Anatomical investigation of the canine cranial tibial artery
A potential source of severe haemorrhage during proximal tibial osteotomies

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Cranial tibial artery, triple tibial osteotomy, tibial plateau levelling, haemorrhage, canine

Summary
Objective: To investigate arterial vascularity at the level of the proximal tibia as a potential source of the severe intra-operative haemorrhage, which has been previously reported as a complication during tibial plateau levelling osteotomy (TPLO) and triple tibial osteotomy (TTO) surgeries in dogs. To devise a surgical approach for the management of this complication.

Method: Eight pelvic limbs from five canine cadavers were dissected and the vascular structures at the level of the proximal tibia were identified and photographed. An arterial phase angiogram was performed on a sixth cadaver to further describe the vasculature in situ. Additional dissection was performed on four pelvic limbs to devise a medial surgical approach to the popliteal artery and the cranial tibial artery proximal to the stifle.

Results: The cranial tibial artery was identified as the most likely source of profuse haemorrhaging if damaged during proximal tibial osteotomy. Its course and branching are described. A simple medial approach to the popliteal artery at the level of its bifurcation into the cranial and caudal tibial arteries was developed.

Clinical relevance: Understanding of the vascular anatomy at the level of the proximal tibia may prevent iatrogenic damage and resulting haemorrhage during TPLO and TTO surgeries. Temporary occlusion of the cranial tibial artery can be achieved through a simple medial approach, proximal to the stifle, in the event of severe haemorrhage associated with TPLO or TTO.

Introduction
Numerous proximal tibial osteotomies have been described for the surgical treatment of cranial cruciate ligament disruption in the dog. Each of the techniques fundamentally attempt to neutralise cranial tibial thrust by ensuring that the compressive forces on the stifle joint are perpendicular to the tibial plateau slope. Tibial plateau levelling osteotomy (TPLO) involves the creation and rotation of a cylindrical osteotomy in the proximal tibia (1). The ideal position for this osteotomy requires that the intercondylar eminences remain at the centroid of tibial plateau rotation (2). In reality, the position of the osteotomy is influenced by the location of the proximal jig pin, the size of the tibial tuberosity, the radius of the saw blade and the size of the plate. However it is commonly accepted that a more proximal and caudally located osteotomy is preferred. Three retrospective studies published in the literature have reported the complications with this procedure (3–5). In all studies, marked intraoperative haemorrhage is listed as a potential surgical complication (1–2% of cases). More recently, triple tibial osteotomy (TTO) has been described for neutralising tibial thrust by performing three osteotomies with the removal of a caudal wedge of tibia and advancement of the tibial tuberosity during subsequent fragment reduction (6). The location of the caudal tibial osteotomies in this technique is determined by the patella tendon length; however it is often very proximal in the tibia. Intraoperative haemorrhage associated with the osteotomies has also been reported as a complication with this technique (6). Due to the potential risk of haemorrhage, the proponents of both of these techniques advocate protection of the underlying soft tissues from inadvertent saw damage by the packing of gauze swabs around the area and use of retractors lateral to the tibia under the proposed osteotomy bone (7, 8).

In the authors’ experience, haemorrhage resulting from laceration of the lateral vasculature deep to the exposed tibia in both the TPLO and TTO procedures, although uncommon, can be profuse and difficult to control. Gauze swabs packed between the m. popliteus and m. flexor digitorum profundus musculature, and the caudolateral surface of the tibia provide pressure to temporarily control bleeding, however the removal of this packing is often followed by the resumption of haemorrhage. The position of the vasculature, deep and cranial to the exposed caudomedial margin of the tibia, makes visibility of...
the lacerated vessel difficult during TPLO and TTO, especially in the face of ongoing haemorrhage. The use of suction to improve visibility may lead to considerable blood volume loss. Furthermore, it has also been the authors’ experience that more than one vascular branch may be involved. The aim of this study was to identify and further describe the anatomy of the cranial tibial artery as it courses over the proximal tibia. A surgical approach to the popliteal artery as it bifurcates into the cranial and caudal tibial arteries proximal to the stifle, and to allow temporary occlusion of these vessels, is also detailed in this report. This approach involves only minor proximal extension of the standard medial incisions used in both the TPLO and TTO procedures.

Materials and methods

Anatomical study

A male Staffordshire Bull Terrier, a female Kelpie crossbreed, and three male Greyhounds, which had been euthanatized for reasons unrelated to this study, were used for cadaveric dissections of left and right pelvic limbs in order to trace the cranial tibial artery from the popliteal artery to the point where it tracks deep to the m. extensor digitorum longus. Eight limbs were carefully dissected from the lateral side. Caudoproximal reflection of the m. flexor hallucis longus and proximal reflection of the fibula were required to expose the caudal face of the proximal tibia and the associated soft tissue structures at this level, including arterial and venous structures. Photographs of the specimens were taken.

