Surg Radiol Anat (2006) 28: 38–45
DOI 10.1007/s00276-005-0044-1

ORIGINAL ARTICLE

Didier Hannouche · Fabrice Duparc · Philippe Beaufils

The arterial vascularization of the lateral tibial condyle: anatomy and surgical applications

Received: 23 September 2004 / Accepted: 11 August 2005 / Published online: 7 October 2005

Abstract The contribution of the inferior lateral genicular artery (ILGA) and the anterior tibial recurrent artery (ATRA) in the arterial supply of the lateral tibial condyle (LTC) has not been comprehensively studied and remains controversial. Eleven knee joints were injected with colored latex and the arteries were dissected macroscopically. The ATRA yielded several osseous branches supplying the tibial metaphysis and the anterior part of the tibial epiphysis and several rami supplying the anterior tibial tuberosity and the lower part of the patellar tendon. The ILGA ran under the lateral collateral ligament and had a horizontal direction towards the retro-patellar fat pad. The ILGA yielded 4–6 branches ascending or descending perpendicularly to its main direction. Full anastomoses between branches derived from the ATRA and the ILGA were observed in front and behind the lateral intercondylar tubercle in all the specimens, but each vessel seemed to provide predominantly the blood supply to a specific area. The anterior part of the LTC drew its blood supply from the ATRA, the posterior part from the ILGA and the mid-portion from both arteries. The standard anterolateral approach to LTC fractures with sub-meniscal arthrotomy appears particularly harmful to epiphyseal vascularization since it interrupts many of the branches deriving from the ILGA and ATRA. The recent development of arthroscopy in the treatment of LTC fractures may be particularly advantageous as it spares the vascularization of the LTC.

Presented on 12.11.1999 at the "Société Française d' Arthroscopie" meeting.

D. Hannouche (✉) · P. Beaufils
Service de Chirurgie Orthopédique et Traumatologique, Hôpital André Mignot, Versailles, France
E-mail: didier.hannouche@lrb.ap-hop-paris.fr
Tel.: +33-1-49-95-91-34
Fax: +33-1-49-95-91-22

F. Duparc
Laboratoire d'Anatomie, Faculté de Médecine et de Pharmacie, Rouen, France

Keywords Anatomy · Vascularization · Lateral condyle · Tibia · Fracture · Arthroscopy

Introduction

Among the tibial condyle fractures, single-tuberosity fractures of the lateral tibial condyle (LTC) are the most frequent. Their treatment is most often surgical and aims to achieve anatomical and stable reduction to enable rapid mobilization of the knee after the procedure [23]. The treatment is usually conducted through an open-wound via an anterolateral approach with anterior desinsertion of the muscles of the leg. Stabilization is then ensured by screws or an epiphyseal plate, particularly when a crushing component is present. More recently, several publications have reported the value of arthroscopy in the treatment of fractures of the LTC. Arthroscopy enables, via limited access wounds, evacuation of hemarthrosis, a precise assessment of the joint lesions, and control of the articular surface after reduction. Arthroscopy is associated with light percutaneous osteosynthesis usually without bone grafting. The method is minimally invasive and is gradually becoming a reliable alternative to conventional surgery [1, 2, 9, 10, 15]. In addition to the direct image of the joint surface procured by the endoscope, the method is advantageous in that it spares the vascularization of the LTC deriving from the inferior lateral genicular artery (ILGA) and the anterior tibial recurrent artery (ATRA) [4, 21, 22] (Figure 1). The contribution of each of those two arteries to the epiphyseal vascularization of the LTC has not been studied extensively and the subject remains controversial. While the studies by Martinez [13] and Kirschner et al. [12] have stressed the importance of the ILGA, that of Gambarelli [8] assigns a more important role to the ATRA.

The objectives of this study were to evaluate the contribution of the ATRA and ILGA to arterial vascularization of the LTC and envisage the consequences of anterolateral surgical access routes on tibial epiphyseal vascularization.

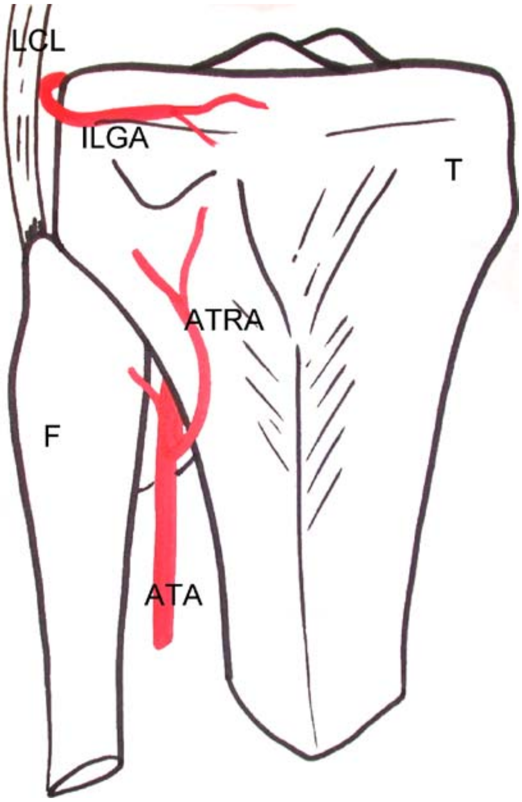


Fig. 1 Vascularization of the lateral tibial condyle by the inferior lateral genicular artery and the anterior tibial recurrent artery. *ATA*, anterior tibial artery; *ILGA*, inferior lateral genicular artery; *LCL*, lateral collateral ligament; *ATRA*, anterior tibial recurrent artery; *F*, fibula; *T*, tibia

Material and methods

The study was conducted on 11 knees, 6 right and 5 left knees, derived from 6 embalmed cadavers free from scars. The donors were three men and three women of mean age 76.8 years. Their mean height was 168 ± 8 cm.

