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Evaluation of echocardiographic variables of morphometry and function in horses submitted to minimally invasive partial pericardiotomy

[*Avaliação de variáveis ecocardiográficas morfométricas e funcionais em cavalos submetidos à pericardiotomia parcial minimamente invasiva*]

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ABSTRACT

This study aimed to evaluate the impact of minimally invasive partial pericardiotomy on echocardiographic variables of morphometry and function in healthy horses. Minimally invasive pericardiotomy was performed in six healthy horses. Echocardiographic evaluation was executed in different moments: prior to the surgical procedure (M0); 24 hours post procedure (M1); 72 hours post procedure (M2) and 28 days post procedure (M3). The following variables were measured: Right ventricular internal diameter in diastole and systole (RVd and RVs), interventricular septum thickness in diastole and systole (IVSd and IVSs), left ventricular internal diameter in diastole and systole (LVd and LVs), left ventricular free wall thickness in diastole and systole (LVFWd and LVFWs), aortic root diameter (Ao) and left atrial diameter (LA). From this data, the following variables were calculated: fractional shortening (FS%), fractional thickening of the interventricular septum (IVS%), fractional thickening of the left ventricular free wall (LVFW%) and the relationship between left atrial and aortic diameters (LA/Ao). After 28 days, a new thoracoscopy was performed for inspection of the thoracic cavity. In M1 and M2 ECO evaluations, a statistically significant change in LVFW and a decrease in RVd, LVd, LVFWs, LA, LVs, FS% and IVS was documented. Pericardiotomy is a promising technique in horses, with minor postoperative complication. The variations in the echocardiographic parameters were transient and did not cause hemodynamic damage to the animals.

Keywords: echocardiography, equine, cardiac function, thoracoscopy

RESUMO

O objetivo do presente estudo foi avaliar o impacto da pericardiotomia parcial minimamente invasiva sobre as variáveis ecocardiográficas morfométricas e funcionais em cavalos, visto que não há nenhum trabalho que tenha avaliado o impacto da pericardiotomia na espécie equina. Foram utilizados seis cavalos hígidos, nos quais se realizou pericardiotomia minimamente invasiva. Em todos eles, foi efetuado exame ecocardiográfico em diferentes momentos: previamente ao procedimento cirúrgico (M0); 24 horas após (M1); 72 horas após (M2) e 28 dias após (M3). Foram mensurados: diâmetro interno do ventrículo direito (VDd e VDs), espessura do septo interventricular (SIVd e SIVs), diâmetro interno do ventrículo esquerdo (VEd e VEs), espessura da parede livre do ventrículo esquerdo (PLVEd e PLVEs), diâmetro interno da aorta (Ao) e diâmetro atrial esquerdo (AE). Foram calculadas as variáveis fração de encurtamento (FEC%), espessamento fracional do septo interventricular (SIV%), espessamento fracional da parede livre do ventrículo esquerdo (PLVE%) e relação entre diâmetro do átrio esquerdo e diâmetro aórtico (AE/Ao). Após 28 dias, realizou-se nova toracoscopia para inspeção da cavidade torácica. Nas avaliações do ECO no M1 e no M2, houve alteração estatisticamente significativa no PLVE em diástole (28±5,5 e 31,7±2, respectivamente) e diminuição dos parâmetros VDd,(30,1±11,6 e 31,7± 10,7) VEd

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(113,3±21 e 121,7±13,7), PLVEs (42±8,2 e 43,9±2,8), AE (78,5±6,1 e 82,7±4,7), VEs (74,1±16 e 71,5±9,3), FEC (34,4±10,2 e 41,2±5,7) e SIV (27,1±8,7 e 42,3±27,9). A técnica de pericardiotomia empregada mostrou-se promissora em equinos. As variações dos parâmetros ecocardiográficos foram transitórias, não causando prejuízos hemodinâmicos aos animais.

