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Arterial supply to the scrotum: A cadaveric angiographic study

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Abstract

Objective: To determine the dominant arterial supply to the scrotum.

Study design: Experimental anatomic study.

Animals: Intact male canine cadavers ($n = 10$).

Methods: Barium sulfate was injected into the internal iliac artery ($n = 7$) or into the pudendoepigastric trunk ($n = 3$). The perineal, scrotal, and prescrotal skin was sharply dissected from cadavers and radiographed. Angiograms were subjectively reviewed by 3 investigators.

Results: Angiograms were completed successfully in all 10 dogs, with no difference between frozen and fresh cadavers. The dominant blood supply to the scrotum was consistently identified as arising from the ventral perineal arteries, originating from the internal pudendal arteries, coursing ventrally and cranially toward the caudal scrotum before terminating as the dorsal scrotal arteries ($n = 7$). The blood supply to the cranial scrotum was more limited ($n = 3$) as only the cranial border of the scrotum was perfused by the ventral scrotal arteries.

Conclusion: Based on this anatomic perfusion study, the dorsal scrotal arteries appear to supply a larger area than the ventral scrotal arteries.

Clinical significance: These results provide evidence to justify further consideration of a scrotal flap using the caudal perineal skin as the main cutaneous pedicle to reconstruct defects located on the caudal, medial, and lateral thighs in dogs. Such a flap should be based on the caudal blood supply and the base of this flap should be located caudal to the scrotum to preserve its main blood supply.

1 | INTRODUCTION

Wound management is based on consideration of multiple factors such as wound size, anatomic location, condition of the wound, and availability of local skin for closure. Closure of large skin defects on the medial, caudal, and lateral aspects of the proximal thigh and perineum is assumed to be challenging due to the lack of loose adjacent skin close to these problematic regions and the presence of bony prominences.[1,2] Second intention healing can be considered; however, bandaging can be challenging due to the proximity to the anus, and contamination of wounds with feces can delay or complicate wound healing.

Closure of large perineal wounds may require the use of skin flaps, including subdermal plexus flaps or axial pattern flaps. Axial pattern flaps, by definition, incorporate a direct cutaneous artery and vein at their base, which allows incorporation of a larger surface area of skin in the flap design.[3,4] Axial pattern flaps have also been associated with most consistent survival;[5] in a report of one study, a 95% survival area was described for axial pattern flaps, whereas a survival area of 53% was reported for flaps without direct cutaneous vasculature.[6]

In dogs, axial pattern skin flaps used to reconstruct wounds in the perineal and proximal thigh region have included the caudal superficial epigastric flap,[7–9] the dorsal branch of the deep circumflex iliac flap,[6] the vulvar flap in females,[10] and the lateral caudal flap.[11,12] A ventral perineal flap has been described in cats to reconstruct perineal wounds.[13] The caudal superficial epigastric flap and the deep circumflex iliac flap, although reliable in most patients, require extensive incisions due to the distant location of their base.

A scrotal transposition skin flap has been described to reconstruct wounds of the perineum and the proximomedial and caudal aspect of the thigh.[14,15] The first report, a clinical study, was performed to evaluate the use of the scrotum as a transposition flap for closure of surgical wounds in 3 dogs with excellent flap survival.[14] The scrotal pedicle flap was used to cover defects created by tumor excision in the perineum or caudal and medial aspect of the thigh. The flap survival was 100% in 2 dogs and 90% in another dog. In this study, the skin at the base of the scrotum was incised cranially and laterally, preserving a cutaneous pedicle on the side opposite the defect and maintaining perfusion via one of the dorsal scrotal arteries and the subdermal plexus. In the second report, the use of a modified scrotal flap to reconstruct perineal skin defects was described in an experimental setting in 5 dogs.[15] In this study, a scrotal flap was created by making a U-shaped incision around the scrotum, with the base of the flap at its cranial border, potentially preserving both ventral scrotal arteries and severing both dorsal scrotal arteries. Flaps had approximately 27% distal flap necrosis (range, 16.5-53.4%).

The primary objective of our study was to determine the dominant blood supply to the scrotum, to facilitate development of a scrotal flap with optimal chance of survival. We hypothesized that the dorsal scrotal arteries constitute the dominant blood supply to the scrotum rather than the ventral scrotal arteries.