All the knees underwent stain injection using the same technique via a longitudinal posterior approach. The popliteal artery was used as a chamber of injection, and was approached by its medial side in order not to damage the rami supplying the LTC. The pedicle supplying the medial head of the gastrocnemius muscle was systematically ligated. The popliteal artery was dissected along all its length and ligated downstream of the superior genicular arteries. The proximal part of the posterior tibial artery was ligated. After location of the ILGA, a third ligation was left upstream of the popliteal artery bifurcation, thus separating the artery into two injection chambers: one for the ILGA, the other for the ATRA (Figure 2). After flushing the artery with normal saline solution until peripheral venous distension was achieved, some 50 ml of latex (Neoprene Latex 671, UK, Dupont Limited®), stained with eosin (2% aqueous eosin, 5 ml Gilbert®) or methylene blue (methylene blue, 2 ml, Gilbert®), was injected manually under pressure into each of the arteries in succession. Injection was initiated randomly in either the ILGA or the ATRA, using each of the stains in alternation (Table 1).

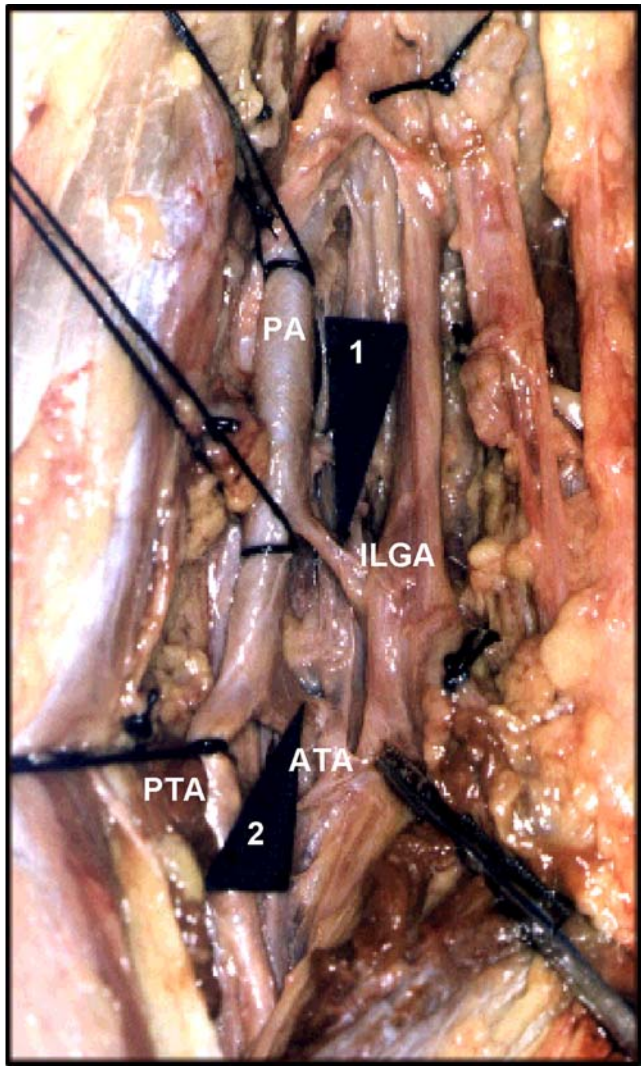


Fig. 2 Posterior view of the right popliteal artery. The popliteal artery is separated into two injection chambers. The first black arrow indicates the chamber for the anterior tibial artery (ATA), and the second the chamber for the inferior lateral genicular artery (ILGA). *PA*, popliteal artery; *PTA*, posterior tibial artery

The study began with a description of the ramifications of the various arterial branches supplying the LTC. The ATRA was dissected by an anterolateral approach. The anterior tibial muscle was reclined taking care not to damage the collaterals of the ATRA. The metaphyseal and epiphyseal distribution of the various branches was noted together with their relationships with the joint capsule of the knee. The ILGA was exposed through a window cut, 5 cm in width and 7–8 cm in length, in the iliotibial tract above the lateral intercondylar tubercle. The iliotibial tract was left inserted in the lateral intercondylar tubercle and turned back to expose the ILGA and its various collaterals. The distance of that artery relative to the joint line was measured.

Table 1 Staining used during injection in each artery

	ILGA 1 / Blue	ILGA 1 / Red	ATRA 1 / Blue	ATRA 1 / Red
ILGA 2 / Blue				2R / 3R /3L
ILGA 2 / Red			1L / 6R	
ATRA 2 / Blue		1R / 2L / 5L		
ATRA 2 / Red	4L / 4R / 5R			

ILGA, inferior lateral genicular artery; *ATRA*, anterior tibial recurrent artery; *ILGA 1 / Blue*: ILGA injected first with blue-colored latex; *4L*: case 4, left side

Following a descriptive analysis, the knee was disjointed and the bone segments bore. The LTC was then cut into 3–4 mm slices to study the intraosseous vascularization. Eight to ten para-sagittal sections were obtained depending on the size of the tibia. Each section was then measured (height, anteroposterior length, thickness) and examined. The presence of intraosseous vessels was reported and the intraosseous stain distribution on each section was documented in a diagram.

