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Venographic differences in feet of lame vs non-lame horses[1]

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ABSTRACT.- Sales J.V.F., Melotti V.D., Nascimento A.A., Campebell R.C. & Teixeira Neto A.R. 2025. **Venographic differences in equine feet of lame vs non-lame limbs.** *Pesquisa Veterinária Brasileira 45:e07449, 2025.* Hospital Escola de Grandes Animais, Faculdade de Agronomia e Medicina Veterinária, Universidade de Brasília, Área Especial SRB, Galpão 4, Granja do Torto, Brasília, DF 70636-200, Brazil. E-mail: raphaeltx@unb.br

Understanding vascular occurrences within the hoof has become the focus of scientific work. Venography has begun to be used as a minimally invasive, practical and essential diagnostic method to access digital circulation, with accurate prognostic value. The aim of this study was to evaluate venograms of lame and sound horses, using a semiquantitative scale of radiographic contrast filling, in the following anatomical regions: terminal arch, dorsal laminar vessels to the distal phalanx, coronary plexus, circumflex vessels, and heel bulb. For the venographic study of forelimb hooves, 19 horses (12 males and seven mares), with a mean age of 9.5 ± 4.4 years, were used; 11 animals without clinical signs of lameness (sound) and eight with some degree of claudication (lame), according to the American Association of Equine Practitioners (AAEP). Obtained data were subjected to ANOVA statistical analysis, complemented by the Tukey test, with a significance level of $p < 0.05$ for comparison between all groups. A difference was observed between venograms of lame and sound horses, regardless of the thoracic limb used for the analysis. Lame animals presented lesser digit perfusion. The decrease in blood circulation was more frequently present in the terminal arch, circumflex vessels, and dorsal laminar vessels. Lame animals with normal or long toe/low heel hoof angles presented higher perfusion scores than clubfoot hoof horses. Despite the hoof angle conformations, digital perfusion was not influenced in sound animals. A larger number of animals should be tested to validate the proposed semiquantitative scale.

INDEX TERMS: Horse, venogram, perfusion, lameness, hoof.

RESUMO.- [**Diferenças venográficas podais em membros torácicos de equinos claudicantes e não claudicantes.**] Compreender as ocorrências vasculares dentro do casco tornou-se o foco de trabalhos científicos. A venografia começou a ser utilizada por ser um método diagnóstico minimamente invasivo, prático e essencial para acessar a circulação digital, com valor prognóstico preciso. O objetivo deste estudo foi avaliar venogramas podais de equinos claudicantes e não claudicantes, utilizando-se uma escala semiquantitativa de preenchimento de contraste radiográfico, nas seguintes regiões anatômicas: arco terminal, vasos laminares dorsais a falange distal, plexo coronário, vasos circunflexos e bulbo do talão. Para o estudo venográfico dos cascos dos membros torácicos foram utilizados 19 equinos (12 machos e sete fêmeas), com idade média de 9,5 ± 4,4 anos. Onze animais sem sinais clínicos de claudicação (não claudicantes) e oito com algum grau de claudicação (claudicantes), segundo a Associação Americana de Praticantes de Equinos (AAEP). Os dados obtidos foram submetidos à análise estatística ANOVA, complementada pelo teste de Tukey, com nível de significância de $p < 0,05$ para comparação entre todos os grupos. Foi observada diferença entre venografias de cavalos claudicantes e não claudicantes, independentemente do membro torácico utilizado para análise. Animais claudicantes apresentaram menor perfusão digital. A diminuição da circulação sanguínea foi mais frequente no arco terminal, vasos circunflexos e vasos laminares dorsais a falange distal. Animais claudicantes com ângulo do casco normal ou achinelado apresentaram maiores escores de perfusão do que cavalos com casco encastelado. Nos animais hígidos (não claudicantes), apesar das conformações do ângulo do casco, a perfusão digital não foi influenciada.

TERMOS DE INDEXAÇÃO: Cavalo, venograma, perfusão, claudicação, casco.

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INTRODUCTION

Horses adapt to lameness with compensatory movements of specific body parts. Support lameness is characterized by abnormal head and body movements as the horse tries to redistribute its weight whenever the hoof of the affected limb touches the ground. With most lameness conditions, the horse attempts to "unload" the lame limb during weight-bearing or the stance phase of the stride. The animal raises its head in an attempt to displace the center of balance and reduce weight on the limb (Baxter & Stashak 2020). Due to less contact with the ground, the hoof does not properly perform some of its functions, such as impact absorption, animal weight load, resistance to wear and supporting the return of blood from the distal limb (Nicoletti et al. 2000, Gerard 2021).