2 | MATERIALS AND METHODS

Ten intact male canine cadavers, medium to large breed, weighing between 25 and 34 kilograms, of different ages, were used for this study. These dogs had died or had been euthanatized for reasons unrelated to our study and were obtained from an animal shelter with granted permission from this facility for study purposes. Some specimens were obtained fresh ($n = 6$), and others were frozen ($n = 4$); all cadavers were used at room temperature; frozen cadavers were thawed to room temperature. Each dog was placed in dorsal recumbency and any rigor mortis that may have been present was resolved by flexing and stretching of the hip and stifle joints.

A. Group A (total of 7 cadavers: 4 frozen and 3 fresh)

A ventral midline surgical approach to the caudal abdomen was performed, the terminal aorta cranial to the aortic bifurcation was isolated with blunt and sharp dissection, and the aorta was clamped 2 cm proximal to this region. An 8-French red rubber catheter was placed 3 cm into the terminal aorta via a 1 cm incision made through the ventral wall of the aorta. The catheter was secured using a single circumferential ligature that was placed around the aorta, located distal to the external iliac arteries but proximal to the internal iliac arteries. Using hand pressure 150 ml solution of barium sulfate mixed 1:1 with water (Liquibar, 60% [w/w] barium sulfate; E-Z-EM Inc., Westbury, New York) was infused into the terminal aorta. In a pilot study, which had been conducted prior to the actual research study, we found that 150 mL of barium sulfate was sufficient to fill the injected terminal aorta and all of its terminal arterial branches properly, providing adequate anatomic perfusion of the perineum. After the injection of barium, each canine cadaver specimen was placed in lateral recumbency for 5 minutes on each side, then repositioned again to dorsal. The perineal, scrotal and prescrotal skin was sharply dissected from all cadavers at the junction of the deep fascia and subcutaneous tissues. The dartos fascia was elevated with the scrotum.

B. Group B (3 fresh cadavers)

A skin incision was made on the lateral aspect of the 5th mammary gland, making a dissection plane at the level of the caudal abdominal wall to the external inguinal ring. The cranial aspect of the inguinal ring was incised to expose the pudendoepigastric trunk and deep femoral artery. The deep femoral artery was incised, and an 8-French catheter was placed within the vessel via the arteriotomy and secured with an encircling ligature around this vessel. The deep femoral artery was ligated proximal to the catheter insertion site and distal to the pudendoepigastric origin before it becomes the medial circumflex femoral artery. The caudal epigastric artery was isolated and ligated before it reached the caudal border of the rectus abdominis muscle. Using hand pressure, 25 ml solution of barium sulfate mixed 1:1 with water

(Liquibar, 60% (w/w) barium sulfate; E-Z-EM Inc.) was infused into the pudendoepigastric trunk, which perfused the caudal superficial epigastric and the cranial scrotal arteries. The same procedure was repeated on the contralateral side. In a pilot study, which had been conducted prior to the actual research study, we found that 25 ml of barium sulfate for each side was sufficient to fill the injected portion of the deep femoral artery and all of its isolated terminal arterial branches properly. The perineal, scrotal and prescrotal skin was sharply dissected from all cadavers at the junction of the deep fascia and subcutaneous tissues. The dartos fascia was elevated with the scrotum.

Each skin flap was spread out on a plastic sheet (Press'n Seal; Glad Products, Oakland, California) and radiographed (Cuattro DR, Heska, Loveland, Colorado). The radiographic studies were viewed and studied by the authors using OsiriX (Newton Graphics, Sapporo, Japan) Digital Imaging and Communications in Medicine (DICOM) viewer to evaluate distribution of the cutaneous vasculature of the perineum, scrotum, and periscrotal skin subjectively. After a group discussion between the 3 authors, consensus was reached to determine the extent and location of the vascular perfusion within the excised skin flaps. The images were then correlated with the gross flap, and after group discussion, a consensus was reached to determine the anatomical borders of the cutaneous angiosomes.