Results

Latex injection was considered easy in all cases. In all specimens, marked reflux of stained latex was observed at the level of the second artery suggesting the existence of full anastomosis of the two arterial networks. Different staining of the two vessels was only obtained twice. Table 2 summarizes the staining obtained on the two arterial networks as a function of the order of injection and color. When both networks were the same color, the proximal portion of the ILGA and ATRA was dissected and arteriotomy conducted in order to check that the injection chamber did indeed communicate with the injected artery.

Ramification of the two arterial networks

The ATRA derived, in all cases, from the first few centimeters of the anterior tibial artery at an average distance of 8 cm below the joint line. The arterial path was ascending, and oblique upwards and forwards, along the anterolateral surface of the tibial metaphysis. The artery showed a fan-like network (Figure 3) reaching the anterior tibial tuberosity and the patellar tendon as well as, above, the joint line. In all the cases, the ATRA yielded two highly asymmetrical branches: a lateral branch that supplied the head and neck of the fibula and a more bulky medial vessel that supplied a more extensive territory. The medial vessel divided nine times into two collateral branches and twice into three collateral branches. The branches of the medial vessel yielded several rami: metaphyseal osseous rami (between 3 and 7 entry points), anterior epiphyseal osseous rami (between 1 and 4 entry points), several rami supplying the anterior tibial tuberosity and anastomozing with branches derived from the inferior medial genicular artery, a ramus supplying the lower part of the patellar tendon, one ramus or several rami perforating the anterior joint capsule and anastomozing with branches derived from the ILGA, and two extra-capsular rami with an ascending direction, one in front of the lateral intercondylar tubercle and the other behind it, communicating with branches of the ILGA.

The ILGA was, in all cases, located above the lateral intercondylar tubercle on the deep face of the iliotibial tract (Figure 4a). The artery originated from the popliteal artery and had a horizontal back to front path. It turned around the LTC running under the lateral collateral ligament (LCL) and ran in the direction of the retro-patellar fat pad. In its initial portion behind the LCL, the artery was located 6–10 mm below the joint line. In front of the LCL, the artery had an ascending path crossing the joint line to terminate 10–15 mm above it (Figure 5b).

Behind the LCL, the ILGA yielded several rami supplying the head of the fibula. In front of the LCL, the artery gave rise to a series of collateral branches ascending or descending perpendicularly to the axis of the artery. Numbering 4–6, these branches were symmetrically arranged on either side of the artery (Figure 4b). After a short extra-capsular path, the branches perforated the capsule, branching out in depth (Figure 6a). In addition

Table 2 Staining obtained on the two arterial networks as a function of the order of injection and color

	ILGA 1 / Blue ATRA 2 / Red			ILGA 1 / Red ATRA 2 / Blue			ATRA 1 / Blue ILGA 2 / Red		ATRA 1 / Red ILGA 2 / Blue		
CASE	4L	4R	5R	1R	2L	5L	1L	6R	2R	3R	3L
ILGA in RED	+	+	+	+	+	+	+	+	+	+	+
ILGA in BLUE											
ATRA in RED	+	+	+	+	+			+	+	+	+
ATRA in BLUE						+	+				

ILGA, inferior lateral genicular artery; *ATRA*, anterior tibial recurrent artery; *ILGA 1 / Blue*: ILGA injected first with blue-colored latex; *4L*: case 4, left side; *ILGA in red*: ILGA looked red during dissection