Palavras-chave: ecocardiografia, equinos, função cardíaca, toracoscopia

INTRODUCTION

Pericardiotomy consists in a surgical opening of the pericardium, and the indication occurs in cases of recurrent pericardial effusions, in order to eliminate the risk of cardiac tamponade. The pericarditis abides one of the cases (Ventura *et al*., 2009; Shaw and Rush, 2007). This procedure can be performed by conventional assessment such as right lateral thoracotomy and video-assisted thoracic surgery or minimally invasive thoracoscopic surgery (thoracoscopy) (Shaw and Rush, 2007). There are two possibilities for the procedure to be accomplished, with the standing horse or in recumbency (Zoppa *et al.*, 2001b).

When compared to thoracotomy, thoracoscopy presents great advantages, including the reduction of postoperative pain, recovery time, better cosmetic appearance and fewer complications regarding surgical wounds (Latham and Dullye, 2011; Ginsberg, 1993). Pericardiotomy is frequently effective in the treatment of recurrent pericardial effusion, being a quick and easy technique to perform, rarely leading to significant complications (Ventura *et al*., 2009).

Echocardiography is the gold standard noninvasive method for evaluation of cardiac function, flow and structure in horses, representing an important tool for the diagnosis, monitoring and treatment of heart disease (Armstrong *et al*., 2014; Marr and Bowen, 2011). In addition, the aforementioned technique has no deleterious effects and can be repeated as many times as necessary without causing any harm to the animal (Brunner *et al*., 1995). The purpose of this study was to evaluate the impact of minimally invasive partial pericardiotomy on echocardiographic variables of morphometry and function in horses.

MATERIAL AND METHODS

The study protocol was approved by the Committee of Ethics in the Use of Animals (CEUA) of the Department of Agrarian Sciences - Federal University of Paraná - Brazil, in a meeting held on December 17th, 2015, under protocol number 081/2015. After physical examination, where heart rate (HR), respiratory rate (RR), body weight, capillary filling time, rectal temperature, frequency of fecal movements and hydration status were evaluated, six horses (four males and two females) were selected for a prospective longitudinal study. Laboratory tests such as blood count, creatine kinase (CK), aspartate aminotransferase (AST), gamma glutamyl transferase (GGT), urea and creatinine were performed. The inclusion criteria applied in this study was the absence of abnormalities in clinical and laboratorial exams. All selected horses were considered fit for the procedure.

The animals were kept in a horse-stock, in a quiet environment and under low light (Voros *et al*., 1991) during transthoracic echocardiographic examination (ECO). The use of sedatives was not required. Examination was performed in four different moments: prior to the surgical procedure (M0); 24 hours post procedure (M1); 72 hours post procedure (M2) and 28 days after surgery (M3). To optimize echocardiographic image quality, trichotomy was performed at the right hemithorax, between the 4th and 5th intercostal spaces (ICS), and the right thoracic limb was fractioned and positioned slightly ahead of the contralateral limb. The images were obtained with a MyLab 30 Gold (Genova, Italy) ultrasound machine, equipped with a 2 MHz sector transducer and capable of performing Bidimensional (B), Time-motion (M) and Doppler modes.

In cross-sectional images of the left ventricle, the following structures were measured at the chordae tendineae level, in diastole and systole: right ventricular internal diameter (RVd and RVs), interventricular septum thickness (IVSd and IVSs), left ventricular internal diameter (LVd and LVs) and thickness of the left ventricular free wall (LVFWd and LVFWs). The internal diameter of the aortic root (Ao) and left atrial diameter (LA) were posteriorly measured at aortic level. These parameters enabled the calculation of the following variables: fractional shortening (FS%), fractional thickening of the interventricular septum (IVS%), fractional thickening of the left ventricular free wall (LVFW%) and left atrium to aortic root ratio (LA/Ao). After basal echocardiographic evaluations (M0), the animals were submitted to partial pericardiotomy by thoracoscopy.

