be performed during the echocardiographic examination.

M-mode echocardiography

The M-mode echocardiogram yields a one-dimensional view of the cardiac structures moving over time. The echoes from various tissue interfaces along the axis of the beam are moving during the cardiac cycle and are swept across time, providing the dimension of time. The lines on the recordings correspond to the position of the imaged structures in relation to the transducer and other cardiac structures at any instance in time. More accurate placement of the M-mode cursor within the heart is performed by using the two-dimensional (2-D) real-time image as a guide. The M-mode echocardiogram uses a high sampling rate and can yield cleaner images of cardiac borders, allowing the echocardiographer to obtain more accurate measurements of cardiac dimensions and more critically evaluate cardiac motion [5]. Careful placement of the M-mode beam at the appropriate locations within the heart and obtaining clean echoes of endocardial surfaces are critical to obtain accurate measurements and to make the calculations performed from these measurements, meaningful. Standard M-mode views are obtained from the right parasternal position. The M-mode cursor should be positioned within the heart using the right parasternal short axis view, to avoid inclusion of a papillary muscle within the left ventricular free wall thickness. The standard M-mode views utilized 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.

Two-dimensional echocardiography

Two-dimensional echocardiography allows a plane of tissue (both depth and width) to be imaged in real time. Thus, the anatomic relationships between various structures are easier to appreciate than with M-mode echocardiographic images. An infinite number of imaging planes through the heart are possible; however, standard views are used to evaluate the intra and extra cardiac structures [8]. The standard views are obtained from either the right parasternal window in all species and from the left parasternal window in adult large animals or in other species when imaging the heart from the left side is desirable. Occasionally, images are obtained from subxiphoid (subcostal) or thoracic inlet (suprasternal) positions. These views are usually only feasible to obtain in small animals or young large animals.

The standard views include the right parasternal long axis views of the 4 chambers (4 chamber view), left ventricular outflow tract, and right ventricular outflow tract and the short axis views perpendicular to this plane (left ventricle at the chordal level, mitral valve, and aorta/ left atrial appendage). In large animals left parasternal long axis views of the mitral valve, aorta and pulmonary artery are also obtained when indicated.

Doppler echocardiography

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. Estimations of blood flow and cardiac output can also be made. Doppler echocardiography is based on detection of frequency changes (the Doppler shift) occurring as ultrasound waves reflect off individual blood cells moving either away from or toward the transducer [9]. Calculation of blood flow velocity is possible when the flow is 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.

Doppler echocardiography uses color to map the blood flow in the heart. Doppler echo is used to determine whether the blood flow is too fast in certain areas, such as with subaortic stenosis or pulmonic stenosis (congenital heart defects that cause narrowing of the openings that blood flows through) [7,10]. Doppler echo can determine the severity of the defect by measuring the velocity of blood flowing through these narrowed areas. Doppler echo also can detect holes in the wall of the heart, such as occur with ventricular and atrial septal defects. Doppler echo can also detect leakage of the heart valves [11]. Three-dimensional (3D) echocardiography is available on some echo machines. It gives an accurate image of the heart but currently is used mainly for teaching purposes.

Two types of Doppler echocardiography are used clinically: pulsed wave and continuous wave. Pulsed wave (PW) Doppler uses short bursts of ultrasound transmitted to a point (designated the "sample volume") distant from the transducer [8]. 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 calculated. The main disadvantage is that the maximum velocity that can be measured is limited because the pulse repetition frequency is limited. 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 with CW so high velocity flows can be measured. 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 [9].

Color flow Doppler echocardiography is a form of PW Doppler ultrasonography which combines the M-mode and 2-D modalities with blood flow imaging. With color flow Doppler, multiple sample volumes are analyzed along multiple scan lines. The mean frequency shift obtained from these many sample volumes is color-coded for direction and velocity. Several types of mapping are usually available. Most systems code blood flow toward the transducer as red and flow away as 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 utilize variations in brightness and color [12].

Contrast echocardiography

Contrast echocardiography, or Contrast-enhanced ultrasound is the addition of ultrasound contrast medium, or imaging agent, to traditional ultrasonography. The ultrasound contrast is made up of tiny microbubbles filled with a gas core and protein shell. This allows the microbubbles to circulate through the cardiovascular system and return the ultrasound waves creating a highly reflective image. The most commonly used types of ultrasound contrast are known as Definity®, Optison®. Both have been approved by the FDA. There are

multiple applications in which contrast-enhanced ultrasound can be useful. The most commonly used application is in the enhancement of LV endocardial borders for assessment of global and regional systolic function. Contrast may also be used to enhance visualization of wall thickening during stress echocardiography, for the assessment of LV thrombus, or for the assessment of other masses in the heart. Contrast echocardiography has also been used to assess blood perfusion throughout myocardium in the case of coronary artery disease.

