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Review Article

Patellar Vascularity and Surgical Intervention About the Knee: Is Postoperative Anterior Knee Pain Secondary to a Patellar Vascular Insult?

Naomi E. Gadinsky, Dean G. Lorich, and Lionel E. Lazaro*

Department of Orthopedic Surgery, Hospital for Special Surgery and New York-Presbyterian/Weill Cornell, USA

***Corresponding author**

Naomi Gadinsky, Department of Orthopedic Surgery, Hospital for Special Surgery and New York-Presbyterian/ Weill Cornell, 535 East 70th Street, New York, NY 10021, USA, Tel: 212-606-1641, Email: gadinskyn@hss.edu

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Abstract

Patients commonly report anterior knee pain (AKP) during daily activities following various knee surgeries including: (i) open reduction internal fixation (ORIF) of patellar fractures, (ii) total knee arthroplasty (TKA) and (iii) anterior cruciate ligament (ACL) reconstruction with bone-patellar tendon-bone (BPTB) autograft. It is also known that the blood supply to the patella is disrupted during these surgical interventions. We therefore reviewed the literature to investigate the disruption of patellar blood supply as a potential source of AKP following various surgical interventions about the knee joint.

ABBREVIATIONS

AKP: Anterior Knee Pain; ORIF: Open Reduction Internal Fixation; TKA: Total Knee Arthroplasty; ACL: Anterior Cruciate Ligament; BPTB: Bone-Patellar Tendon-Bone; AVN: Avascular Necrosis; MRI: Magnetic Resonance Imaging

INTRODUCTION

Despite advancements in surgical technique, patients continue to suffer from persistent anterior knee pain (AKP) following surgical interventions about the knee joint [1-4]. Rates of unexplained AKP have been reported as 33% at one year and 22% at ten years after TKA [2], while rates of 40-60% have been observed following ACL repair with BPTB autograft [3,4] and 80% following ORIF of patellar fractures [1].

During patellar fixation, TKA and ACL reconstruction with BPTB autograft, vascular supply to the patella is at risk of being disrupted [5-7]. Although patellar osteonecrosis is not usually reported following these interventions, patellar ischemia may be more common than we realize. We will therefore review the vascular supply to the patella as well as select surgical techniques to further explore ischemic pain as potential cause of postoperative AKP.

Anatomy of Patellar Blood Supply

As described in Scapinelli's cadaveric injection study [8], there are two main intraosseous arterial systems supplying blood to the patella: the midpatellar and polar vessel systems. The midpatellar vessels enter the middle third of the anterior surface of the patella through vascular foramina. The polar vessels enter the distal pole between the patellar tendon and the articular cartilage and course proximally to anastomose with the midpatellar vessels. Scapinelli also noted that there was a paucity of vascular supply to the border of the patella [8]. Because of this anatomical picture, he believed that the distal pole received greater blood supply than the proximal pole and was therefore less susceptible to avascular necrosis (AVN).

In 1980, Björkström and Goldie performed another cadaveric injection study that demonstrated small vessels feeding the border of the patella through the quadriceps tendon at the polar aspect as well as through the medial and lateral retinacular insertions [9]. They felt that circumferential wire fixation of the patella may compromise these vessels and affect healing.

Building on the findings of Scapinelli and Björkström, a more recent cadaveric anatomical study best describes the surgical anatomy of the arterial supply to the patella [5]. Using a simulated patellar fracture model and magnetic resonance imaging (MRI), this study qualitatively and quantitatively evaluated the blood supply to the patella. They found that the main blood supply to the patella comes from a peripatellar anastomotic ring formed by 6 arteries: the supreme genicular, medial and lateral superior genicular, medial and lateral inferior genicular and anterior tibial recurrent arteries. The medial superior genicular artery provides dual supply to the medial side of the ring. The lateral and medial portions of the peripatellar ring are formed from parapatellar branches representing anastomotic connections between the superior and inferior vessels both medially and laterally (Figure 1).