3 | RESULTS

Four frozen and 6 fresh intact male canine cadavers, medium to large breed, weighing between 25 and 34 kg, were used for this study. Angiograms were successfully completed in all 10 dogs, with no difference between frozen and fresh cadavers. Due to similar size and weight of the cadavers, all harvested skin flaps

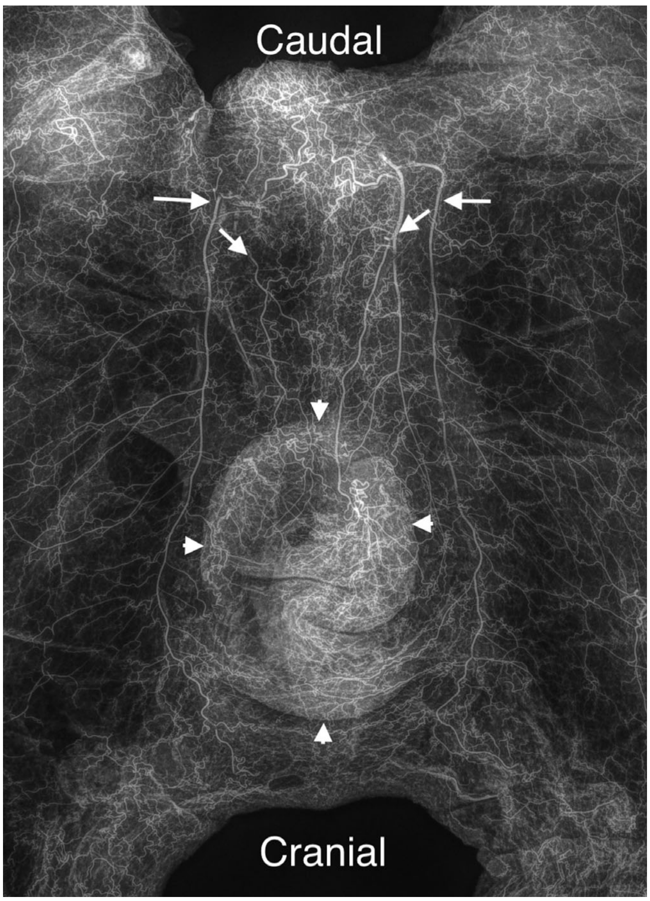

FIGURE 1 Angiography obtained after catherization of the internal iliac arteries: Note the complete anatomic perfusion of the scrotum (arrow heads) from the ventral perineal arteries (arrows). The dorsal scrotal arteries are those vessels penetrating the scrotum from the labeled ventral perineal arteries. For reference, the anus would be located at the top of the image

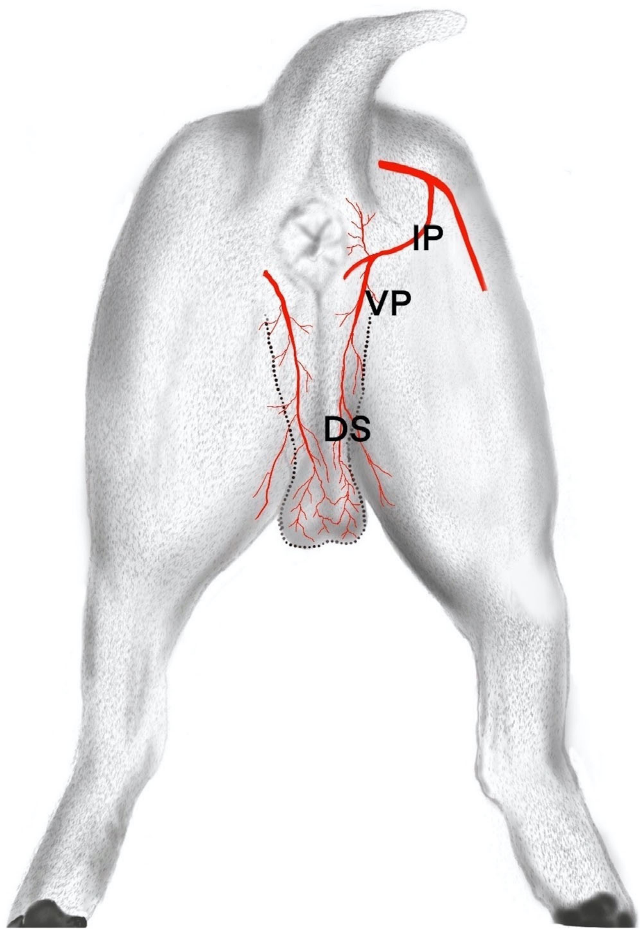

FIGURE 2 Caudal view of perineum and scrotum: Note the dominant vascular supply to the scrotum that extends from the ventral perineal arteries. DS, dorsal scrotal artery; IP, internal pudendal artery; VP, ventral perineal artery