The presence of a large volume of blood inside the hoof is necessary for the pressure to soften the initial impact with the ground (Davies et al. 2007). Lateral expansion of the hoof and cartilage increases the pressure on the venous plexus, which acts as a hydraulic buffer, forcing proximal blood into the digital veins. However, when the hoof is off the ground, strategic valves prevent blood from returning to the hoof (Parks 2003, Pollitt 2004).

Regarding the vascularization of the digit, blood vessels provide nutrients, remove waste, and are a route for chemicals such as hormones and toxins in hoof tissues (Davies et al. 2007). Medial and lateral palmar digital arteries are responsible for the arterial blood supply of the digit (Burg et al. 2007). In relation to venous return, the most striking difference is the presence of three interconnected venous plexuses in the hoof: the coronary, the dorsal venous in the lamellar dermis, and the palmar venous in the solar corium. These plexuses are formed by the lateral/medial digital veins (Parks 2003, Gerard 2021).

Coffman et al. (1970) explored hoof circulation using the angiography technique in anesthetized horses when laminar hypoperfusion in laminitis processes was demonstrated. Redden (2001) developed the venography technique on standing horses.

Venography is a minimally invasive, practical diagnostic method capable of revealing the health of an animal's vascular system providing information about areas of vascular compression or damage within the hoof (Kramer et al. 2018). It can therefore assist veterinarians and farriers by choosing the appropriate therapy for lame horses, has an accurate prognostic value and monitors patients. It can also be repeated from three to 14 days (Redden 2001, Rucker 2010). Therefore, the present study aimed to evaluate digital venograms of lame and sound horses, based on a semiquantitative scale of radiographic contrast filling, in pre-established anatomical regions of the horse hoof.

MATERIALS AND METHODS

Ethical approval. The protocol (166740/2016) was approved by the Animal Use Ethics Committee (CEUA) of "Universidade de Brasília" (UnB).

Twelve geldings and seven mares were included in the study, with a mean age of 9.5 ± 4.4 years and a mean weight of 333.2 ± 70.8 kg). Due to the fact that all of them were rescued and referred to the Veterinary Teaching Hospital by state services, the precise history of each one was not obtained. In all animals a complete clinical examination and blood cells count was done. They presented with an average body condition score of 3/9 (Henneke et al. 1983) and a regular condition. No clinical evidence of systemic illness was noted, although six horses exhibited a mild degree of anemia, considering the reference values according to Friedrichs et al. (2022). Oral ivermectin 0.2 mg/kg (Eqvalan Pasta®)[3] was administered for each horse right after the admission.

All horses (19) passed a complete lameness physical exam by three veterinarians with more than five years of equine clinical practice. This examination defined the lameness degree of each animal, according to AAEP (1996). Eleven horses were sound, and eight of them revealed lameness. Of the lame group, four showed hoof morphological alterations, suggesting chronic laminitis. A horse was diagnosed with septic pododermatitis and at surgery, alar cartilage necrosis was confirmed and treated. Another animal reveled navicular syndrome, and two others did not have a conclusive diagnosis.

The hoof of each horse was cleaned to perform digital venography, and the palmar aspect of the pastern region of thoracic limbs was clipped for subsequent puncture of lateral or medial digital palmar vein. The animal was led to a flat, previously cleaned surface with a halter restraint. Sedation was performed with 0.01 mg/kg detomidine hydrochloride (Detomidin 1%)[4], and an employee, accustomed to working with horses, was responsible for restraining the animal with the halter, with attention to keeping the head straight and aligned, after applying the contrast to avoid any uneven limb support. A hoof gauge was used to determine hoof angles, and the central sulcus of the frog was filled with modeling clay to minimize image artifacts.

According to the technique described by Redden (2001) and Rucker (2010), lateral or medial palmar digital perineural anesthesia was performed in the pastern region, with 3 mL of lidocaine 2% without vasoconstrictor (Xylestesin®)[5], and each limb was positioned on a wooden block to be radiographed. After surgical antisepsis at the venipuncture site, a tourniquet was attached to the base of the fetlock at the height of the proximal sesamoid bones. One of the palmar digital veins was cannulated with a 21 scalpel, and then 20 mL contrast 60% diatrizoate meglumine (Reliev®)[6] was injected and divided into two 10 mL syringes (Fig.1-2).