Prior to the surgical procedures the horses were kept 12 hours off feed and six hours off water. Anesthesia was based on intravenous administration of xylazine (0.5mg/kg) as preanesthetic medication (PAM), induction with guaifenesin (75mg/kg) and intravenous propofol (2mg/kg), followed by intubation of the right lung, with tracheal probe n14 adapted and coupled in a 26mm tracheotube, guided by tracheal endoscopy. For anesthetic maintenance, 0.18mg/kg/min of propofol or 1% of isoflurane was administered, with propofol rate or isoflurane concentration adjusted as to maintain desired anesthetic plane.

To perform the surgical procedure, the animals were positioned in right lateral recumbency because the lateral access would be evaluated. The thoracic cavity was accessed through a skin incision of approximately 2cm in the chosen left intercostal space, in the humeral-scapular joint line, followed by blunt incision and blunt musculature divination. The choice of intercostal spaces for the first two animals (8th and 5th ICS) was based on previously consulted literature (Vachon and Fischer, 1998; Textor *et al*., 2006). In the last four animals, however, the 7th ICS proved to be a better option for this technique.

With the use of a Cocker hemostat, the incision was deepened by blunt divulsion until the parietal pleura was perforated, resulting in pneumothorax. Through the opening, an 11mm trocar with thread (endotip) was introduced, into which the 10mm optics coupled to the micro camera was inserted. The inspection was performed initially with a 0° optics with a length of 33cm. Posteriorly, a 30° optics with 54cm in length was used. The pneumothorax was created with carbon dioxide and adjusted to a maximum pressure of 4mmHg, inferior to the pressure used by Fernández *et al*. (2004).

The placement of two more portals, one in the 5th and the other in the 6th ICS, was performed in order to introduce the instruments in the first three procedures, under direct visualization. In each of these portals, a smooth endotip was placed to insert the instruments. For the last three procedures, only two portals were placed, one for inserting the optics and the other for the passing of the instruments. In these procedures, the access for the insertion of the second portal was performed in the 6th ICS, with subsequent placement of the smooth endotip.

After insertion of the auxiliary instruments, the pericardium was drawn and incised from the cardiac base to the apex, exposing the left auricle. The pericardiotomy began with a small incision of 1cm and, from this opening, the pericardium was drawn, facilitating the enlargement of the opening up to approximately 30cm. In the first three procedures, seizing forceps and scissors were used for the incision of the pericardium and, in the following procedures, only the Hook forceps was used.

By the end of all the procedures, the portals were removed, the musculature was approximated, and the musculature and skin sutures were performed with non-absorbable polypropylene n2 wire, in standard Wolf stitches. The pneumothorax was removed with a surgical aspirator, as cited by Zoppa *et al*. (2001a). The surgical procedures were performed by an experienced team in performing video-surgeries, with technical knowledge of pericardiotomy in dogs, however, without previous experience with this technique in horses. After 28 days of the first surgical procedure, a second thoracoscopy was performed to inspect the thoracic cavity and the pericardial window, with similar access to the first procedure, using only one portal for the introduction of the optics.

Postoperative care of both thoracoscopies consisted of clinical evaluation of the animals and daily dressings at the incision site, including thorough evaluation of the surgical wound. Flunixin meglumine was administered at a dose of 1.1mg/kg intravenously for three days, along with antibiotics (benzylpenicillin benzathine, benzylpenicillin procaine, benzylpenicillin potassium, streptomycin and piroxicam) at a dose of 20000 IU/kg by intramuscular route, based on benzylpenicilin benzathine in a total of three applications, with a 48-hour interval, plus methadone at a dose of 0.05mg/kg intramuscularly on the first day after surgery. Skin sutures were removed after 10 days. All variables were submitted to analysis of variance followed by Dunnett's test, considering $P<0.05$.

