Small Ruminant Research 152 (2017) 119–127

Contents lists available at ScienceDirect

Small Ruminant Research

journal homepage: www.elsevier.com/locate/smallrumres

Ultrasonographic examination of the heart in sheep

E.I. Vloumidi[a,*], G.C. Fthenakis[b]

[a] MRC London Institute of Medical Sciences, Imperial College London, Du Cane Road, W12 0NN, London, United Kingdom
[b] Veterinary Faculty, University of Thessaly, 43100 Karditsa, Greece

ARTICLE INFO

Article history:
Available online 19 December 2016

Keywords:
Blood flow
Calcinosis
Cardiomyopathy
Doppler
Echocardiography
Endocarditis
Heart
Myocarditis
Pericarditis
Reference values
Sheep
Ultrasonography
Valve

ABSTRACT

In sheep, echocardiography (ultrasonographic examination of the heart) includes two-dimensional examination, with which right or left parasternal images are taken, employed to image the various anatomical structures of the heart, M-mode examination, employed to image one-dimensional views of the heart visualised over time, and conventional Doppler examination, employed to record normal blood flow velocities through the cardiac valves and great vessels and to detect abnormalities of blood flow through these structures and through the interatrial or interventricular septum. Several studies have proposed reference values for the various echocardiographic parametres in healthy sheep; however, differences occur between authors, which may arise from lack of consistency regarding animal age, sex, weight, status of consciousness, breed, as well as technique employed. There is limited scope in clinical use of the methodology, due to the small incidence risk and clinical significance of cardiac disorders in sheep; there are a few case reports of specific heart diseases in sheep investigated by means of echocardiography; these include congenital heart defects, calcinosis, myocardial disease (myocarditis and cardiomyopathy), endocarditis, pericarditis and cardiac tumour. The main application of echocardiography in sheep refers to using the animals as models in human cardiovascular research, where it can be applied in models for development of functional indices, for evaluating systolic and diastolic left ventricular performance, for studying valvular disorders and for investigating effects of intracoronary microembolisation; results of echocardiography applied in sheep have indicated that the model is suitable for extrapolating results in humans.

1. Introduction

Ultrasonographic examination of the heart ('echocardiography') is a widely-applied technique, which is of particular usefulness in the diagnosis of heart diseases. By using two-dimensional (2D) echocardiography, M-mode echocardiography or conventional Doppler echocardiography, a variety of heart diseases can be accurately diagnosed, e.g., pericardial effusions, vascular stenosis, tumours, intracardiac blood clots, valvular disorders. In most cases, the technique is performed transthoracically; the transducer is placed on the chest of the animal under examination, often as part of an ultrasonographic examination of the lungs (Scott, 2017). In recent years, three- or four-dimensional echocardiographic examination has also been developed, whilst findings of the technique can be improved by using contrast media.

There is some work referring to echocardiographic examination of sheep. In most cases, the relevant publications refer to use of sheep as animal models in cardiovascular research in humans. Nevertheless, there are also references related to the study of heart diseases of sheep. Objective of this review is to present the echocardiographic examination in sheep and to discuss its applications within the frame of sheep health management.

2. Methodology of ultrasonographic examination

2.1. Equipment

Echocardiography in sheep is challenging. The heart occupies a medial position in the chest; it is cranially located and covered by the olecranon and the caudal brachial muscles (Olsson et al., 2001). Further, configuration of the chest in this species, which is keel-shaped with narrow intercostal spaces, makes difficult to position the ultrasound transducer and limits the acoustic window (Olsson et al., 2001; Donadio Abduch et al., 2013). Moreover, presence of gas in the reticulo-rumen interferes with ultrasound beams, making difficult the acquisition of subcostal and apical views (Olsson et al., 2001; Leroux et al., 2012; Donadio Abduch et al., 2013).

* Corresponding author.
E-mail address: eleni.vloumidi@lms.mrc.ac.uk (E.I. Vloumidi).

http://dx.doi.org/10.1016/j.smallrumres.2016.12.019
0921-4488/

Choice of transducer is important, in order to acquire good quality images. A sector transducer is more useful for echocardiography than a linear one (Long, 1995). The ultrasound beam of a sector transducer diverges from a relatively small footprint, which can be easily positioned between the ribs (Long, 1995). Further, linear transducers can produce a limited number of image planes, as they must be placed vertically between the ribs to maintain good contact with the skin (Long, 1995).

Transducer frequency is another factor to be considered, as it affects depth of penetration and resolution of the image (Long, 1995; Boon, 2011). Low-frequency transducers (2.0–3.5 MHz) allow sound waves to travel deeper into the tissues before weakening, which supports their use in animals with a larger surface area (Boon, 2011; Donadio Abduch et al., 2013); this is at the expense of resolution quality (Boon, 2011). In contrast, high-frequency transducers (4.0–8.0 MHz) offer better resolution, but do not penetrate to a sufficient depth and would be more suitable for small or young animals (Long, 1995; Boon, 2011; Donadio Abduch et al., 2013). In general, for sheep in the range of 13.5–23 kg bodyweight, transducers with a frequency of 5.0–7.5 MHz can be used, whilst in heavier animals transducers with frequencies up to 5.0 MHz would be more useful (Boon, 2011). Boon (2011) has suggested that when performing two-dimensional (2D) or M-mode echocardiography, it would be better to start scanning using a higher frequency transducer before changing to one with a smaller frequency, to allow for evaluation of its applicability. This would allow acquisition of images of improved quality for diagnostic purposes. However, in conventional Doppler echocardiography it is advised to change to a smaller frequency transducer, even if all cardiac views can be obtained with only one transducer (Long, 1995; Boon, 2011). Smaller frequency transducers are able to record higher velocities of blood flow and can provide increased signal strength at greater depths (Long, 1995; Boon, 2011).