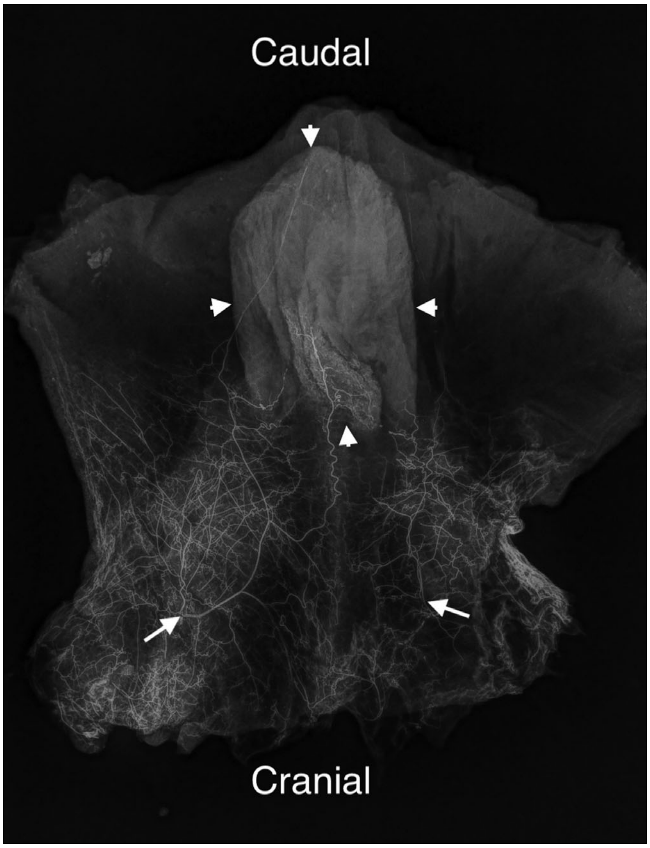

FIGURE 3 Angiography obtained after catherization of the pudendoepigastric trunk: Note the anatomic perfusion of the scrotum (arrow heads) from the ventral scrotal arteries (arrows), arising from the external pudendal arteries. Also note the limited anatomic perfusion from these vessels compared to Figure 1

were very similar with respect to total surface area and skin thickness, and the standard amount in each group was sufficient to properly fill the targeted angiosomes as expected.

Group A: In all 7 cadavers including the 4 frozen and 3 fresh cadavers, the left and right internal pudendal arteries at the ischiorectal fossae gave rise to the ventral perineal arteries. The left and right ventral perineal arteries ran sagittally along the lateral aspects of the penis and over the penis within the skin, extending from the anus to the scrotum. A series of arterial branches flanked the scrotum representing the dorsal scrotal arteries, extended from the left and right ventral perineal arteries, and gave rise to an extensive plexus of vessels that covered the entire scrotum (Figures 1 and 2).

Group B: Poor anatomic perfusion of the scrotum was present in all 3 fresh cadavers. In the 3 dogs, only the cranial border of the scrotum was perfused by the ventral scrotal arteries, and the remaining portion was either sparsely perfused or not perfused by the contrast media (Figures 3 and 4).

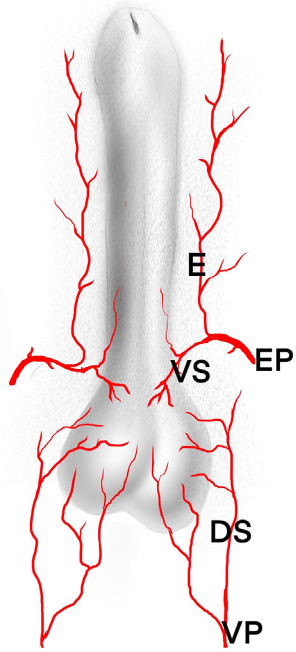

FIGURE 4 Ventral view of scrotum: Note the dominant blood supply from the dorsal scrotal arteries. DS, dorsal scrotal artery; E, caudal superficial epigastric artery; EP, external pudendal artery; VS, ventral scrotal artery; VP, ventral perineal artery