These medial and lateral parapatellar vessels, located within the retinaculum, give off small peripatellar branches that course through the capsule and synovial tissue to penetrate the borders of the patella. They also supply the oblique prepatellar vessels which branch off superiorly and inferiorly, course superficially and give way to the prepatellar anastomotic network. This prepatellar network exists in a thin connective tissue layer overlying the fibrous extension of the extensor mechanism and supplies the midpatellar vessels (dorsal vessel system). These dorsal vessels then penetrate the anterior cortex of the patella and contribute to the intraosseous blood supply [5].

The superior part of the peripatellar ring is formed from the superior transverse branch which anastomoses the main superior vessels of the ring. The inferior portion of the ring is formed from the transverse infrapatellar branch which runs through the fat pad posterior to the patellar tendon. The transverse infrapatellar branch gives off branches forming the polar vessel system, which runs between the patellar tendon insertion and the articular cartilage to enter the distal pole and penetrate the inferior border of the patella [5].

Therefore, to summarize the findings of these cadaveric studies, the main intraosseous blood supply to the patella can be divided into two main arterial systems: 1) the dorsal system, which includes the midpatellar vessels from the prepatellar anastomotic network that enter the anterior cortex of the patella, and 2) the radial system, which includes the peripatellar vessels and the polar vessels that feed the borders of the patella [5,8,9] (Figure 1). In Lazaro's study, MRI analysis confirmed that the majority of blood flow comes inferomedially, and that the distal pole receives greater blood flow than the proximal portion of the patella [5].

Vascular Implications Following ORIF of Patellar Factures

Patients continue to experience suboptimal clinical results following patellar fracture fixation [1,10-15]. We are able to achieve accurate reductions, stable fixation and good union rates postoperatively. However, regardless of these acceptable radiographic outcomes, patients often report poor postoperative satisfaction, rarely return to their pre-injury level of function and commonly experience anterior knee pain during daily activity [1]. One study prospectively collected functional outcomes data on 30 patients with isolated surgically treated patellar fractures [1]. Analysis revealed decreased muscle performance and persistent functional deficits at 12 months postoperatively. More significantly, 80% of participants reported AKP during daily activities postoperatively.

Many etiologies have been proposed to explain persistent AKP, including patellar osteonecrosis [16-18]. In 1955, Watson-Jones first reported histological confirmation of AVN of the proximal pole of the patella following screw fixation of a transverse patellar fracture [19]. In 1967, Scapinelli examined radiographs of transverse patellar fractures and found osteonecrosis of the proximal pole 25% of the time, as well as 3 histologically-confirmed cases of osteonecrosis [8]. In a more recent study of patients who underwent operative patellar fracture fixation, persistently hyperdense areas noted on postop radiographs were confirmed by MRI and histological analysis to be areas of AVN in 2 patients [20].

A recent cadaveric injection study was done using MRI to qualitatively and quantitatively evaluate the blood supply to the patella following a simulated transverse fracture pattern meant to replicate vascular injury seen in common patellar fracture patterns [5]. Using pairs of fresh-frozen cadaveric knees, one side of the pair was randomly selected to undergo either midpatellar or distal-pole osteotomy. Following transverse osteotomy, a decrease in patellar enhancement on MRI was observed, which

