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Case report

THICK MODERATOR BAND IN THE RIGHT VENTRICLE OF A HORSE: AN ACCIDENTAL FINDING

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Summary

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The purpose of this case report is to describe and document a rare anatomical variation of a moderator band located in right ventricle of a stallion referred for cryptorchid castration. During routine pre-anesthetic echocardiography, a thick moderator band was detected crossing the right ventricle. No other cardiovascular abnormalities were identified. Anesthesia and recovery occurred uneventfully. This variation is important not only for anatomy but also for the evaluation of normal heart both during ultrasound and electrocardiographic examination.

Key words: echocardiography, heart, horse, moderator band, trabecula septomarginalis dextra

The moderator band (MB) or trabecula septomarginalis is a muscular ridge crossing the ventricular cavities without being attached to the cusps, connecting the interventricular septum to the free wall (Cocchieri & Bardelli, 1992). MBs are reported as normal structures in the right ventricle of most mammals, including humans (Kosinski, 2010), horses (Sathyamoorthy & Ramesh, 2008; Bombonato *et al.*, 2015), pigs (Gulyaeva & Roshchevskaya, 2012), dogs (Bombonato *et al.*, 2012), cats (Fox, 1999), dromedary camels (Ghonimi *et al.*, 2014), ostriches (Parto *et al.*, 2010), cows (Nascimento *et al.*, 2019), goats (Leao *et al.*, 2010) and buffaloes (Ghonimi *et al.*, 2015). In particular, MBs are reported to cross the right ventricle of 92% of human patients (Rajiad *et al.*, 2019). Although rarely, they can be found in the left ventricle of humans as well. A study by Gerlis *et al.* (1984) reported the presence of MB crossing the left ventricle in 48% of human patients of all age and in 95% of hearts from animals of six species, including horses, sheeps, cats, dogs, oxen and pigs.

MB was first noticed by Leonardo Da Vinci as the "catena of the right ventricle" (Rajiad *et al.*, 2019). In 1837 King used the term "moderator band" as he thought he might have a role in controlling the

capacity of right ventricle, permitting or preventing dilation (Grant *et al.*, 1961). In 1913 Tandler named it "septomarginal trabecula" (or "trabecula septomarginalis") according to its attachment: the septum (proximal) and the free wall (distal) (Tandler, 1913). Although the term "moderator band" is the most commonly used, the terms trabecula septomarginalis dextra/trabeculae septomarginales sinistrae are in accordance with modern anatomical nomenclature (Nomina Anatomica Veterinaria, 2017). Particular attention has been recently given to this structure because of its role in impulse conduction.

MB in the right ventricle extends from the attachment of the largest papillary muscle in the interventricular septum (IVS) to the parietal part (free wall) of the right ventricle (Bombonato *et al.*, 2015). In humans, it is possible to distinguish this structure already at the 9th week of foetal age (Kosinski *et al.*, 2010). At imaging, it is depicted as the most prominent trabecula in the right ventricle, extending from the septum to the free wall (Rajiad *et al.*, 2019). However, its imaging may be difficult as it was reported that echocardiographic findings compatible with MB can be obtained in only 0.4% of adults and 21.7% of children (Gerlis et al, 1984). In human medicine, CT and MRI are used to image the trabecula better and to distinguish it from other structures (Rajiad *et al.*, 2019).

The size and course are highly heterogeneous. Individual differences in the thickness of this structure, ranging from 2 to 10 mm, were observed both in humans and in horses (Kosinski *et al.* 2010). In the equine heart MB is commonly up to 4 mm and rarely exceeds 8 mm. No correlation between size and breed was found (Else & Holmes, 1972). MB tissue composition varies among species especially regarding the amount of muscle tissue present, suggesting that MB thickness is highly dependent on this tissue. MB in horses consists of a thick outer endocardial layer, Purkinje fibres, myocardial fibres, blood vessels and nerves (Sathyamoorthy & Ramesh, 2008). In particular, it is composed of cardiac striated muscle (69.37%), connective tissue (25.27%) and conductive tissue (5.33%). MB presents different types of insertion: simple, double, triple, quadruple, branched and irregular. The double insertion was found to be the most common in horses (Bombonato *et al.*, 2015).