RESULTS AND DISCUSSION

All details regarding the surgical procedures are shown in Table 1.

Table 1. Description of the animals submitted to the surgical procedure, number of accesses performed, surgical time, difficulties encountered, complications and whether or not myocardial injury occurred

N*	Sex	Breed	Age (years)	Weight (kg)	Optic ICS	Number of accesses	Surgical time (minutes)	Myocardial injury	Complications
1	Male	BSH	11	540	8	3	40	No	No
2	Male	MB	26	460	5	3	48	Yes	Yes
3	Male	TB	3	520	7	3	34	Yes	No
4	Female	TB	15	550	7	2	30	Yes	No
5	Female	TB	20	552	7	2	30	No	No
6	Male	TB	5	477	7	2	16	No	No

*N: Animal used.**ICS Intercostal space where the optic was applied. Brazilian Sport Horse (BSH); Mixed Breed (MB); Thoroughbred (TB).

The pericardiotomy technique can be accomplished with the horse standing or in recumbency. When the procedure was accomplished with the horse standing, just a sedation and local anesthesia is required. Although, when the horse is in recumbency, dorsal or lateral, total anesthesia is necessary (Textor *et al*., 2006). When the last option is chosen, monopulmonary intubation can be done. In this study, the pericardiotomy was successfully performed in all procedures, with the pericardium window approximately 30cm, to prevent an adhesion or closed the window. However, some difficulties were encountered. The main one was the seizure of the pericardium in order to perform the first incision, which occurred in all surgeries.

This setback was caused by the presence of superficial fat tissue (Figure 1) and due to the tension and low elasticity of the pericardium, which made it difficult to separate it from the myocardium, forcing the surgeon to perform the incision very close to the heart. In addition to the difficulty in drawing the pericardium, cardiac movements increased the risk of iatrogenic injury to the myocardium. Moving the surgical instruments and optics in the intercostal spaces was also difficult, due to the stiffness of the costal arch in the equine species. The sum of these factors resulted in small myocardial lesions in three animals, caused by the surgical instrument, which led to temporary bleeding.

According to Zoppa *et al*. (2001b), surgical access during thoracoscopy should be performed through a skin incision, followed by divulsion of the musculature and perforation of the parietal pleura with hemostatic forceps. This allows gradual induction of the pneumothorax, resulting in a safer trocar passing, reducing the possibility of injury to lung tissue. This technique was reproduced in the present work. Pericardiectomy was not performed due to difficulties in grasping the pericardium after pericardiotomy, unlike in dogs, where pericardiectomy is feasible (Atencia *et al*., 2013). However, after pericardiotomy, the pericardium underwent retraction, becoming limited by the sternum-pericardial ligament and allowing a wide access window to the heart.

Atencia *et al*. (2013) performed the technique of pericardial window by thoracoscopy in 15 dogs, being successful in 14 procedures, with one animal requiring conversion to open surgery. The authors reported that the surgical time ranged from 45 to 80 minutes. In our study, the time ranged from 16 to 48 minutes. This difference was due to the presence of a surgeon learning curve, who was experienced in performing video-surgeries, and due to the use of the Hook forceps (Figure 1 II) in the last three animals, which facilitated the procedure, reducing surgical time.