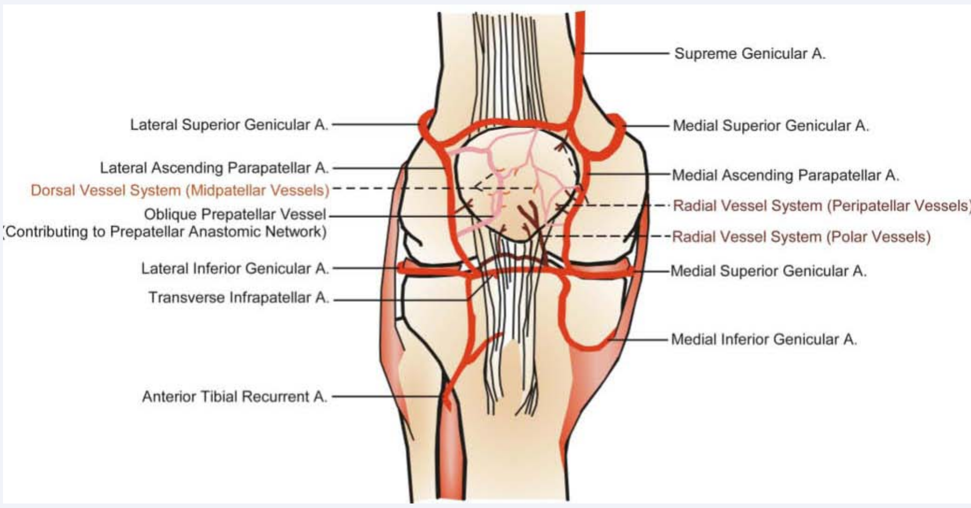

Figure 1 Drawingrepresenting the extraosseous and intraosseous vasculature of the patella. The dorsal vessel system gives off branches penetrating the anterior cortex of the patella. The radial system gives off branches penetrating the patellar border. Reprinted with permission from Lazaro et al. [8].

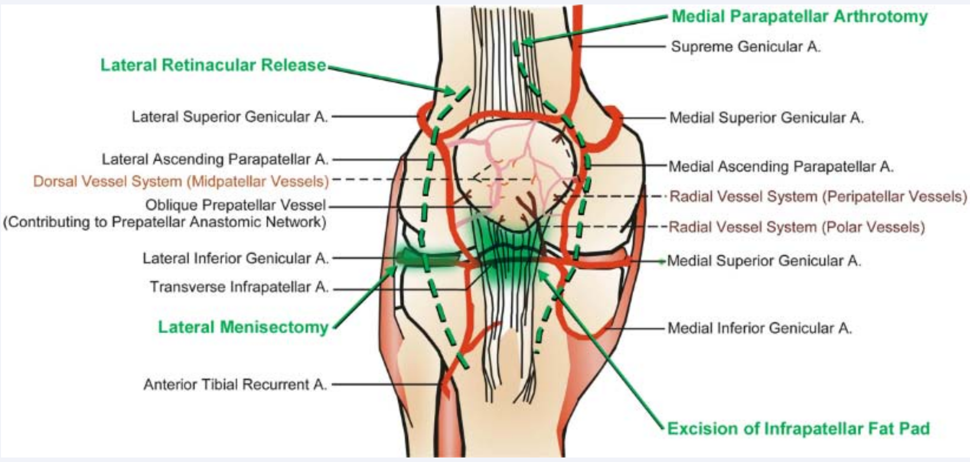

Figure 2 Drawing of the arterial supply to the patella and standard TKA approaches. Reprinted with permission from Lazaro et al. [9].

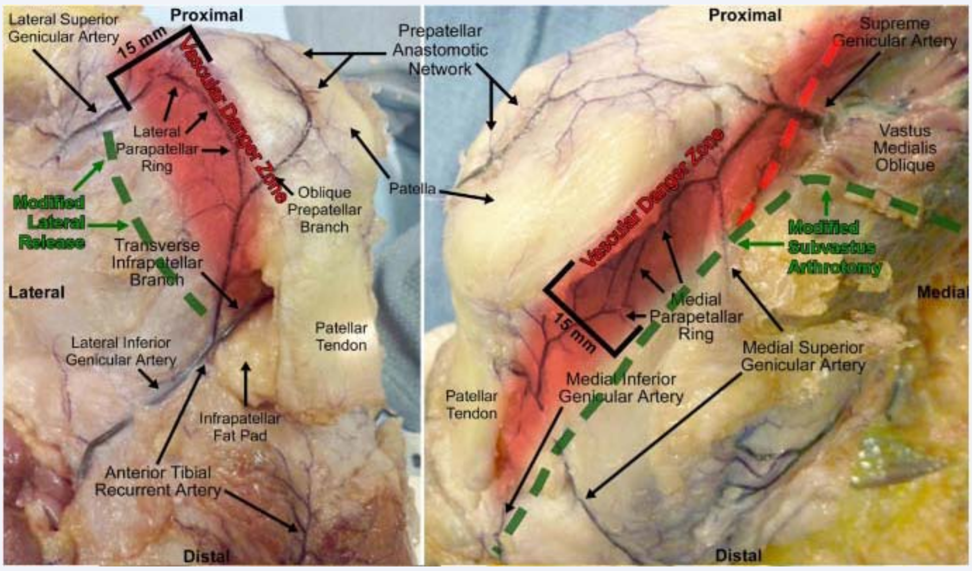

Figure 3 Gross dissection specimens with potential modifications to protect patellar vasculature a) laterally and b) medially during TKA.vReprinted with permission from Lazaro et al. [9].