MB main function is to prevent overdistention of the right ventricle during diastole (Kosinski *et al.*, 2010) and to provide support to the papillary muscle (Rajiad *et al.*, 2019). The artery of the moderator band is supposed to play an important role in collateral circulation in case of obstruction of the coronary arteries in humand (Reig *et al.*, 2000). MB is important for the conduction of the stimuli since the right bundle branch passes through the MB to reach the anterior papillary muscle (Sathyamoorthy & Ramesh, 2008). In this way, MB provides a shorter path for the impulse conduction for an approximately simultaneous contraction of all ventricle (Bombonato *et al.*, 2015).

Depending on the amount and thickness, MBs are associated with congestive heart failure, diastolic deficiency and arrhythmias. The presence of the MB is associated with increased arrhythmia incidence in humans (Sagcan, 2010), in particular, the conductive ways within the MB may trigger Mahaim tachycardia (Kosinski *et al.* 2010). Ventricular arrhythmias, especially premature ventricular contraction (PVC), were also reported to arise from MB in humans (Yasumoto *et al.*, 2019). In a study by Russo (2015)

10 of 394 patients (2.5%) with idiopathic ventricular arrhythmias had a MB source. Although the rate of occurrence is quite rare, PCVs arising from MB can be underdiagnosed if adequate diagnostic tools, such as intracardiac echocardiography (ICE) or cardiac mapping are not used. PVCs arising from MB may trigger monomorphic ventricular tachycardia or idiopathic ventricular fibrillation in the absence of underlying structural heart disease. Recurrence after ablation is quite often and 60% of patients with ventricular arrhythmia of MB source require a second surgery (Russo, 2015). MB may constitute a site for a clot or bacterial vegetation. A developed MB may also cause misdiagnoses during visual examinations and limits the operating fields especially during cardiac surgery of low-located ventricular septal defects, disturbing the proper localisation and the stitching phase. Its removal during a surgery may cause arrhythmias and heart block (Kosinski *et al.*, 2010). Aberrant, anomalous or hypertrophic moderator bands may be the cause of a rare congenital heart defect called double-chambered right ventricle in humans (Loukas *et al.*, 2013). Excessive moderator bands in the left ventricle is a rare congenital abnormality in cats associated with congestive heart failure (Liu *et al.*, 1982; Ferasin *et al.*, 2003; Wray *et al.*, 2007; Cavalcanti *et al.*, 2018). However, fine networks of traversing trabecular fibres (referred to as "excessive moderator bands") have been reported as a normal finding in the right ventricles of monkeys, sheep, pigs and oxen (Liu *et al.*, 1982) and in the right and left ventricle of dogs (Koie *et al.*, 2007; Bombonato *et al.*, 2012), cats (Fox, 1999) and humans (Liu *et al.*, 1982). A thick MB was recently found in an adult sport horse with a partial atrioventricular septal defect (Drábková *et al.*, 2020).

Case description

A three-years-old 420 kg warmblood stallion was referred to the Clinic of Horses of the University of Veterinary Medicine and Pharmacy in Košice for cryptorchid castration under general anaesthesia. The horse was bright, alert and in good body condition – 6/9 Henneke scoring system (Henneke *et al.*, 1983). Clinical examination on admission revealed a regular heart rhythm of 36 beats per minute, a respiratory rate of 16 breaths per minute, pink mucous membrane with normal capillary refilling time and normal body temperature. The remainder of the clinical examination, including lung auscultation, was normal. Haematology and biochemistry values were within normal range. A transthoracic echocardiogram was performed as part of a study about heart dimensions. A 2-2.5 MHz microconvex sector transducer was used. Sedation was not necessary. Benzyl alcohol was used as a medium. Echocardiographic measurements were within the reference ranges (Table 1). Valves appeared normal. Colour flow Doppler showed no signs of valvular regurgitation. A thick muscular band was present crossing the right ventricle between the interventricular septum and the right free wall. Measurements were taken in all views were it was visible, both at end diastole and end systole. The band measured 1.1±0.1 cm on its middle part, 1.3±0.3 cm next to its attachment on the interventricular septum and 1.5±0.2 cm next to its attachment on the right free wall (Fig. 1 and 2). Electrocardiography showed sinus rhythm with a heart rate of 36 bpm and no cardiac arrhythmias were noticed. Further investigation had been declined.