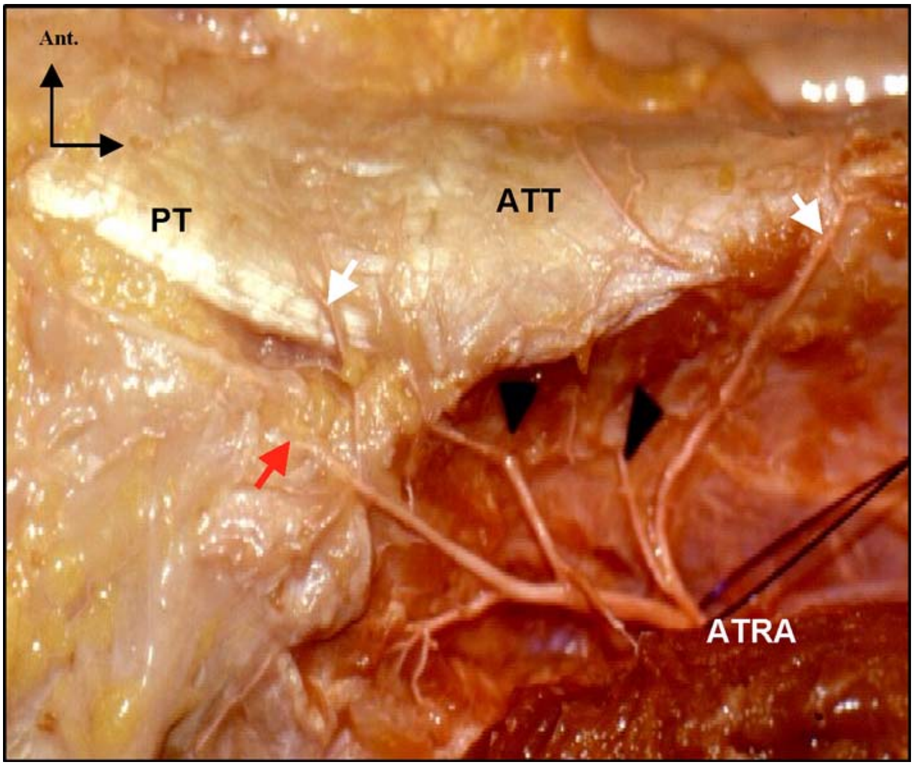


Fig. 3 The anterior tibial recurrent artery showed a fan-like network along the anterolateral surface of the tibial metaphysis. The anterior branch of the anterior tibial recurrent artery yielded several osseous branches vascularizing the tibial metaphysis (black arrow) and the anterior part of the tibial epiphysis (red arrow), several rami supplying the anterior tibial tuberosity and the lower part of the patellar tendon (white arrow). *ATT*, anterior tibial tuberosity; *PT*, patellar tendon

to those capsular rami, the ILGA also formed two extra-capsular branches of greater caliber fully communicating with branches derived from the ATRA.

In all the cases, full anastomosis between the two branches derived from the ATRA and the ILGA was demonstrated in front (Figure 5a) and behind the lateral intercondylar tubercle (Figure 5b). Dissection showed a blue–red junction zone within a given vessel confirming this hypothesis. This was observed four times: at the level of the posterior portion of the ILGA (case 5R), in the collateral branches of the ILGA (case 6R), in a posterior branch of the ATRA (case 5L), and in the intra-capsular network formed by the terminal branches of those two arteries (case 1L).

The intra-capsular branches of the ATRA formed, with the branches derived from the ILGA, a vascular plexus located on the deep surface of the capsule (Figure 6b). This fine vascular network gave rise to multiple branches, which penetrated the epiphysis at capsule insertion zone level. In one case (case 1L), a blue–red junction was noted in that network, thus confirming the contribution of both arteries to vascularization of the LTC. In another case, fine intra-capsular branches appeared to have been stained by both stains and were violet in color.

Intraosseous vascularization

The mean number of bone sections made was 8.3 (8–10). The mean anteroposterior length was 47.2 ± 8.4 mm, the mean height was 26.7 ± 3.9 mm and the mean thickness was 3.4 ± 0.5 mm. Intraosseous vessels deriving from the ATRA or ILGA were observed in all the specimens. They were more numerous on the more lateral sections but were sometimes visible on sections through the middle of the LTC. For the ATRA, the vessels had an anterior entry point and extended several millimeters in the anteroposterior axis. When the section plane was parallel to that of the vessel, the vessel path could be followed into the tibial epiphysis over about 20 mm (Figure 7). For the ILGA, the entry point was most frequently posterior and the intraosseous path seemed shorter than that of the branches derived from the ATRA.

The intraosseous distribution of the stain was difficult to interpret. While the branches derived from the ATRA were mainly distributed in the anterior part of the LTC and those of the ILGA in the posterior part, the intermediate part was vascularized indiscriminately by one or the other of the arteries. This zone was irregular and violet in color, yielding a speckled appearance on the sections.

Discussion

The LTC is vascularized by two periosteal arteries: the ATRA, a branch of the anterior tibial artery, and the ILGA, a branch of the popliteal artery. While the descriptive anatomy of the two arteries is well known [4, 6, 8, 17, 18, 19, 21, 22], the relative contribution of each of the arteries to vascularization of the LTC is yet to be fully elucidated and has only been the subject of rare