Indications and clinical use of echocardiography in horses

Echocardiography is performed when heart disease is suspected or chest radiographs (x-rays) show that the heart is enlarged [13,14]. The echocardiogram (echo) shows the size of the heart chambers and how well the left side of the heart is functioning. It shows whether the heart valves are normal or thickened.

An echo can detect the presence of extra fluid in the pericardial sac around the heart and sometimes the presence of tumors in the heart that are causing the extra fluid. Although heart murmurs may indicate valvular disease or congenital malformations, they are also found in a large number of clinically normal horses and foals. Horses can suffer from congenital cardiac malformations, valvular disease, myocardial disease, other acquired cardiac defects, and cardiac arrhythmias. Heart murmurs are frequently detected on cardiac auscultation in horses.

Differentiation of physiologic (functional) from pathologic heart murmurs can be difficult or impossible based on physical examination and auscultation alone. Cardiac arrhythmias occur frequently in horses, either as primary disorders of impulse generation and conduction, or secondary to underlying structural cardiac disease. Detection of any underlying cardiac disease may have important implications on prognosis and treatment of arrhythmias. Occasionally, cardiac disease can lead to very unspecific clinical signs such as poor performance or fever.

Echocardiography can be used to identify a cardiac disease, make the correct anatomical diagnosis, assess hemodynamic consequences, provide important prognostic data, monitor progression of the disease, and identify complications of a known diagnosis [15]. Evaluation of heart murmurs, assessment of clinical significance of pathologic murmurs, dysrhythmias, detection of underlying cardiac disease, suspected congenital defects, evaluation of heart murmurs, unexplained cyanosis, or signs of heart failure in neonates [16,17], exercise intolerance / poor performance, detection of cardiac disease, muffled heart sounds, detection of pericardial effusion, fever of unknown origin, detection of endocarditis, unexplained collapse / episodic weakness, detection of cardiac disease, clinical signs of congestive heart failure, cause of heart failure, assessment of severity, monitoring of progression and response to treatment severe respiratory disease. Detection of pulmonary hypertension, detection of patent foramen ovale in foals with respiratory disease form the indications of echocardiography.

The Two-dimensional examination reveals enlargement of the left ventricle and left atrium. It is still uncertain as to how frequently the ductus arteriosus itself can be visualized. The M-mode Echocardiographic study does not increase our understanding of this disorder. On the M-mode examination the measured thickness of the interventricular septum is increased as well as that of the right ventricular free wall. The motion of the interventricular septum is noted to be abnormal demonstrating a flat motion in systole [18].

The Doppler Echocardiographic study reveals the presence of turbulence in the main pulmonary artery which occurs in both systole

and diastole. This picture of turbulence in the main pulmonary artery is similar to that seen with pulmonic stenosis, however with pulmonic stenosis this pattern of turbulence is noted only in systole. Furthermore, the Doppler Echocardiographic examination is ideal to identify the co-existence of other congenital cardiac disorders [18]. The Doppler Echocardiographic study yields data which usually definitively establishes the diagnosis of aortic stenosis and provides evidence of the severity of the disorder. Doppler Echocardiography determines the velocity of blood flow as it exits the left ventricle. The normal maximal velocity of blood flow exiting the left ventricle is approximately 1.5 meters per second. Thus velocities detected in excess of 1.5 m/s suggest stenosis of the column of blood flow (especially velocities in excess of 2.0 m/s) [19].

Echocardiography is of outstanding value to confirm a presumptive diagnosis of aortic stenosis or subaortic stenosis. In this disorder, short of cardiac catheterization, there is no other method available to confirm the existence of aortic stenosis [19]. Although routine Two-dimensional Echocardiography may give us clues to the existence of aortic stenosis, in many cases this test is inconclusive. In severe cases of aortic stenosis, the Two-dimensional exam may reveal left ventricular concentric hypertrophy and a discrete subvalvular lesion, in the case of subaortic stenosis. The M-mode Echocardiographic examination may reveal a clue to the presence of co-existent aortic valve insufficiency (diastolic fluttering of the anterior leaflet of the mitral valve) premature closure of one cusp of the aortic valve. As well this modality should indicate evidence of left ventricular concentric hypertrophy [12].