The horse was monitored for three days and showed no clinical signs of heart disease. Surgery was performed on ge-

Table 1. Two-dimensional and M-mode echocardiographic measurements in comparison with chosen reference view

Parameters	Unit	Measurements	Reference ranges	Reference
IVSd	cm	3.1	2.4–3.5	Al-Haidar *et al.*, 2017
IVSs	cm	4.4	3.8–5.2	Al-Haidar *et al.*, 2017
LVIDd	cm	11.3	9.0–13.3	Al-Haidar *et al.*, 2017
LVIDs	cm	8.5	4.9–8.7	Al-Haidar *et al.*, 2017
LVFWd	cm	2.4	1.9–2.9	Al-Haidar *et al.*, 2017
LVFWs	cm	4.1	3.3–4.9	Al-Haidar *et al.*, 2017
LV FS	%	40.0	31–46	Zucca *et al.*, 2008
AODd	cm	7.2	6.8–8.9	Zucca *et al.*, 2008
PAD	cm	5.5	5.1–7.8	Al-Haidar *et al.*, 2017
LAD	cm	11.1	9.2–13.3	Al-Haidar *et al.*, 2017
RVIDd	cm	3.8	2.2–5.4	Long *et al.*, 1992
RVIDs	cm	2.5	1.0–4.9	Long *et al.*, 1992

IVS: interventricular septum, LVID: left ventricular internal diameter, LVFW: left ventricular free wall thickness, LV FS: left ventricular fractional shortening, from M-mode right parasternal short-axis view at the level of the chordae tendinae; AOD: aortic diameter from M-mode right parasternal short-axis view at aortic valve level; PAD: pulmonary artery diameter from 2D-right parasternal right ventricular inflow-outflow view; LAD: left atrial end-systolic internal diameter from left parasternal long-axis view optimized for the left atrium; RVID: right ventricular internal diameter from M-mode right parasternal long-axis four chamber view; d: end-diastole; s: end-systole.

neral anaesthesia the third day. Premedication included 1.1 mg/kg xylazine (Rometar 2%; Bioveta a.s., Ivanovice na Hane, Czech Republic) and 0.02 mg/kg diazepam (Apaurin; Krka, Novo Mesto, Slovenia). Induction was performed with 2.2 mg/kg ketamine (Ketamidor 10%; Richter Pharma, Wels, Austria). A mix of xylazine (0.55 mg/kg Rometar 2%) and ketamine (1.1 mg/kg Ketamidor 10%) was administered as needed to prolong anaesthesia. Duration of surgery was 45 min and recovery occurred uneventfully.

Post-surgical therapy included potentiated sulphonamides (20 mg/kg iv bid Borgal 24%; Virbac, Carros, France) and flunixin meglumine (1.1 mg/kg iv bid Vetaflumex; MultiTrade Company Vet-Agro, Lublin, Poland) for 5 days.

The patient was discharged four days after surgery and regular cardiac examination (including echocardiography and electrocardiography) was suggested.