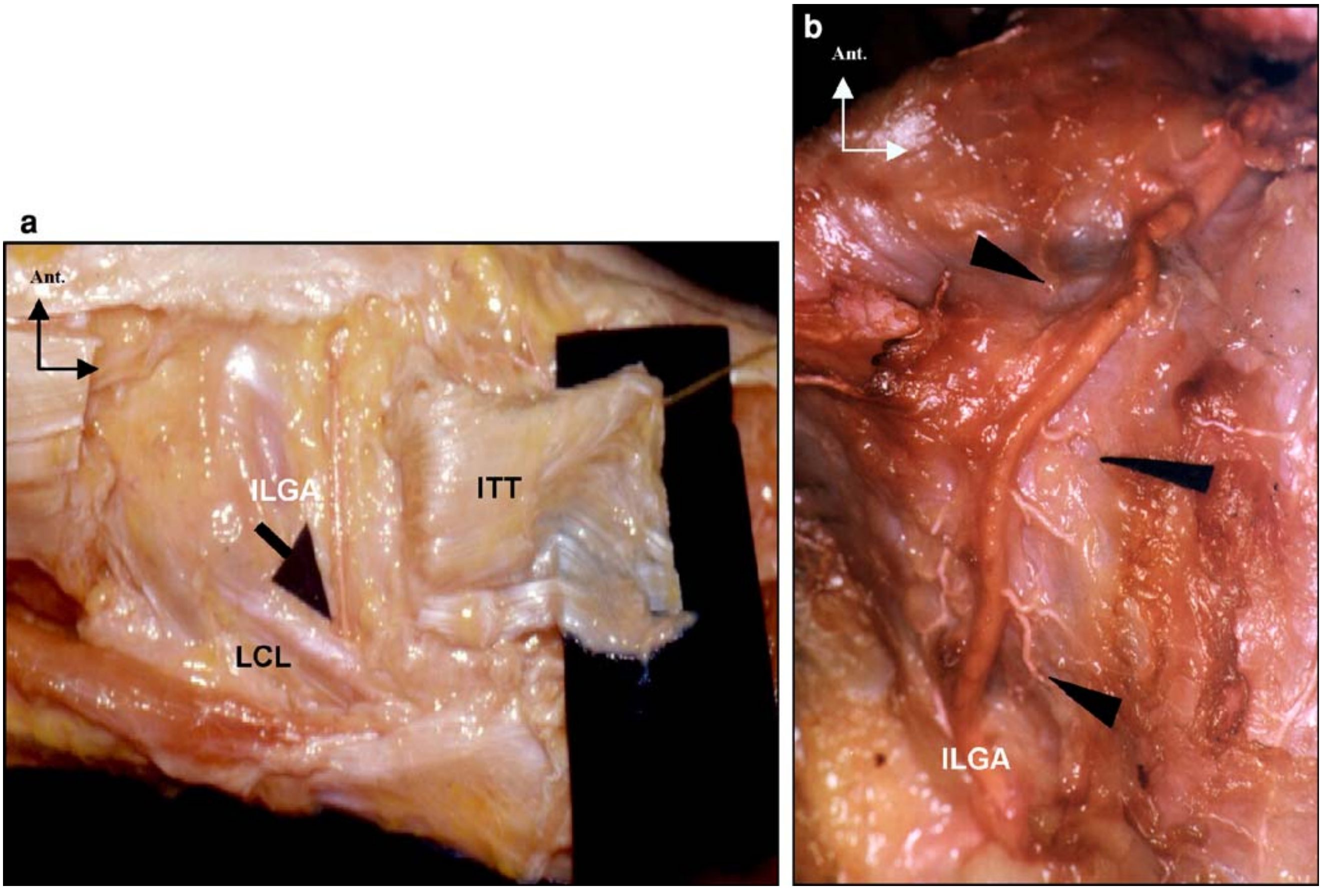


Fig. 4 a, b A window cut, 5 cm in width and 8 cm in length, was made in the iliotibial tract to expose the inferior lateral genicular artery and its collaterals. **a** The inferior lateral genicular artery ran under the lateral collateral ligament (black arrow) and had a horizontal direction towards the retro-patellar fat pad. **b** The inferior lateral genicular artery yielded 4–6 branches ascending or descending perpendicularly to its main direction (black arrow). *ITT*, iliotibial tract

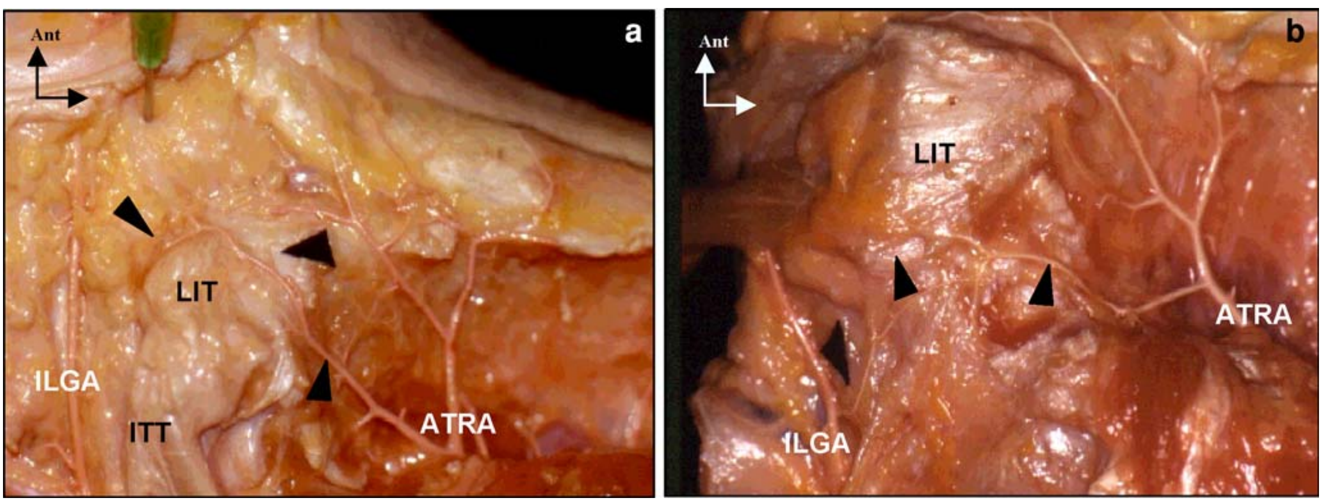
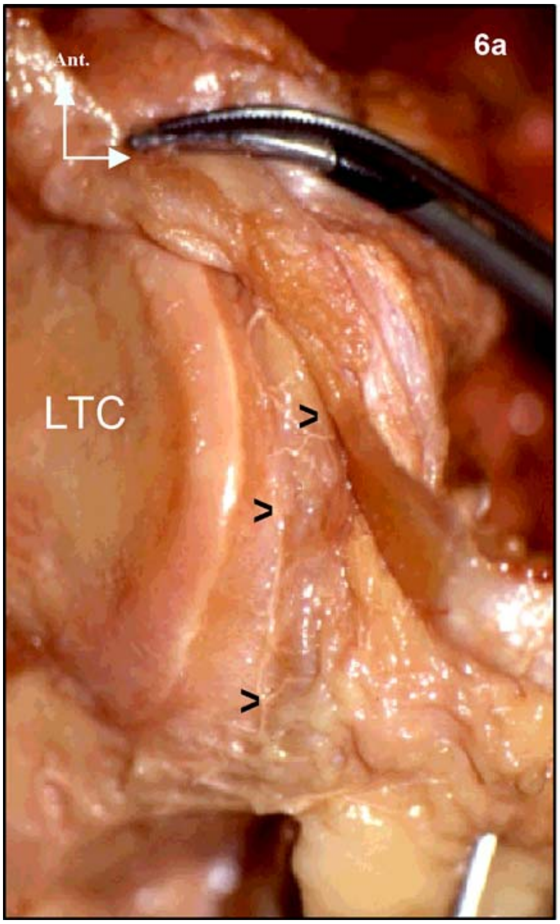