4 | DISCUSSION

The internal pudendal artery arises from the internal iliac artery, courses caudally through the pelvic canal and in the male gives off the prostatic artery at the level of the levator ani, and subsequently the caudal rectal and ventral perineal arteries, either separately or as a common trunk.[16] The ventral perineal artery travels superficially to supply the skin and fat just dorsal to the ischial plateau in pelvic outlet region; it leaves this region and courses distally and ventrally over the perineum toward the scrotum, becoming the dorsal scrotal branch (Figure 2).[16] The deep femoral artery arises from the external iliac artery with the pudendoepigastric trunk forming its major intra-abdominal branch. The pudendoepigastric trunk gives off the caudal epigastric artery before exiting the abdomen as the external pudendal artery through the inguinal canal then bifurcates terminally into the caudal superficial epigastric (coursing cranially) and the small ventral scrotal branch (coursing caudally toward the scrotum) (Figure 4).[16] The vascular supply to the scrotal skin is derived from the ventral scrotal arteries that arise from the external pudendal artery, the cremasteric artery arising from the deep femoral artery and the dorsal scrotal arteries that arise from ventral perineal branches of the internal pudendal artery. The draining veins follow the same course in reverse.[17] The branches of the ventral scrotal arteries and the dorsal scrotal arteries anastomose to supply the scrotal tissue from the cranial and caudal aspects respectively.[18] The ventral scrotal branch has been reported to be extremely small or actually absent in some dogs.[16] The scrotal blood supply courses superficially to the parietal layer of the tunica vaginalis and is also within the dartos fascia.[17]

In this study, the dorsal scrotal branches of the ventral perineal arteries were consistently found to perfuse most of the scrotum and are likely the dominant blood supply to this tissue. The scrotum has been utilized in human reconstructive efforts as a simple advancement style flap for closing defects of the adjacent inner thigh.[18] In humans, microvascular studies of the scrotal blood supply show that all the skin from the scrotal midline to its insertion into the mid penile raphe receives its vascularization via the perineal arteries and their branches, even though historically perineal arteries were considered to perfuse only the posterior face of the scrotum.[19]

The arterial contribution to the scrotal vascular supply has not been clearly defined in the dog, with the literature often referring to the external pudendal artery (via the ventral scrotal branch coursing caudally to the scrotum) as the principal perfusion to the scrotum.[17,18,20] However, the diminutive size or even absence of this vessel in male dogs is mentioned in *Miller's Anatomy of the Dog*.[16] Substantial scrotal skin flap necrosis (27%) was reported by Grigoropoulou when flaps were based on the cranial blood supply, when the caudal blood supply from the dorsal scrotal branches of the ventral perineal arteries was transected.[15] In addition, tension that is applied to the scrotal skin as it is advanced toward the perineum may result in further compromise to its blood supply. In Matera's series of 3 cases of scrotal flaps using a laterally based pedicle, at least one of the dorsal scrotal arteries likely was left intact based on their description, thus maintaining a greater blood supply to the flap, and resulting in superior flap survival (90%-100%).[14] From our study, the optimal supply for a scrotal flap would be clearly based on a caudal pedicle, including one or both of the dorsal scrotal branches of the ventral perineal arteries.

Based on the robust caudal anatomic perfusion noted in this study, it could be hypothesized that the flap could be islanded and survives purely on its vascular pedicle, but further studies are indicated. If this were shown to be the case, it would substantially enhance the versatility of the flap. In the light of the results of this study, we found evidence that justifies further consideration of using scrotal skin as an extension of the ventral perineal artery flap, and this flap could be considered as a viable axial pattern flap in most dogs.

Based on the angiograms made in this study, the flap borders should be about 2.5-3 cm lateral to the midline (in a large-breed dog) or at least the same width of the scrotal pouch to follow the rule of thumb for creation of axial flaps. These incisions can be extended to just dorsal to the ischiatic table without concern for transection of the important vasculature. The distal border of the flap is the cranial edge of the scrotum. This large flap is served by 2 large vessels, right and left ventral perineal arteries, with evidence of macroscopic communication between the right and left dorsal scrotal arteries in the perineal skin (Figure 1). We also noted anastomoses between the dorsal and ventral scrotal arteries in the scrotal skin. Survival of the extremity of the scrotal skin will be dependent on the chock vessels opening up from the right and left dorsal scrotal arteries, into the angiosome previously perfused by the ventral scrotal arteries. Care should be taken during skin flap elevation to preserve both ventral perineal arteries as they course toward the scrotum.