An additional radiographic and computed tomographic angiogram of the arterial vasculature of the left pelvic limb of a male Bull Terrier cross was performed. This sixth dog had also been euthanatized for reasons unrelated to this study.

Medial approach to the distal popliteal artery

Further medial dissection was performed on four limbs from three of the previously mentioned cadavers. A skin incision was made medially over the stifle consistent with that used for a medial stifle arthroplasty when performing TPLO or TTO surgery (9). A surgical approach that allowed access to the proximal cranial tibial artery directly after it’s branch-

Fig. 1 Cadaveric dissection of right tibia, caudolateral aspect. The cranial tibial artery (open arrows) can be seen as it branches from the popliteal artery and courses between the caudal stifle joint capsule and m. popliteus (reflected caudally) and then between the tibia and fibula.

Fig. 2 Caudolateral view of the cranial tibial artery and vein (open arrows) demonstrating the vascular ‘five-ways’ at the level of the proximal tibia. The fibula has been reflected proximally at its proximal articulation.

Results

Anatomical study

In all specimens, the cranial tibial artery was found to pass immediately caudal to the stifle between the tibial condyles, deep to the m. popliteus and just medial to the popliteal sesamoid. It then ran distolaterally following the course of the caudolateral buttressing ridge of the lateral tibial condyle. At about the proximal third of the tibia, the artery then coursed laterally deep to the m. extensor digitorum longus, reaching the cranial aspect of the distal tibia. Throughout the proximal third of the tibia, the artery ran superficial to its mirrored venous counterpart; both vascular structures being in direct apposition to the bone. Just distal to the fibula head articulation, a small branch coursed laterally to supply the joint capsule at this level. Distal to the most cranial aspect of the tibial tuberosity, a vascular ‘five-ways’ system arose with cranialateral branches supplying m. peroneus longus, a caudomedial branch supplying m. flexor digitorum longus, and caudal branches supplying m. flexor hallucis longus. In five of the dissected limbs, these vessels arose immediately adjacent to each other at the same level of the cranial tibial artery. In the other three limbs, these branches arose separately from a segment of the cranial tibial artery, approximately 6 mm in length. This vascular ‘five-ways’ system was considered by the authors to be consistently located at the same level of the tibial condylar cortex, which would be osteotomised during the TPLO and TTO procedures. Further distal to the ‘five-ways’, three sequential cranialateral branches were noted to leave the cranial tibial artery and enter m. extensor digitorum longus before the artery finally passed cranially, deep to this muscle, over the lateral surface of the tibia (Figures 1 & 2). The arterial angiogram performed on a single cadaver was found to be consistent with the eight anatomic dissections, again highlighting a single point of multiple vascular branching over the caudolateral aspect of the proximal tibia (Figures 3, 4 & 5).
Medial approach to the distal popliteal artery

The distal portion of the popliteal artery and most proximal part of the cranial tibial artery were reliably identified in all four specimens through a simple identical approach. The skin incision on the medial aspect of the stifle was extended proximally by 2 cm. The loose fascia between the distal muscular bellies of m. sartorius cranialis and m. sartorius caudalis was dissected with Metzenbaum scissors and a pair of Gelpi retractors was inserted to maintain retraction between these two muscles. The strong medial fascial attachment between the distal aspects of m. vastus medialis and m. semimembranosus was then sharply incised with a scalpel over a distance of approximately 3 cm and blunt dissection was performed to separate these muscle bellies allowing access to the popliteal fossa in which the cranial tibial artery could be identified as it branched from the popliteal artery (Fig. 6). Temporary vascular occlusion of the cranial tibial artery could be achieved at this level.

Discussion

Severe haemorrhage has been reported as an intraoperative complication in both TPLO and TTO procedures (3, 4, 5, 6). In some of these studies, the haemorrhage has been attributed to inadvertent vessel damage during elevation of m. popliteus and the deeper caudolateral musculature from the tibia, while in others it has been attributed to direct damage from the oscillating saw blade. All of the studies have associated the haemorrhage with injury to the popliteal artery or vein, or to both of these vessels. In the dog, the popliteal artery is the continuation of the femoral artery through the popliteal fossa entering the gastrocnemius musculature. The cranial tibial artery is the major branch of the popliteal artery. As it courses distal to the stifle along the caudolateral aspect of the tibia, the artery along with its corresponding vein, become the most likely sources of intraoperative haemorrhage associated with TPLO and TTO procedures.