Fig. 5 a, b In all the specimens, full anastomosis between branches derived from the ATRA and the ILGA was observed in front **(5a)** and behind **(5b)** the lateral intercondylar tubercle (black arrows). The green needle indicates the femoro-tibial joint space. *LIT*, lateral intercondylar tubercle

publications. For Shim [22], distinct boundaries for the area supplied by each artery are not possible to define. Scapinelli [21] stated that the upper tibial epiphysis receives its blood supply from three groups of arteries penetrating the epiphysis radially: the juxtametaphyseal arteries, branches of the anterior and posterior tibial



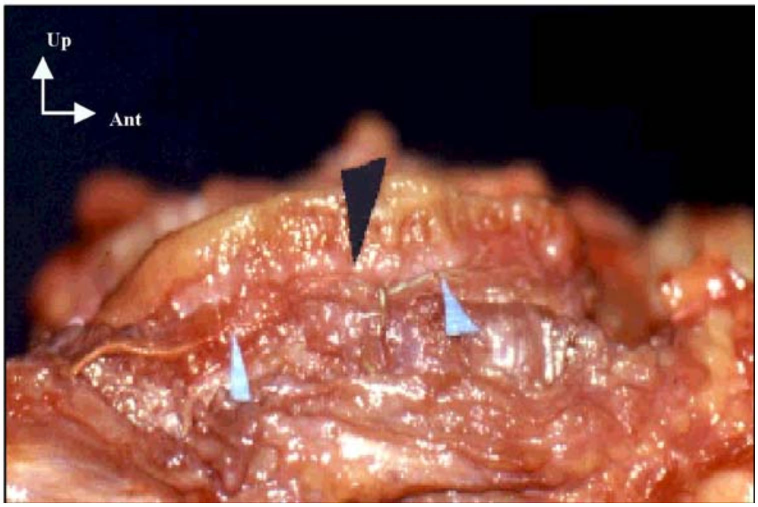


Fig. 6 a, b The intra-capsular network.**a**After a short extra-capsular path, the branches derived from the ILGA and the ATRA perforated the capsule and joined to form a vascular plexus located on the deep surface of the capsule **(6a)**. This network yielded several osseous branches for the tibial epiphysis. In Fig. **6b**, a blue–red junction was shown (black arrow), thus confirming the contribution of the ILGA and the ATRA (blue arrows) to the vascularization of the lateral tibial condyle. *LTC*, lateral tibial condyle

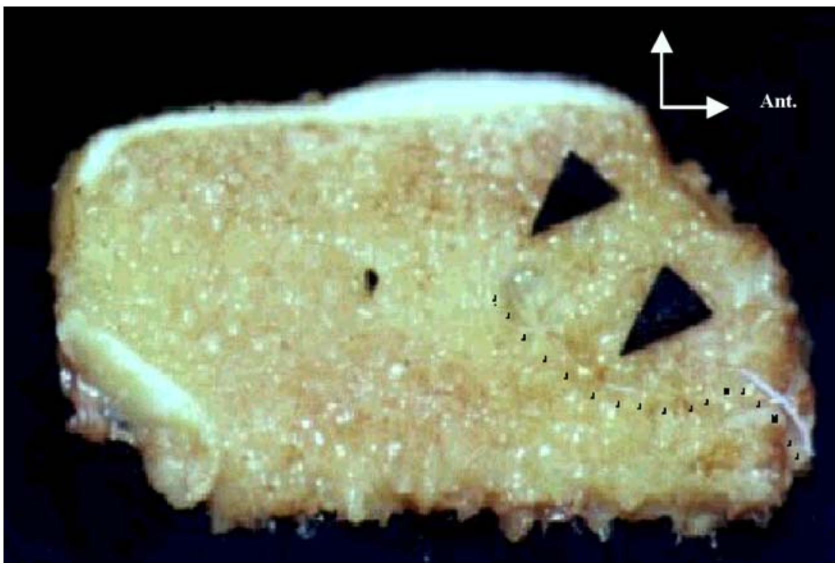


Fig. 7 Intraosseous vessels deriving from the ATRA had an anterior entry point, and extended several millimeters in the anteroposterior axis (black arrows)