was most significant in the proximal fragment in both the midpatellar and distal-pole osteotomy groups. MRI analysis also revealed that the majority of arterial supply to the patella came through the distal pole in 100% of control specimens, and that the dominant artery was inferomedial in 80%. Additionally, the distal portion of the patella exhibited 69% greater MRI enhancement than the proximal portion in intact control knees. Based on these findings, the blood supply to the patella largely comes from the inferior pole, and the proximal pole is most susceptible to a decrease in perfusion following patellar fracture. Therefore, it is imperative to leave the distal pole intact during surgical interventions such as patellar ORIF in order to preserve the main source of patellar blood flow and help prevent AVN.

Vascular Implications Following TKA

Patellofemoral joint complications following TKA are commonly reported in the literature [2,21,22], with disruption of patellar blood supply during common surgical maneuvers identified as a possible source. One study reportedthat 12% of revision TKAs were due to extensor mechanism and patellofemoral joint issues [23]. Furthermore, 33% of patients report AKP following TKA at 1 year and 22% report AKP at 10 years postoperatively [2].

Many components of the vascular supply to the patella are affected during various steps of a TKA. The prepatellar vascular network, identified in cadaveric studies as the main contributor to the midpatellar vessels [5], can be disrupted while raising medial and lateral soft tissue flaps. It has been recommended that the surgeon dissect superficially during this part of the operation to minimize disruption of these vessels [6].

The majority of the blood supply to the patella comes from the inferomedial portion of the ring, and it has been demonstrated that the medial superior genicular and supreme genicular arteries both give dual blood supply to the peripatellar ring [5,6]. Medial parapatellar arthrotomy may injure these medial arteries as well as the medial inferior genicular artery, therefore leaving the lateral arteries as the main contributors to patellar blood flow. Multiple studies have noted up to a 40% decrease in patellar vascularity following medial parapatellar arthrotomy [24,25].

Excision of the infrapatellar fat pad is also a common maneuver performed during TKA. Based on our anatomical analysis, this will compromise the transverse infrapatellar branch and the distal polar vessels, which contribute significantly to patellar blood supply [5,6]. Up to a 51% reduction in patella vascularity has been noted following complete excision of the infrapatellar fat pad [24,25].

The lateral blood supply is also at risk during TKA. Complete lateral meniscectomy can damage the lateral inferior genicular artery, while a complete lateral release can injure the inferior and superior lateral genicular vessels, disrupting the only residual arterial supply following medial arthrotomy and fat pad excision [6]. Multiple studies have observed patellar osteonecrosis and fracture in association with lateral release [26-28].

Vascular Implications Following ACL Repair with BPTB Autograft

ACL reconstruction with BPTB autograft is another knee intervention that can potentially injure the patellar vasculature. While postoperative fracture rates are low, many studies report an association between BPTB harvest and AKP [29,30], with some studies noting postoperative AKP in 40-60% of patients [3,4].

During BPTP harvest, the central 1/3 of the patellar tendon is harvested along with a small central portion of the patellar bone. The infrapatellar fat pad may be cut during the tendon harvest, potentially disrupting the polar vessels system. The prepatellar network may be disrupted during the patellar bone cut, affecting the midpatellar vessels. As shown by previous cadaver models [5,8,9], the midpatellar and polar vessels are the major contributors to intraosseous patellar blood supply.