In the authors’ experience, laceration and subsequent haemorrhage from the cranial tibial vein during proximal tibial osteotomies is usually easily controlled with packing between the m. popliteus and flexor musculature, and the caudal tibial cortex at the level of the osteotomy. The elasticity in the musculature apparently provides enough pressure on the packing over the lacerated vessels to stop blood loss, and any continued bleeding after removal of the packing material usually abates once the osteotomy has been reduced. In contrast, haemorrhage resulting from the laceration of the cranial tibial artery is often more difficult to control without substantial blood loss, and usually requires attenuation of the damaged vessels. This study confirmed the authors’ experience that the lacerated vasculature often appears complicated, with numerous branches involved. A vascular branching network, which we have described as a ‘five-ways’, was found to arise from the proximal cranial tibial artery at the level of the tibia at which TPLO and TTO osteotomies are commonly performed.

It has been recommended to pack gauze between the caudal and lateral surfaces of the proximal tibia and the overlying muscles so that the soft tissue structures are protected from damage by the oscillating saw blade during TPLO and TTO (7,8). Despite following this recommendation, the authors have still inadvertently damaged the cranial tibial artery in two clinical cases. This may have been
the result of inadequate amounts of packing or incorrect application. From the anatomical study, it is evident that the presence of multiple branches radiating in different directions provide vectors that hold the centre of the vascular ‘five-ways’ close to the bone. If only the cranial or caudal branches of the tibial artery are elevated from the bone with packing, or the packing is inadvertently placed superficial to the vessels, then the remaining branches may remain closer to the bone surface thus resulting in an increased risk of injury during osteotomy.

Stauffer et al. reported that the application of gauze packing and clotting agents were sufficient to control haemorrhage during TPLO surgery without the need for vessel ligation (3). However, other studies have reported the need to use haemostatic clips to ligate the damaged vessels, and Priddy et al. found that multiple attempts to place clips were invariably necessary for the control of haemorrhage (4). This has also been the authors’ experience. As blood loss can often be considerable during attempted ligation of the cranial tibial vasculature, the second aim of this study was to describe a surgical approach to the artery proximal to the stifle joint that would allow temporary occlusion at this level and decrease blood loss during attenuation. The distal popliteal artery and the proximal cranial tibial artery could be reliably accessed just proximal to the medial femoral condyle in the popliteal fossa by separating the cranial and caudal bellies of *m. sartorius* and dissecting between *m. vastus medialis* and *m. semimembranosus*. This approach was rapid and facilitated by a minor increase in the size of the surgical exposure that would be routinely used in both TPLO and TTO procedures.

Sudden attenuation of a previously patent artery supplying an extremity often causes abrupt onset of severe distal ischemia in man (10). In one human study into acute traumatic injury of the popliteal artery, 74% of patients required limb amputation when the main method of management was ligation of the injured vessel (11). In contrast, experimental ligation of the femoral artery to the origin of the deep femoral artery in dogs has not resulted in limb ischemia (12). The authors have not found any case reports in the literature of distal extremity ischemia in dogs following injury and ligation of the cranial tibial artery, nor have the authors’ recognised ischemia in their two clinical cases requiring attenuation of the injured cranial tibial artery. Based on the findings of this study, the authors propose the following approach for the control of ongoing severe haemorrhage associated with cranial tibial artery laceration that cannot be resolved with pressure alone:

1. Pack the artery at the site of the laceration to control bleeding.
2. Expose the popliteal artery proximal to the stifle as described above, and cross-clamp temporarily with an atraumatic vascular clamp; alternatively pack gauze swabs between the hamstring apparatus, gastrocnemius origins and the caudal femur in the popliteal fossa to provide enough pressure for temporary arterial occlusion.
3. Remove the distal packing caudal to the tibia, and with suction and caudal retraction of the musculature, locate the damaged vessels.
4. Place haemostatic clips or ligate all damaged vessels.
5. Remove the proximal temporary arterial occlusion to re-establish cranial tibial artery flow.

The cranial tibial artery and vein are the vascular structures most likely to be damaged during TPLO and TTO osteotomies. This study identified and further described the

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**Fig. 6** Cadaver dissection of the left pelvic limb, medial aspect. A) Medial incision over the proximal tibia as would be made for a tibial plateau leveling osteotomy (TPLO) or triple tibial osteotomy (TTO) procedure however with proximal extension above the stifle. The level of the patella (arrow head) and tibial tuberosity (solid arrow) are marked. B) Sharp separation and cranial and caudal retraction of the cranial and caudal bellies of *m. sartorius* respectively exposing *m. semimembranosus* and *m. vastus medialis*. C) Following sharp and blunt dissection of the fibrous attachment between *m. semimembranosus* and *m. vastus medialis*, retraction allows identification of the popliteal vessels proximo-caudal to the femoral condyles in the popliteal fossa (solid arrows).

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course and branching of the cranial tibial artery at the level of the proximal tibia. Improved knowledge of the cranial tibial vasculature may help prevent inadvertent damage during surgery. A simple surgical approach to the popliteal artery as it bifurcates into the cranial and caudal tibial arteries was also described. This approach allows temporary occlusion of these vessels if the cranial tibial artery is accidentally damaged during TPLO or TTO.

References


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