Preparation of Animal

Little preparation is needed for an echo examination. A few animals need to be tranquilized, but most do not. Aggressive cats that cannot be handled easily when awake may require general anaesthesia or sedation to perform this procedure. It is best not to feed your animal on the morning of the procedure, just in case sedatives are needed. In order to get the best possible contact between the echo transducer and the skin, the hair is usually shaved on both sides of the chest [20]. Animals with thin hair coats may not be clipped, but if the hair is not clipped, the quality of the echo image may not be sufficient to make a diagnosis. Most animals are required to lie on their sides for this procedure. More experienced ultrasonographers may perform the examination with the animal standing or sitting up. The procedure is done in a quiet room, with a minimal amount of stress to the animal [21].

Description of Technique

Echocardiography is a type of ultrasound examination. All types of ultrasounds bounce sound waves off an object and record the returning sound waves [22]. Special probes are placed on the animal's chest. These probes send and receive the sound waves or echoes [23]. The echo machine converts these sound waves into images of the heart. It takes special training and months of experience to become proficient in performing echocardiograms (Figure 2). Several types of echocardiography exist and may be performed in sequence. Two-dimensional (2D) echocardiography shows the heart as it is moving, as well as the inner chambers and outer walls of the heart. Echo in 2D allows gross (major) abnormalities to be detected and identifies areas of the heart to be examined more closely [3]. Tumors, extra fluid in the pericardial sac, and clots in the heart can be found with this technique. Abnormal heart rhythms (arrhythmia) can be identified, and most echo have built-in electrocardiographic capability, so the arrhythmia can be examined or recorded during the echo procedure [24].



Figure 2: Preparing a horse for echocardiography.

Once the heart has been examined with 2D echo, an area is selected for examination with M-mode echo. This form of echocardiography is used to measure the chambers of the heart and to determine how well the left heart is functioning. Because M mode freezes the motion of the heart, it makes measuring the different areas easier. M-mode measurements must be done properly, because in accurate measurements can underestimate or overestimate problems.

Stress Echocardiography

A stress echocardiogram, also known as a stress echo or SE, utilizes ultrasound imaging of the heart to assess the wall motion in response to physical stress. First, images of the heart are taken “at rest” to acquire a baseline of the patient’s wall motion at a resting heart rate. The patient then walks on a treadmill or utilizes another exercise modality to increase the heart rate to their target heart rate. Finally, images of the heart are taken “at stress” to assess wall motion at the peak heart rate. A stress echo assesses wall motion of the heart; it does not, however, image the coronary arteries directly. Ischemia of one or more coronary arteries could cause a wall motion abnormality which could indicate coronary artery disease (CAD) [17]. The gold standard test to directly image the coronary arteries and directly access for stenosis or occlusion is a cardiac catheterization. A stress echo is a non-invasive test and is performed in the presence of a licensed medical professional, such as a cardiologist, and a cardiac sonographer.

Limitations and Potential Complications

Echocardiography is a well-established diagnostic method in equine medicine, and allows for diagnosis of heart disease, assessment of cardiac function, and better understanding of the normal physiology of the heart. Animal size, anatomical characteristics of the equine thorax, and technical features of (human) echocardiography equipment sometimes limit the ability to image the equine heart [25]. While this is usually less problematic for standard 2D imaging, determination of blood flow velocities using Doppler imaging techniques is often difficult, due to the inability to achieve adequate alignment with blood flow [21]. Alignment for Doppler echocardiographic studies of left ventricular inflow and outflow can be improved by using transesophageal echocardiography [26]. Although this technique has been described in horses, it is not routinely used in a clinical setting. As echocardiographic technology advances, it may be possible that this technique will be applied for the evaluation of cardiac function in resting and exercising horses [7]. Echocardiography is a very safe

procedure with no long-term or short-term side effects. The only potential complications are those that may arise post administration of tranquilizers, sedatives, or general anesthesia. Side effects of these drugs are uncommon. Any carelessness in any of these procedures would give rise to various kinds of legal liabilities [27]. Such liability creates both personal as well as institutional liability. In such cases, both the doctor as well as the institution (hospital) is held liable. This is a matter of grave concern particularly in relation to equines because they are a source of income to a large number of families in Jammu and Kashmir. Such negligence in post procedure treatment may also amount to cruelty of animals and would attract criminal prosecution as well.

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