The muscular band found in the right ventricle was likely to be a hypertrophic moderator band. Thick MB often accompanies congenital defects in humans, can cause haemodynamic disorders and be the origin of arrhythmogenic foci (Kosinski *et al.* 2010). In horses, a correlation between size of MB and presence of cardiac lesions was not found (Else & Holmes, 1972). Although no relation was established, a thick MB was recently reported in an adult sport horse with a partial atrioventricular septal defect (Drábková *et al.*, 2020). In the reported case, a complete echocardiographic examination was performed to rule out the presence of pos-

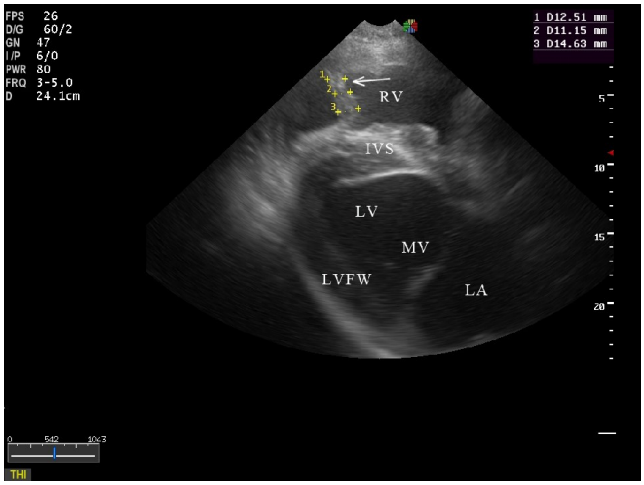

Fig. 1. Thick moderator band (arrow) and respective measurements (mm) in the right ventricle of a horse from a right parasternal view. RV – right ventricle, IVS – interventricular septum, LV – left ventricle, MV – mitral valve, LA – left atrium, LVFW – left ventricular free wall thickness, 1 – measurement of the MB next to the right free wall, 2 – measurement of the MB on its middle part, 3 – measurement of the MB next to the IVS. Bar = 1 cm.

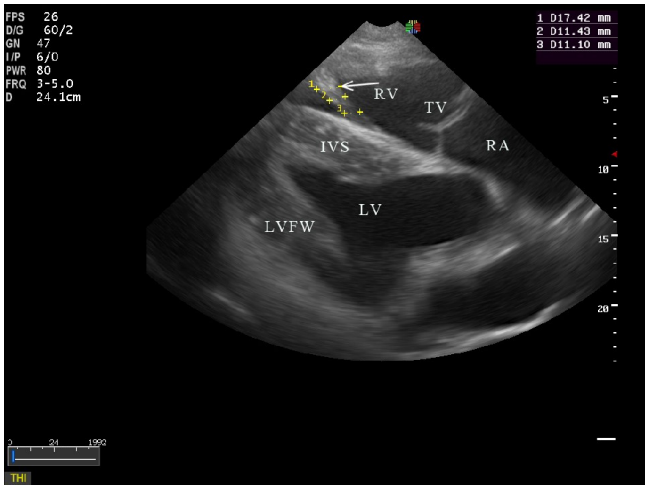

Fig. 2. Thick moderator band (arrow) and respective measurements (mm) in the right ventricle of a horse from a right parasternal view. RV – right ventricle, TV- tricuspid valve, RA – right atrium, IVS – interventricular septum, LV – left ventricle, LVFW – left ventricular free wall thickness, 1 – measurement of the MB next to the right free wall, 2 – measurement of the MB on its middle part, 3 – measurement of the MB next to the IVS. Bar = 1 cm.

sible congenital defects or signs of cardiac dilation, hypertrophy, remodelling, lesions or valvular regurgitation.

An ECG was also performed to check possible arrhythmias. No cardiovascular abnormalities were found and cardiac

dimensions, indices of cardiac function and Doppler measurements were within normal ranges. Surgery, anaesthesia and recovery occurred uneventfully. The horse is now in full training showing no clinical signs of cardiac distress. In conclusion, the variation found gives the opportunity to learn more about equine cardiac anatomy and physiology. The thick MB was an accidental finding and had no influence on cardiac functions or anesthetic parameters. We can conclude that thick bands in horses don't necessary cause cardiac problems at least in young age and anesthesia can be safely performed if ultrasound shows no abnormalities. Further studies are needed to assess the influence of thick MBs in the equine heart.

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