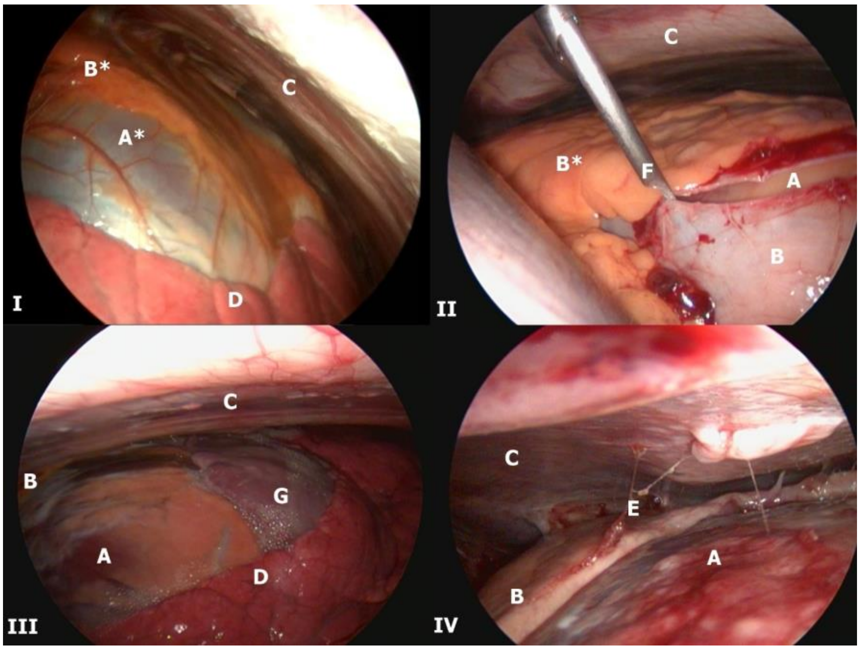

Figure 1. Image of the left hemithorax of horses submitted to thoracoscopy. It can be observed in I A *: heart coated by intact pericardium, B* pericardial fat, D: lung and C: costal arch; II, III and IV A: exposed heart after pericardiotomy; I and II B *: pericardial fat; III and IV B: residual pericardium; I, II, III and IV C: left costal arch; I and III D: ventral lung limit; IV E: adhesions visualized after 28 days; II F: Hook forceps, III G: exposed left auricle.

According to Atencia *et al*. (2013), after performing pericardiotomies by thoracoscopy in dogs, patient discharge happened between one and six days, for some animals developed edema, emphysema and pain at the incision site. With the horses of this study, except for one animal which developed radial nerve palsy, hospital discharge would have been possible 24 hours after surgery, since the animals did not present complications that made their release contraindicated, like those found by the afore mentioned authors.

The intrathoracic pressure used during thoracoscopy may cause hemodynamic and respiratory changes in the patient, but they do not cause postoperative clinical sequelae (Barash *et al*., 2013), provided that it is used during short periods (Polis *et al*., 2002). Owing to the great discrepancy of pneumothorax values established by the literature among the different species, in the present study we opted for the pressure of 4mmHg, which provided good visualization and adequate working space for the surgeon and team. The pressure was maintained by the insufflator, where de maximum of pressure was fixed.7

Among all six operated animals, only one developed postoperative complication, which was radial nerve palsy. This complication coincided with the longer surgical time (48 minutes), however, treatment was performed, and the patient fully recovered within three days. According to Thomassian (2005), radial nerve palsy may be caused by lateral recumbency, resulting in signs of partial or total impairment. The prognosis is good in cases of partial paralysis, as manifested by the horse of this study.

In a follow-up of 266 thoracoscopies in humans documented by Kaiser and Bavaria (1993), death resulting from the procedure was not observed, however, complications such as reintervention due to hemothorax, hematoma, surgical wound infections, atrial arrhythmia, and recurrent pneumothorax are described. In a study by Barash *et al*. (2013), a few complications were observed in dogs, such as atelectasis, decreased cardiac output, pericardial effusions with consequent cardiac tamponade and respiratory and neurological complications, such as peripheral nerve lesions, mainly in the brachial plexus. Other possible complications include bleeding, seroma formations, and pulmonary thromboembolism (Atencia *et al.*, 2013). There is the possibility that, in this study, other complications besides radial nerve palsy were not observed due to the use of healthy animals and the short duration of the procedures.

During the evaluation performed 28 days after the procedure, in five of the six animals, the auricle was exposed after pericardiotomy (Figure 1 III G), with a wide pericardial window. In only one animal this was not observed. This finding has a probable relation to surgeon learning curve, since it happened only in the first procedure, and new choices of surgical instruments and access points in the thorax were made from then on.