recurrent arteries; the intercondylar arteries arising from the middle genicular artery; and the condylar arteries arising from the genicular arteries. Martinez [13] considered that the vascularization of the LTC is exclusively supplied by the ILGA, which turns around the LTC running directly in contact with it. Martinez considered three posterior branches of good caliber at the LCL level and multiple small branches, with more anterior locations, which penetrate the epiphysis in a radial manner at capsule insertion zone level. The predominant role of the two inferior lateral arteries in the vascularization of the proximal tibial epiphysis is also cited by Kirschner et al. [12] in a study of vascularized allogenenic grafts of the knee. Other authors [8, 16] considered that the ILGA plays a less important role. Less bulky than the inferior medial artery or the ATRA, the ILGA only rarely reaches the median line. Gambarelli [8] considered that the domain of the artery is more peroneal than tibial.

The contribution of the ATRA to the vascularization of the LTC is restricted to the metaphyseal region for most authors. This artery derives from the anterior tibial artery 6–8 cm beneath the joint line and follows an ascending path towards the tibial crest [20]. This artery is much more strongly developed than the ILGA and gives rise to a considerable number of collateral branches—Menck et al. [16] report 8–11 and, in the present study, 10–25 were observed. The branches fan out over the whole of the anterolateral surface of the tibial metaphysis where they give rise to metaphyseal osseous branches and branches supplying the anterior tibial tuberosity [19]. The ATRA also contributes to the peripatellar circle by anastomozing with rami deriving from the inferior lateral and inferior medial genicular arteries.

The present study showed that the two arterial networks are closely connected and both contribute to the vascularization of the LTC in adults. Vascularization occurs through large-caliber epiphyseal vessels and the intra-capsular capillary plexus.

The posterior epiphyseal vessels derive from the ILGA, which forms two or three branches behind the LCL. The anterior epiphyseal vessels are collaterals of the ATRA branching off before the lateral intercondylar tubercle. The intraosseous path may be 20 mm in length as observed in certain bone sections.

The intra-capsular capillary plexus observed in the entire specimens gives rise to most of the epiphyseal vessels. It is formed by the merging of branches derived from the ILGA and ATRA, which fully anastomosed in front and behind the lateral intercondylar tubercle. This intra-capsular network gives rise to rami over all the periphery of the LTC. The rami penetrate the bone in a radial manner at capsule insertion zone level [4, 5, 21].

Study of the intraosseous distribution of the stains on bone sections showed that the posterior part of the LTC was vascularized by the posterior epiphyseal collaterals of the ILGA. The anterior part was constantly vascularized by the anterior epiphyseal collaterals of the ATRA. The intermediate part was vascularized indifferently by one or the other artery (probably via the intra-capsular plexus).

Enhanced knowledge of the anatomical relationships between the two vessels supplying the LTC and their vascularization territories enables enhanced prediction of the vascular lesions that may be induced by the various surgical approaches. To the authors' knowledge, this aspect has only been addressed by two anatomical studies. Kirschner et al. [12], in a global study of the vascularization of the knee with a view to allogenenic grafting, propose approaching the knee by its posterior surface. They advise against damaging the two inferior arteries, particularly the inferior medial genicular artery. Martinez's [13] study addressed the anterolateral approach in tibial high metaphyseal osteotomy. After a descriptive study of the relationships between the various vessels and the LTC, Martinez concluded that the approach might damage the ILGA, the main vascular supply for the LTC. No mention is made of the ATRA or of the intraosseous vascularization territories. The present study shows that the anterolateral approach in fractures of the LTC is likely to jeopardize the LTC vascularization, since it interrupts a large proportion of the vessels deriving from the ATRA and the ILGA. The LTC is usually approached by a curvilinear or oblique linear route from the lateral intercondylar tubercle and reaching the tibial crest [14]. The cutaneous margins are reclined and the aponeurosis of the leg and periosteum are incised along the length of the lateral tuberosity and tibial crest. The incision is prolonged over the iliotibial tract, which is desinserted from the lateral intercondylar tubercle. The anterior tibial muscle is desinserted under the periosteum and over some 10 cm in order to expose the anterior and lateral surfaces of the upper extremity of the tibia and the upper part of the diaphysis. The joint is then opened by a horizontal sub-meniscal incision. Chaix et al. [3] prefer not to desinsert the iliotibial tract from the external separation fragment and thus conduct longitudinal arthrotomy in the continuation of the separation line. This method has the disadvantage of imposing meniscectomy. After fracture reduction, numerous authors prefer strong osteosynthesis with an epiphyseal plate. The length of the plate varies as a function of the height of the separation line and insertion sometimes necessitates prolonging the desinsertion of the muscles from the anterior limb over the diaphysis. Consequences of the anterolateral approach on the arterial blood supply of the LTC might be summarized as follows. 1 - The approach to the epiphyseal–metaphyseal region is conducted sub-periosteally, thus interrupting all the metaphyseal and epiphyseal rami deriving from the ATRA. 2 - The ILGA situated above the joint line in the anterior part of all our specimens may be damaged on incision of the iliotibial tract. Situated immediately underneath the fascia, it is nonetheless surrounded by a protective accumulation of fat. 3 - Sub-meniscal arthrotomy, indispensable for imaging the joint surface, interrupts all the intra-capsular epiphyseal rami, which penetrate the bone at capsule insertion zone level.