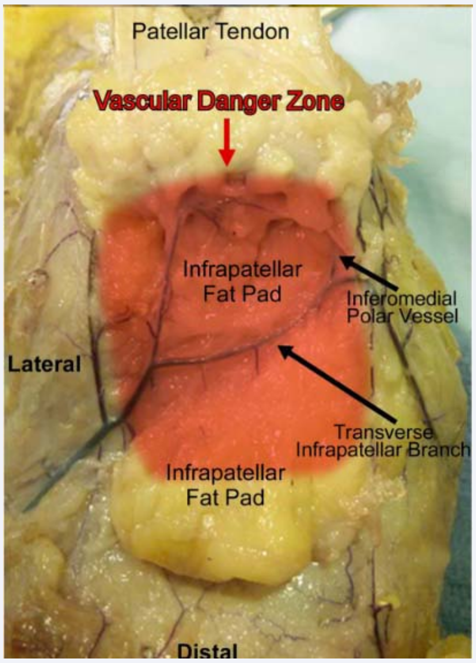

Figure 4 Gross dissection specimen showing the infrapatellar space with at-risk vessels. Reprinted with permission from Lazaro et al. [9].

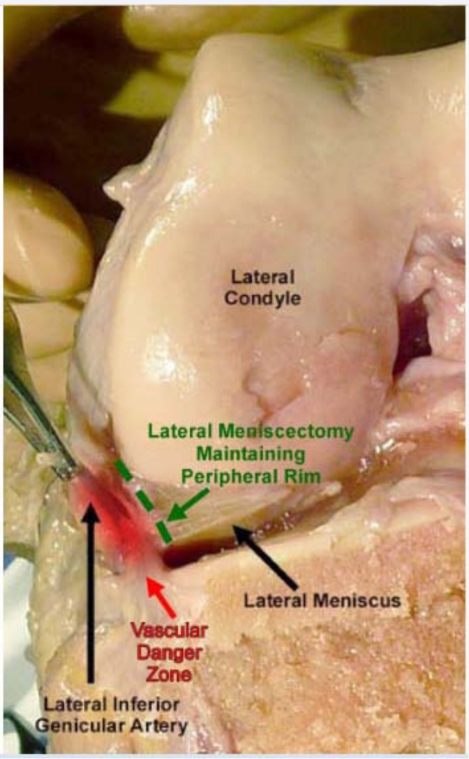

Figure 5 Gross dissection specimen revealing the close proximity of the inferior lateral genicular artery and the lateral meniscus in the lateral compartment of the knee. Reprinted with permission from Lazaro et al. [9].

Another cadaver study utilizing MRI and a simulated patellar tendon harvest [7] corroborated previous findings of a robust inferomedial blood supply to the patella. This study also demonstrated the potential for disruption of the dominant inferomedial vessel during BPTB harvest with a resultant decrease in patellar blood flow, shown by decreased enhancement on MRI.

DISCUSSION & CONCLUSION

Patellar fracture ORIF, TKA and ACL reconstruction with BPTB autograft are all associated with postoperative AKP, although the etiology of this pain is poorly understood. Based on multiple cadaveric studies [5,7-9], we have a better understanding of patellar vascular anatomy. Correlating this complex anatomy with surgical technique in patellar ORIF, TKA and ACL reconstruction with BPTB harvest, it is clear that these surgical interventions may compromise blood flow to the patella. It is reasonable to believe this may cause ischemic-type pain leading to the high rates of unexplained AKP following various interventions around the knee.

During these types of surgical interventions, steps can be taken or avoided to help minimize patellar vascular compromise secondary to iatrogenic damage. In patellar ORIF, using a