No adhesion was observed between the pericardium and the epicardium, but in horses number 2 and 3, a small point of adhesion occurred between the epicardium and the thoracic wall, and in horse number 3 several small points of adhesion between the residual pericardium and the thoracic wall were observed. (Figure 1 IV E). Despite the formation of adhesions in these animals, there was no impairment to cardiac movement, thus, they were not considered complications.

No free fluid in thoracic cavity or pulmonary adhesion was observed in any of the horses, and in all animals the pericardial window was well delimited. Boulton *et al*. (1986) reported that, after thoracoscopy, adhesions may occur between the visceral and parietal pleura, at the site of the surgical incision, without damage to respiratory function and the athletic capacity of the animals. Canola (2012) reported the presence of adhesions between the parietal and visceral pleura in four out of seven horses, in which experimental thoracotomy was performed for induction of pneumothorax.

Measurements performed during echocardiographic examination of cross-sectional images at chordae and aortic levels are shown in Table 2. There was no statistically significant difference in any of the measurements, for $P<0.05$. The calculations of the variables obtained from these measurements are shown in Table 3.

Despite no significant difference being observed regarding the morphometric echocardiographic parameters obtained by B and M modes, there was a clear variation between moments M0 and M1 in several parameters, such as RVd, LVd, LVFWs and LA, which decreased 24 hours after the procedure and increased again 72 hours later. The values of LVs decrease at M1 and M2 and rise again by M3. These reductions, although not significant, may reflect a decrease in venous return and preload, probably due to postoperative local inflammation, persistent pneumothorax with consequent increase in thoracic impedance and/or temporary unilateral pulmonary collapse (Canola, 2012).

Table 2. Mean values and standard deviations of the morphometric echocardiographic parameters obtained by B and M modes in horses submitted to minimally invasive pericardiotomy, where * $P<0.05$

Variables	M0	M1	M2	M3
HR (bpm)	45±8	52±13.4	46±9.8	39±6.9
RVd (mm)	32.2±9.1	30.1±11.6	31.7±10.7	34.5±12.1
IVSd (mm)	31.3±5.5	36.2±6.8	35.2±5.3	33±4.9
LVd (mm)	125.4±13.5	113.3±21	121.7±13.7	130.5±15.8
LVFWd (mm)	25.9±5.5	28±5.5	31.7±2	27.1±5.2
RVs (mm)	19.4±7.7	19.6±9.5	18.7±7.2	23.3±9.3
IVSs (mm)	43.8±3.2	45.8±7.9	49±4.9	43.9±4.8
LVs (mm)	76.6±10.5	74.1±16	71.5±9.3	76.2±12
LVFWs (mm)	43.4±4	42±8.2	43.9±2.8	45.1±5.5
LA (mm)	80.3±6.1	78.5±6.1	82.7±4.7	85.7±5.8
Ao (mm)	68±2.8	68±2.8	68±2.8	68±2.8

Heart rate (HR); internal diameter of the right ventricle in diastole (RVd); interventricular septum thickness in diastole (IVSd); internal diameter of the left ventricle in diastole (LVd); left ventricular free wall in diastole (LVFWd); internal diameter of the right ventricle in systole (RVs); interventricular septum thickness in systole (IVSs); internal diameter of the left ventricle in systole (LVs); left ventricular free wall in systole (LVFWs); left atrial diameter (LA); internal diameter of the aortic root (Ao).