Immediately after the contrast application, the limb was flexed and again positioned on the wooden block to perform a lateromedial radiographic projection (LM) with a Poskom PXM-40BT device and CR 30X AGFA image scanning system (Fig.3). The entire procedure took approximately 45 seconds. According to D'arpe & Bernardini (2010), a timeout of 40 to 50 seconds was considered to obtain optimal images before the contrast medium diffuses from the veins. In the end, the catheter was removed, and a compressive bandage was applied until the following day. Each animal was monitored for 96 hours.

A grading system was created considering the perfusion range of contrast in five anatomical regions to evaluate venographic images: terminal arch, dorsal laminar vessels on the distal phalanx, coronary plexus, circumflex vessels, and heel bulb. In this system, each of the five described regions was quantified with values 0, 1, or 2 according to the filling of the vessels: 0 (zero) = absence of regional filling, 1 = partial regional filling (< 50%), and 2 = good regional filling (> 50%). To this end, three qualified examiners were invited to evaluate the venograms without having participated in the previous procedures. The maximum score obtained per region and examiner was 2.

[3] Boehringer Ingelheim, Paulínia, São Paulo, Brazil.

[4] Syntec, Barueri, São Paulo, Brazil.

[5] Cristália, Itapira, São Paulo, Brazil.

[6] BerliMed SA, Madrid, Spain.

After the development of the aforementioned scoring system, which reflected a semiquantitative evaluation scale of digital perfusion index by radiographic contrast, forelimbs results were compared between groups (sound *vs* lame horses) and with each other in the same group.

The values obtained through venogram analysis and scores attribution for the thoracic digits of lame and sound horses were submitted to ANOVA statistical analysis, complemented by the Tukey test, with a significance level of $p < 0.05$ for comparison between groups (Group 1 – without lameness: left thoracic limb and right thoracic limb, Group 2 – lameness: left thoracic limb and right thoracic limb).

RESULTS

At clinical examination of the locomotor system, eleven animals were diagnosed without lameness, grade 0/5 (Group 1) and eight animals with support limb lameness in one of the thoracic limbs, grade 1 to 4/5 (Group 2). Five regions were considered for contrast perfusion evaluation: terminal arch, dorsal laminar vessels, coronary plexus, circumflex vessels, and heel bulb (Fig.4).

A difference was noted in the comparison of venograms between groups ($F_{3,34} = 12.39$, $p = 0.00001$), Group 1 (sound horses) and Group 2 (lame horses). Forelimb digits of sound animals (Group 1) presented no differences between them ($p = 0.9932$) since they were healthy and did not present unequal weight distribution between limbs. The same was observed when comparing forelimb venograms of lame animals (Group 2) ($p = 0.3887$). Only one lame animal in the study presented the contralateral limb fully filled with contrast.

Comparisons between right forelimb of sound and right forelimb of lame horses ($p = 0.00006$), left forelimb of sound and left forelimb of lame ($p = 0.0162$), left forelimb of sound and right forelimb of lame ($p = 0.0001$), and right forelimb of sound and left forelimb of lame animals ($p = 0.0086$) showed significant differences (Fig.5).

It was observed that lame animals presented decreased blood circulation through the digit, which was reflected in lower values in the semiquantitative evaluation scale due to lesser filling of contrast in the vessels. The lowest scores were directly related to support lameness. However, the scores of

Fig.1-2. Equine right forelimb submitted to venography. (**1**) cannulation of the lateral palmar digital vein. (**2**) meglumine diatrizoate based contrast injection.

Fig.3. Lateromedial projection of equine right forelimb after meglumine diatrizoate-based contrast injection.