Overall, only a few posterior epiphyseal rami of the ILGA, situated behind the LCL, are spared. This study shows that extensive lateral surgical approach is particularly harmful to the vascularization of the LTC and the lateral soft tissue envelope. Surgical damage of the epiphyseal and metaphyseal arterial circle may explain the high complication rate historically associated with tibial condyle fractures [7]. Complications include delay in healing, nonunion [7, 11], epiphyseal necrosis, infection secondary to tissue hypoxia and osteoarthritis.

Conclusion

The vascularization of the LTC is ensured by both the ILGA and the ATRA. The ILGA mainly vascularizes the posterior territory while the ATRA mainly vascularizes the anterior territory of the LTC. The median sub-chondral region of the LTC is vascularized by a series of intra-capsular epiphyseal rami derived from the two arteries. The anterolateral approach to LTC fractures with sub-meniscal arthrotomy appears particularly harmful to epiphyseal vascularization since it interrupts many of the branches deriving from the ILGA and ATRA. The recent development of arthroscopy in the treatment of LTC fractures offers several advantages compared to the standard approach. Arthroscopy affords a view of the entire joint surface and enables precise control of the reduction. Stabilization is then ensured percutaneously using screws. Most of all, the arthroscopic management of tibial condyle fractures enables the devascularization induced by the anterolateral approach to be avoided.

References

1. Caspari RB, Hutton MJ, Whipple TL, Meyers JF (1985) The role of arthroscopy in the management of tibial plateau fractures. Arthroscopy 1: 76–82
2. Cassard X, Beaufils P, Hardy P (1999) Ostéosynthèse sous contrôle arthroscopique des fractures séparation-enfoncement des plateaux tibiaux. Rev Chir Orthop 85: 257–266
3. Chaix O, Herman S, Cohen P, Le Balc'h T, Lamare JP (1982) Ostéosynthèse par plaque épiphysaire dans les fractures des plateaux tibiaux. Rev Chir Orthop 68: 189–197
4. Crock HV (1962) The arterial supply and venous drainage of the bones of the human join. Anat Rec 144: 199–217
5. Despreux R, Fontaine M, Descamps C (1947) Vascularisation osseuse. Travaux du Laboratoire d'Anatomie de Lille, Lille, pp 167–184
6. Dubreuil-Chambardel L (1925) Variations des artères du pelvis et du membre inférieur, vol XVI. Masson, Paris, pp 1–272
7. Ebraheim NA, Sabry FF, Haman SP (2004) Open reduction and internal fixation of 117 tibial plateau fractures. Orthopedics 27(12): 1281–7
8. Gambarelli J, Aubrespy P, Courbil LJ (1954) Contribution à l'étude de la vascularisation artérielle des os longs du membre inférieur. Travaux de l'Institut d'Anatomie de la Faculté de Médecine de Marseille, Marseille, Saint-Lambert, pp 39–47
9. Gill TJ, Moezzi DM, Oates KM, Sterett WI (2001) Arthroscopic reduction and internal fixation of tibial plateau fractures in skiing. Clin Orthop 383:243–9
10. Hung SS, Chao EK, Chan YS, Yuan LJ, Chung PC, Chen CY, Lee MS, Wang CJ (2003) Arthroscopically assisted osteosynthesis for tibial plateau fractures. J Trauma 54: 356–363
11. King GJ, Schatzker J (1991) Nonunion of a complex tibial plateau fracture. J Orthop Trauma 5(2): 209–212
12. Kirschner MH, Menck J, Hofmann GO (1996) Anatomic bases of a vascularized allogenic knee joint transplantation. Surg Radiol Anat 18: 263–269
13. Martinez JL (1973) Irrigacion de los palatillos tibiales. IIe simposio internacional de ciencias morphologicas, Cordoba, Argentina, pp 479–481
14. Masquelet AC (1993) An atlas of surgical exposures of the lower extremity. Martin Dunitz, J.B. Lippincott, London, Philadelphia
15. Mazoue CG, Guanche CA, Vrahas MS (1999) Arthroscopic management of tibial plateau fractures: an unselected series. Am J Orthop 28: 508–515
16. Menck J, Bertram C, Lierse W (1992) Sectorial angioarchitecture of the human tibia. Acta Anatomica 143: 67–73
17. Paturet G (1951) Anatomie Humaine. Masson, Paris, pp 1–1096
18. Poirier P (1896) Traité d'Anatomie Humaine. Masson, Paris, pp 1–866
19. Rouvière H (1991) Anatomie Humaine, 13e édition. Masson, Paris, pp 1–774
20. Sanders RJ, Alston GK (1986) Variations and anomalies of the popliteal and tibial arteries. Am J Surg 152: 531–534
21. Scapinelli R (1968) Studies on the vasculature of the human knee joint. Acta Anat 70: 305–331
22. Shim SS, Leung G (1986) Blood supply of the knee joint. Clin Orthop 208: 119–125
23. Tscherne H, Lobenhoffer P (1993) Tibial plateau fractures. Management and expected results. Clin Orthop 292: 87–100