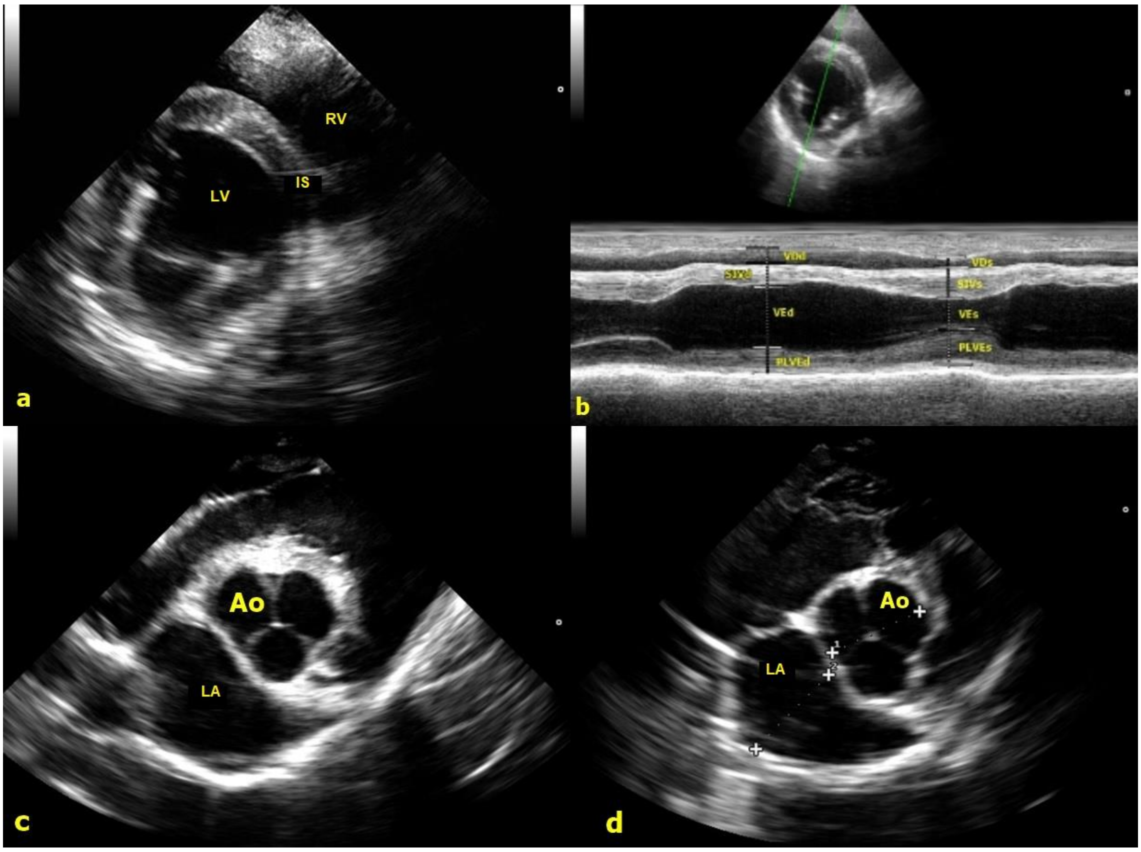

Figure 2. Echocardiographic image obtained by right parasternal window. a: B-mode image, left ventricular cross-sectional view; b: M-mode image, illustrating the measurements of various cardiac structures. Image in diastole (thick arrow) Image in sysole (thin arrow); c Image in aortic plane. Left atrium (LA) and aorta (Ao), with closed valvular leaflets; d: illustration of the measurement of the LA and Ao diameters.

Mean interventricular septum thickness in diastole (IVSd) (Figure 2) before the surgical procedure was 31.3mm, close to those found by Bello *et al*. (2011a) and Bello *et al* (2011b) of 30 ± 5.4mm and 33.1 ± 4.6mm respectively, but much above the average found by Giannico *et al*. (2015) of 22.3 ± 3.9mm. Among athletic animals, eccentric cardiac hypertrophy may occur as an adaptive response of the heart to physical exercises (Bello *et al*., 2011a), thus increasing the mean IVS thickness. The weight of the animals may also influence cardiac measurements (Giannico, 2015; Latorre *et al.,* 2016), being higher in larger horses.