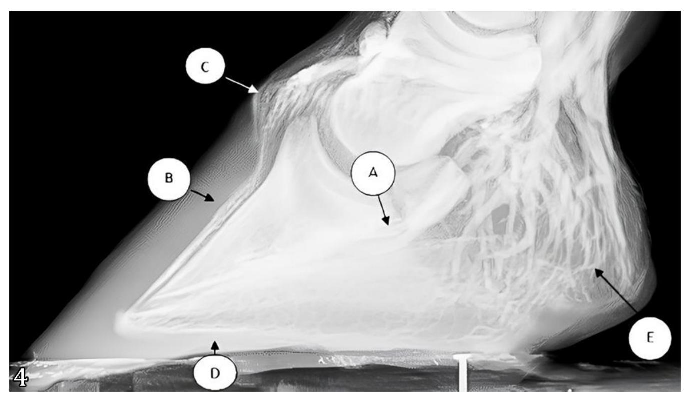

Fig.4. Forelimbs of sound adult horses in lateromedial projection. Reference regions identified in the venograms: terminal arch (A), dorsal laminar vessels (B), coronary plexus (C), circumflex vessels (D), heel bulb (E).

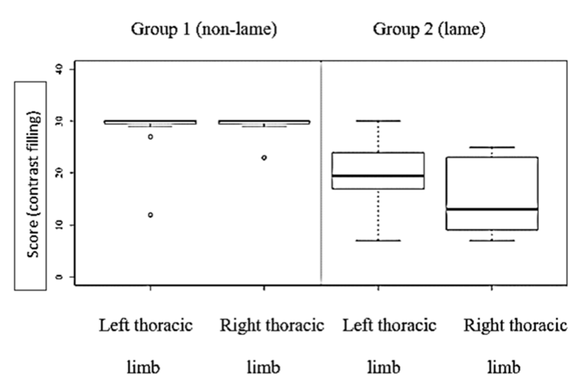

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Fig.5. Graphical representations (box plot) of means and standard deviations of radiographic contrast filling in the digits of sound (Group 1) and lame horses (Group 2).

lame animals did not depend on the degree of lameness. For instance, an animal with 4/5 lameness did not necessarily obtain lower foot perfusion rates than an animal with grade 3/5 (Fig.6-7).

As for anatomical regions, a decrease in perfusion was present in the terminal arch (8/8), circumflex vessels (8/8), dorsal laminar vessels (7/8), coronary plexus (5/8), and bulb of the heel (2/8), in lame horses. All animals (8/8) in Group 2 (lame) presented some degree of decreased perfusion in the region of the terminal arch and a deficit in filling the region of circumflex vessels.

Regarding the hoof angulation, all animals, lame and sound, were classified, according to the angle obtained in the hoof gauge, into: clubfoot (> 54^{o}), long toe (35-49^{o}), and normal (< 54^{o}) conformations.

DISCUSSION

Forelimb digits of sound animals (Group 1) and lame animals (Group 2) presented no differences between them since they were healthy and did not present unequal weight distribution between limbs. In this case, the animals ended up overloading the "sound" limb due to unequal weight distribution, which also started to present lower scores. These results corroborate those of Baxter & Stashak (2020), who reported that some horses with foot disorders may develop complementary lameness in the contralateral limb due to constant support provided by the non-lame limb. Only one lame animal in the study presented the contralateral limb fully filled with contrast.

The difference noted in the comparison of venograms between groups corroborates with Baxter & Stashak (2020), who reported that some horses with foot disorders may develop complementary lameness in the contralateral limb due to constant support provided by the non-lame limb.

All animals in Group 2 presented some degree of decreased perfusion in the region of the terminal arch, and according to D'Arpe & Bernardini (2008), the integrity of that region is crucial for keeping the digit alive. In chronic laminitis, the terminal arch eventually becomes vulnerable, and ischemia can occur (Rucker 2017). This fact corroborates the present study since half of the animals showed suggestive alterations of chronic laminitis.

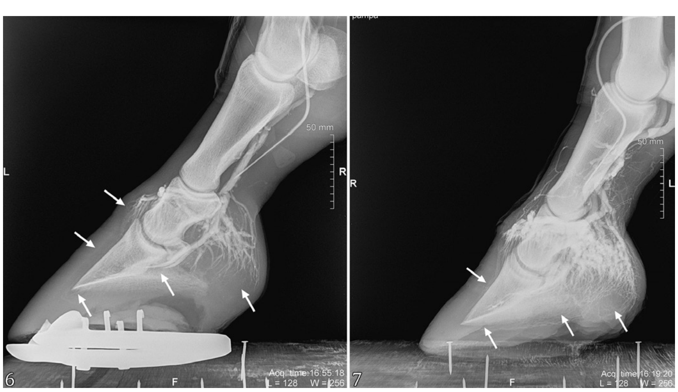

Fig.6-7. (**6**) Venogram of the right forelimb of an animal with 3/5 grade lameness with a total score of 8 points. (**7**) Venogram of the left forelimb of a horse with a 4/5 grade lameness with a total score of 16 points. Decreased perfusion (arrows) in (**6**) coronary plexus, dorsal laminar vessels, circumflex vessels, terminal arch, and heel bulb; (**7**) dorsal laminar vessels, circumflex vessels, terminal arch, and heel bulb.