The scrotal tissue may not flatten completely unless the cranial a third to a half of the scrotum is divided on its midsagittal plane. This will likely not affect the blood supply to the scrotum due to the paired nature of the ventral perineal arteries. Due to the long length of the scrotal flap, its potential use may include resurfacing wounds located in the proximal thigh region. Although the width of the flap likely can be safely increased from the aforementioned borders based on our angiograms, primary closure of the donor site without undue tension will be the limiting factor.

Positioning to expose the donor and recipient sites requires the dog to be in dorsal recumbency, tilted, with positioning bags to expose the perineum. If the defect is on the lateral aspect of the thigh, the dog can be also tilted laterally with abduction of one of the hind limbs to expose the scrotum. Neutered or cryptorchid dogs may have a small or nonexistent scrotum, which may limit the size of the flap distally.

Further investigations into the regional blood supply and flap development will help determine the consistency and viability of pedicle flaps with differing geometries. More research is needed to determine whether viability is affected by the size of the scrotum in different individuals, and how much skin can be stretched without affecting its dorsal blood supply. Other studies are warranted to investigate whether the scrotal flap is applicable to previously neutered or cryptorchid dogs, as their scrotum is often reduced in size or is hypoplastic.

The number, freshness, and sizes of cadavers for this study were limited by the inherent challenges of obtaining intact male canine cadavers. The first 4 cadavers were obtained freshly frozen and the following 3 were fresh; all 7 were used to evaluate the dorsal scrotal arteries angiosome (Group A). The final 3 cadavers (Group B) were fresh and used to evaluate the ventral scrotal arteries angiosome. Findings were consistent in all specimens with no difference between the frozen and fresh cadavers. The authors consider this to be a minor limitation, which is unlikely to have affected results.

Barium sulfate was chosen in this study over iodinated contrast agents such as iohexol for several reasons: it is standard experimental protocol in other published studies in dogs[10] and cats,[13] it allows radiographic evaluation of the blood vessels with excellent filling of the injected main arteries and all of its terminal arterial branches, it allows easy visual identification of small vessels so they can be preserved during subcutaneous dissection, and it shows excellent contrast on radiographic evaluation.

The main limitation of this study is its anatomic rather than physiologic nature. Live animal studies, either in the form of a clinical case series or an experimental animal study, are needed to prove that the scrotal flap would completely survive based on the ventral perineal artery branches. Various preoperative methods have been used for vascular mapping in human reconstructive surgery to determine the location and anatomy of the dominant blood supply; these tests include computer tomography angiography, magnetic resonance angiography and Doppler ultrasonography.[21] These techniques can be utilized for preoperative angiography in canine clinical cases; we expect that selective angiography in a live dog study using fluoroscopy likely will not be practical and will not prove adequate visualization of these small vessels. Finally, in this study we did not evaluate the venous blood supply to the flap, which although is likely to be satellite in nature, may influence survival of the flap.

In conclusion, a modification of the previously reported scrotal flap is proposed from the results of this study, which may enhance its arterial blood supply. The findings of our study likely explain the disparities in the survival of the flap seen in 2 previously reported studies.[14,15] This modified scrotal flap could be considered as an option for moderate sized skin defects within its reach with acceptable cosmetic result and minimal functional impact, facilitating closure of skin defects after traumatic wound debridement or mass removal. Other axial skin flaps that are based on the dorsal branch of the deep circumflex iliac artery and vein,[6] the caudal superficial epigastric artery,[7–9] or the lateral caudal artery,[11,12] remain indicated for dogs with large wounds, if the pet owner dislikes the appearance of the scrotal skin on recipient site or if the dog is to be used for breeding. Additional clinical or experimental live animal studies are required to substantiate survival of the skin flap described in this report.

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Author Contributions: Ibrahim MH, BVSc, DVM: contributed to the study design, performed the cadaveric experiments, reviewed the radiological images for data acquisition and interpretation, and drafted the manuscript. Degner DA, DVM, DACVS: contributed to the conception of the study and study design, performed the cadaveric experiments, reviewed the radiological images for data acquisition and interpretation, and edited the manuscript. Stanley BJ, BVMS, MVetSc, DACVS: reviewed radiological images for data acquisition and interpretation, and edited the manuscript. All authors approved the final version for publication.

CONFLICT OF INTEREST

The authors declare no conflicts of interest related to this report.

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