Therefore, the values found are consistent with the consulted literature, since, although the animals used were not athletes, the horses in this study presented a mean weight greater than those studied by Giannico *et al*. (2015) and Bello *et al*. (2011a). Despite the absence of statistical differences in IVSs and IVSd, when compared to the baseline, the IVSd increased at all times and, in systole, there was an increase only in M1 and M2, as shown in Table 2. It is possible that the increase in IVSd may be related to a decrease in preload, which, consequently, results in minor stretching of the myocytes. Conversely, the increase of IVSs in the initial post-surgical moments may be explained by exacerbated sympathetic activity due to stress.

The mean baseline values of left ventricular free wall thickness in diastole (LVFWd) of the horses in this study was 25.9mm and the mean baseline wall thickness of the left ventricle in systole (LVFWs) was 43.4mm. No significant change in these values when compared to the other moments was documented.

Table 3. Mean values and standard deviations of the variables LA/Ao, FS%, IVS% and LVFW% evaluated in M0, M1, M2 and M3 in horses submitted to invasive minimizing pericardiotomy, where * P<0.05

Variables	M0	M1	M2	M3
LA/Ao	1.2±0.1	1.2±0.1	1.2±0.1	1.3±0.1
FS (%)	38.9±5.3	34.4±10.2	41.2±5.7	41.7±4.1
IVS (%)	42.9±21.6	27.1±8.7	42.3±27.9	35.9±27.02
LVFW (%)	71.3±21.7	50.8±22.4	39±8.72*	68.4±17.14

Left atrium-to-aorta ratio (LA/Ao); fractional shortening (FS%), fractional thickening of the interventricular septum (IVS%); fractional thickening of the left ventricular free wall (LVFW%).

The values of aortic root diameter found in this study (68mm) are very close to the values found by Bonomo *et al*. (2011), which were of approximately 70mm, however, they were above the values of around 63mm described by Giannico *et al.* (2015). This difference can remain in the fact that the animals in this study (mean of 516.2kg) were larger than the traction horses studied by Giannico (mean of 362.5kg). Mean LA/Ao values were similar at all four different moments, between 1.2 and 1.7, an interval considered normal for non-athletes (Voros *et al*., 1991).

The variables FS%, IVS% and LVFW% (Table 3) reflect systolic function but are influenced by preload and afterload. Thus, the reduction of these parameters in M1 and M2 may be related to lower preload and/or the effect of inflammation on the myocytes. Mean FS% at baseline was 38.9%, and in M1 the mean fell to 34.4%. This decrease may be related to the change in ventricular diameter at this time, but it is still within normal values (32% to 55%), according to Reef (1998), characterizing normal left ventricular systolic function.

The fractional thickening of the left ventricular free wall (LVFW%) was statistically different between M0 and M2. At baseline, mean LVFW% was 71.3%, while 72 hours after the procedure it decreased to 39.8%. This change, however, was transient, since in M3 the mean was very close to the one obtained at baseline. It is likely that the reduction of LVFW% may be related to the lower preload and/or the effect of inflammation on cardiac function. In humans, the presence of inflammation is directly related to ventricular dysfunction, with dilation of the ventricles and decreased ejection fraction. Nonetheless, it is reversible (Li *et al*., 2013).

Despite the significant findings of this study, some limitations can be pointed out, such as the small number of animals used, the short evaluation time after surgery, the presence of surgeon learning curve, which resulted in longer procedures at the beginning of the study and lack of standardization of breed and age of the animals used.

CONCLUSIONS

The technique of pericardiotomy applied in this study was performed by a skilled team of surgeons and was promising in the creation of a pericardial window in horses, causing minimal postoperative complications. The documented variations in some echocardiographic parameters were transient, concentrated especially on the first 72 hours after surgery, reflecting a decrease in preload and a response to cardiac inflammation.

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