Deficit in filling the region of circumflex vessels in all lame animals is in accordance with Rucker (2017) because this is usually the first region affected at the beginning of laminitis. The majority of animals (7/8) had perfusion failure in the region of the dorsal laminar vessels, probably due to the direct relationship with the terminal arch (Rucker 2017). The flow direction on the venogram was clearly seen; that is, there was no filling in the terminal arch and, consequently, no filling in the dorsal laminar vessels.

The coronary plexus was not filled in more than half of lame animals (5/8). Thus, one of the main functions of this structure, which is to act as a safety valve for hydrostatic and dynamic pressure (D'Arpe & Bernardini 2008), was not properly performed.

At the heel bulb, 25% (2/8) presented perfusion deficit of lame animal's digits. According to Rucker (2017) and D'Arpe & Bernardini (2008), blood perfusion in the heels is rarely reduced due to the trajectory of the bulbar artery (palmar to metacarpal) and the fact that the majority of tissue damage and mechanical load of the digit occur in the anterior region of the hoof wall.

According to Arthur & Rucker (2003) and Kramer et al. (2018), the coronary plexus, dorsal laminar vessels, and circumflex vessels are normal areas in animals with chronic laminitis, partially corroborating present study data. Animals with clinical laminitis and support lameness, in general, did not present perfused dorsal laminar and circumflex vessels.

Normal angle hooves, less than 54^{o}, align with Bushe et al. (1987) and Baxter & Stashak (2020) studies, which cited values of 50-55^{o}. It was observed that lame animals with normal or long toe/low heel hoof angles obtained higher scores in relation to clubfoot horses, corroborating Frandson et al. (1978), Clayton (1987), and Barrey (1990), who reported that the angle also influences concussion in the digit. The greater the angle, the less the concussion. As a result of this uneven weight support, there is also a separation effect between heels, which in turn causes mechanical collapse of structures that support heel bulb (Turner & Stork 1988, Baxter & Stashak 2020). In sound horses (Group 1), the fact that horses had long toe/low heel, normal, or clubfoot conformations did not contribute to decreased perfusion on the venogram. Possibly, in this case, in addition to these animals already being adapted to the conformation of the hoof, there was no additional effect of support lameness, which caused the hooves to not perform their functions properly due to the lack of constant support of the hoof with the ground.

CONCLUSION

Lame animals with normal or long toe/low heel hoof angles presented higher fulfillment scores than animals with clubfoot hooves; it differed from sound animals, in which different angles did not influence digital perfusion. The degree of lameness was not related to contrast filling decrease in the radiographic examination of lame horses. In addition, decreased irrigation was more frequently present in the terminal arch, circumflex vessels, and dorsal laminar vessels. A larger number of animals should be tested to validate the proposed semiquantitative scale.

Conflict of interest statement.- The authors declare no conflicts of interest.

Credit author statement.- Conceptualization: Juliana V.F. Sales and Antônio R. Teixeira Neto; Methodology: Juliana V.F. Sales, Vitor D. Melotti, Alana A. Nascimento and Antônio R. Teixeira Neto; Validation: Juliana V.F. Sales and Antônio R. Teixeira Neto; Formal analysis: Juliana V.F. Sales, Antônio R. Teixeira Neto and Rita C. Campebell; Investigation: Juliana V.F. Sales, Vitor D. Melotti, Alana A. Nascimento and Antônio R. Teixeira Neto; Writing – review and editing: Juliana V.F. Sales, Antônio R. Teixeira Neto and Rita C. Campebell; Supervision: Antônio R. Teixeira Neto; Project administration: Antônio R. Teixeira Neto. All authors have read and agreed to the published version of the manuscript.

Data availability statement.- The datasets generated and/or analyzed during the current study are available from the corresponding author on reasonable request.

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