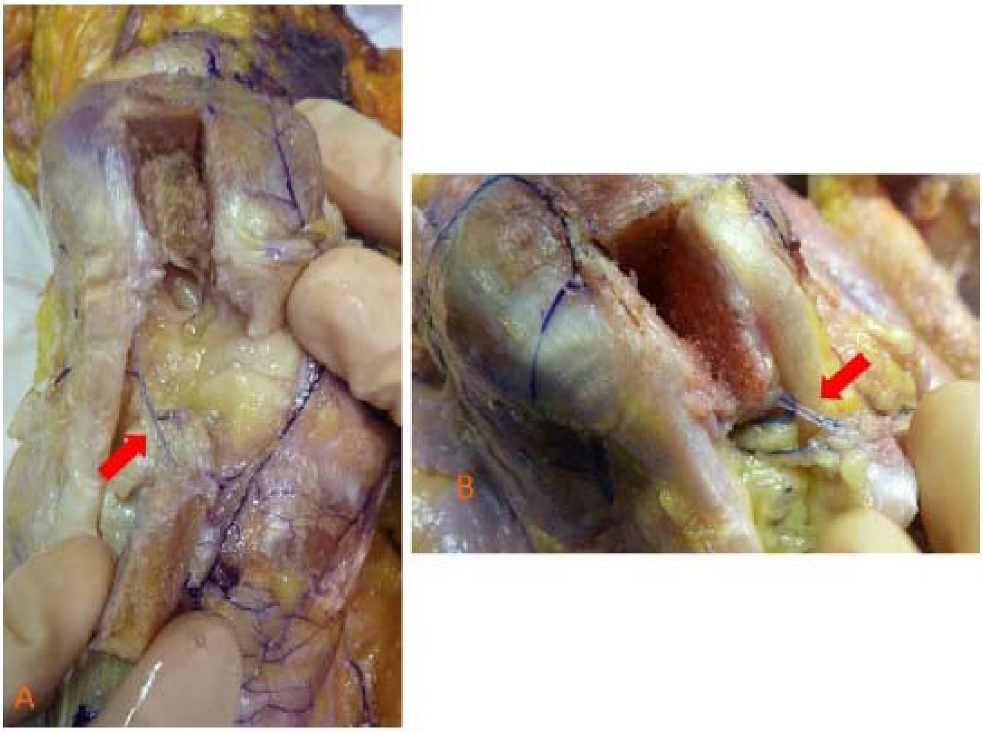

Figure 5 Gross dissection specimen revealing the close proximity of the inferior lateral genicular artery and the lateral meniscus in the lateral compartment of the knee. Reprinted with permission from Lazaro et al. [9].

circumferential wire should be avoided, as it can damage the vessels feeding the borders of the patella [9]. During fixation, care should also be taken to leave the inferior pole intact, as the majority of patellar blood flow comes inferiorly [5]. As discussed, multiple steps of a TKA can potentially damage patellar vasculature (Figure 2). Medial parapatellar arthrotomy can injure the medial vessels, and it has been recommended that performing a subvastus approach or leaving a 15mm or greater medial tissue cuff can help preserve the medial side of the peripatellar anastomotic ring [6] (Figure 3). Complete excision of the infrapatellar fat pad can damage the inferior vessels, which are the main contributors to patellar blood flow, so incomplete or minimal fat pad excision should be attempted [6] (Figure 4). Lateral meniscectomy can damage the lateral inferior genicular artery, and therefore careful lateral meniscectomy is advised, including maintaining a peripheral rim [6,31] (Figure 5). Lateral release, often performed to improve patellar tracking, can disrupt the lateral superior genicular artery, and it has been recommended that a rim of at least 15mm be left lateral to the patellar border duringminimal lateral release in order to protect the lateral blood supply [6] (Figure 3). During ACL repair with BPTB autograft, graft harvest can damage the dominant inferomedial vessel [7], so great care should be taken during tendon harvest to keep the infrapatellar transverse branch intact (Figure 6).

Further research is needed to more adequately assess ischemic pain as a cause of postoperative AKP and to investigate ways to prevent iatrogenic damage to the patellar vasculature. We are currently using cutting-edge techniques in both cadaver and in-vivo models to better elucidate exactly how disruption of the blood supply to the patella is compromised during various surgical techniques involving the knee. Functional and outcomes data including rates of AKP could then be correlated with intraoperative, *in-vivo* reductions in blood supply and surgical technique.

Postoperative AKP is significant because it limits rehabilitation efforts, which may lead to long-lasting functional impairment following various surgical interventions in the knee. Now that we have a clearer picture of patellar vascular anatomy, is crucial that we better investigate the role of ischemic pain and AVN as contributors to AKP in order to maximize surgical outcomes across multiple orthopedic specialties. Effort should focus on how to minimize iatrogenic vascular insultsduring surgical intervention about the knee, hopefully minimizing patellar ischemia and residual anterior knee pain.

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