2.2. Animal preparation and positioning

Before starting the examination, hair on the area on the right and left hemithorax of the animal, from the 3rd to the 5th intercostal space, just behind the elbows, should be clipped, starting 3–5 cm below the olecranon and finishing 5–10 cm above it (Hallowell et al., 2012; Leroux et al., 2012). The skin of the area is then cleaned with water or 70% alcohol solution and coupling gel is applied onto the transducer and the skin.

Sheep can be examined in the standing position or in lateral recumbency, scanned from underneath. When animals are scanned in lateral recumbency for long periods of time, care must be taken to ensure that they would not develop bloat (Long, 1995). When sheep are examined in the standing position, they should be placed into a restraint crate (Moses and Ross, 1987; Boon, 2011). The echocardiographic examination starts from the right side of the animal for all standard long and short axis views and is then completed on the left side. In most cases, in order to acquire good quality standard images, the right front leg of the animal can be pulled forward and slightly abducted. The left front leg should also pulled forward to facilitate echocardiographic examination from the left side (Boon, 2011).

2.3. Two-dimensional (2D) echocardiographic examination

When scanning from the right hemithorax, the transducer should be held with the thumb of the left hand on the reference mark. Conversely, when scanning from the right hemithorax, the transducer should be held with the thumb of the right hand on the reference mark (Long, 1995). The reference mark is used to orientate the image on the screen and defines the plane in which the sound leaves the transducer. Further, a symbol is displayed on the screen of every ultrasound machine, which indicates the direction of the reference mark in the body; in the case of standard echocardiographic examination, it is displayed on the right side of the image (Boon, 2011).

Descriptions herebelow regarding probe orientation during echocardiographic examination in sheep are based on previous descriptions in horses (Bonagura et al., 1985; Reef., 1990; Long et al., 1992; Long, 1995; Boon, 2011) and include adaptations from Hallowell et al. (2012).

2.3.1. Right parasternal images

In order to get the right parasternal long axis view of the left ventricle (LV) (four-chamber view), the transducer is placed on the 4th or 5th right intercostal space. The reference mark of the transducer is at the 12 o'clock position (0° rotation) and the transducer is oriented caudally (the cable can be pulled into the leg of the animal). The right ventricle (RV) and the tricuspid valve (TV) can be seen at the top of the image and the left ventricle (LV) and the mitral valve (MV) at its bottom. In sheep, a portion of the right atrium (RA) may be seen on the top right of the image and a portion of the left atrium (LA) on the bottom right. From this view, by slightly moving the transducer in a more dorsal location with the axial beam angled more dorsally and slightly cranially, a right parasternal long axis apical view is obtained and a larger portion of the right atrium may be visible (Long, 1995).

From the right parasternal long axis view of the left ventricle, if the transducer is held perpendicular to the thoracic wall and rotated clockwise to bring the reference mark at the 1 o' clock position (0–30° rotation), the right parasternal caudal long axis view of the left ventricular outflow tract (LVOT) is obtained. In this view, the right ventricle is at the top of the image and the tricuspid valve, which is at the top right, is visible in 75%–80% of sheep (Hallowell et al., 2012). Below the right ventricle and the tricuspid valve, are the left ventricular outflow tract on the left and the aorta (Ao) on the right of the image. The aortic valve (AV) cusps are clearly seen as curved semilunar lines concave to the aorta. In sheep, this is considered to be the best view to detect abnormalities of tricuspid valve, aortic root and aortic valve.

In sheep, the right parasternal cranial long axis view of the right inflow and outflow tracts is obtained when the transducer is placed on the 4th intercostal space and is held with the reference mark pointed at the 12 o'clock position (0° rotation). The resultant image includes the right ventricular outflow tract (RVOT), the pulmonary valve (PV) and the tricuspid valve.

Further, in order to obtain the short axis views of the mitral and aortic valves, the probe needs to be moved ventrally, down the chest wall and angled dorsally (Hallowell et al., 2012). For all right parasternal short axis views, the transducer is placed on the 4th right intercostal space, 2 cm above the point of the olecranon. The right parasternal caudal short axis view of the left ventricle can be obtained when the transducer is rotated 90° from the 12 o'clock position. The resultant view includes a crescent-shaped right ventricle at the top of the image, a circular-shaped left ventricle below the interventricular septum (IVS) and symmetrically shaped papillary muscles located in the left ventricle. The shape of the left ventricle in this view is described as that of a mushroom (Boon, 2011). From this view, by pointing the transducer towards the base of the heart (i.e., dorso-cranially), the mitral valve comes into view. The leaflets of the mitral valve appear as oval-shaped in the left ventricle chamber, when the valve is open (diastole) and as touching lines when the valve is closed (systole). The right ventricle is seen as crescent-shaped at the top of the image. Pointing the transducer further dorsally a right parasternal short axis view of the aortic valve can be obtained. In sheep, this view also includes the mitral valve, the right ventricle and the tricuspid valve (Hallowell et al., 2012). By pointing the transducer slightly more dorsally and