The Arterial Supply of the Patellar Tendon: Anatomical Study with Clinical Implications for Knee Surgery

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The middle-third of the patellar tendon (PT) is well-established as a potential graft for cruciate ligament reconstruction, but there is little anatomical basis for its use. Although studies on PT vascular anatomy have focused on the risk to tendon pedicles from surgical approaches and knee pathophysiology, the significance of its blood supply to grafting has not been adequately explored previously. This investigation explores both the intrinsic and extrinsic arterial anatomy of the PT, as relevant to the PT graft. Ten fresh cadaveric lower limbs underwent angiographic injection of the common femoral artery with radio-opaque lead oxide. Each tendon was carefully dissected, underwent plain radiography and subsequently schematically reconstructed. The PT demonstrated a well-developed and consistent vascularity from three main sources: antero-proximally, mainly by the inferior-lateral genicular artery; antero-distally via a choke-anastomotic arch between the anterior tibial recurrent and inferior medial genicular arteries; and posteriorly via the retro-patellar anastomotic arch in Hoffa’s fat pad. Two patterns of pedicles formed this arch: inferior-lateral and descending genicular arteries (Type-I); superior-lateral, inferior-lateral, and superior-medial genicular arteries (Type-II). Both types supplied the posterior PT, with the majority of vessels descending to its middle-third. The middle-third PT has a richer intrinsic vascularity, which may enhance its ingrowth as a graft, and supports its conventional use in cruciate ligament reconstruction. The pedicles supplying the PT are endangered during procedures where Hoffa’s fat pad is removed including certain techniques of PT harvest and total knee arthroplasty. Clin. Anat. 22:371–376, 2009. © 2009 Wiley-Liss, Inc.

Key words: patellar; tendon; cruciate; vascular; arterial

INTRODUCTION

The middle-third of the patellar tendon (PT) is commonly utilized in Orthopaedic surgery as a graft for cruciate ligament reconstruction, yet there has been little anatomical research into the basis of this use. There are several practical attributes that make it suitable including the convenience of a single incision to harvest the graft and access the joint space, and well-located bone attachments to utilize as end-plugs. A disadvantage of middle-third PT harvest is donor site morbidity, with documented problems such as sensory disturbance and pain, inability to kneel and knee-walk, and significant radiological and histological abnormalities at 2 years post-operation (Kartus et al., 2001), as well as PT rupture

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(Marumoto et al., 1996). Certain causative factors for this morbidity have been proposed, including the interruption to the blood supply of the remaining PT (Marumoto et al., 1996). However such propositions, as well as the reason for the success of the grafted tissue itself have not been well investigated.

Interest in the vascularity of the PT has mostly arisen from concern about the risk to PT blood supply from surgical procedures such as arthroscopy (Soldado et al., 2002), and for insight into pathology such as patellar tendinopathy (Soldado et al., 2002) and PT rupture (Marumoto et al., 1996). Two previous studies have investigated the relevant vascular anatomy with reference to pedicled grafting of the PT (Paulos et al., 1983; Weinstabl et al., 1986). These studies have described the terminal ramifications of the genicular arteries in Hoffa’s (infra-patellar) fat pad and in the patellar rete, and used photography to illustrate their contribution to the blood supply of the PT (Paulos et al., 1983; Weinstabl et al., 1986; Scapinelli, 1997; Soldado et al., 2002). Whilst the locations of the main pedicles to the PT were clearly demonstrated, finer details of the source arteries and the distribution of the arterial tree as it permeates the tendon were not adequately demonstrated. The present study aims to further define the arterial anatomy of the PT to provide insight into the existing vessels of the PT graft, and the endangerment to its blood supply from certain surgical procedures.

METHODS

The investigation was performed on 10 fresh cadaveric lower limbs from six cadavers (aged 36–82, mean age 71). None of the limbs had undergone previous knee surgery. The limbs were harvested 2 days post-mortem, by disarticulation at the hip. The common femoral artery was dissected clear of perivascular tissue and cannulated. A radiopaque lead-oxide mixture was prepared according to previously described techniques (Rees and Taylor, 1986), which consisted of heated normal saline (to 50°C), 10% weight/volume of commercial grade (96% pure) lead-oxide as an orange powder, and 10% weight/volume gelatine. Each limb was submerged in a warm bath, and the mixture was slowly injected in an anterograde fashion, with the end-point of injection determined when the capillaries of the toes were deemed to be perfused by the mixture, upon distal incision. The specimens were then refrigerated for 24 hr to allow setting of the gelatine, before dissection.

Dissection comprised the identification of feeding vessels to segments of the PT, and dissection of each vessel back to its parent artery and then to the popliteal artery. Once all of the major arteries had been isolated, the named genicular arteries were identified. Upon gross inspection, the overlying anterior paratenon and Hoffa’s fat pad were noted to be richly vascularized, and thus this area was further investigated using the surgical microscope. The relationship of these vessels to the tendon proper was thus described. The vascular anatomy was imaged (and documented) with the use of serial photographs and plain radiographs, which were taken as the nontendon vessels and layers of fascia were gradually removed. A splay of the tendons was created for two-dimensional radiography, which was found to distort the normal arrangement of the tissue, and therefore surgical clips were used to mark the ends of separated vessels, and imaging software (Adobe Photoshop 7.0 CS, Adobe Systems, California) allowed digital tracing of the relevant arterial branches and annotation of the separated vessels.

RESULTS

The source vessels and extrinsic course of these vessels to the PT was adequately seen macroscopically and radiographically in all 10 specimens. The intrinsic arterial anatomy was well demonstrated in six specimens (from four cadavers), however in four specimens the intrinsic anatomy was inadequate for analysis due to a combination of tissue putrefaction and poor microvascular filling.

The arterial supply of the anterior side of the PT was provided by two separate sources, at each of the PT’s proximal and distal ends, with a longitudinal anastomosis linking the two (Fig. 1A and 1B). In all cases, the inferior-lateral genicular artery (ILGA) provided the main pedicle to the antero-proximal supply, with descending branches from the superior-lateral genicular artery (SLGA), superior-medial genicular artery (SMGA), and the musculo-articular branch of the descending genicular artery (maDGA) contributing smaller vessels (Fig. 1A). The anterodistal supply was consistently via a horizontal anastomosis between the inferior-medial genicular artery (IMGA) and the anterior tibial recurrent artery (ATRA), shown macroscopically (Fig. 1A), and both radiographically and schematically (Figs. 2 and 3A). The choke-type anastomosis (connection via many smaller branches) between these antero-distal pedicles has been previously referred to as the “supratubercular arch” (Soldado et al., 2002), discussed further below. It also provided small branches to supply the posterior aspect of the distal PT (Fig. 3B).

The arterial supply of the posterior PT differs markedly with that of the anterior side, with only one main source of vessels identified. The pedicles formed a transversely oriented anastomosis within the antero-superior aspect of Hoffa’s fat pad, which corresponded to the previously described ‘retro-patellar arch’ (Soldado et al., 2002), discussed further below. It was a true-type anastomosis because of the main connection forming from single or dual large vessels (Figs. 1B and 2). In each of the specimens, it formed as either a: Type-I (50%), with pedicles from the ILGA and maDGA; or Type-II (50%), with pedicles from the SLGA, ILGA, and SMGA with accessory input from the maDGA (Fig. 3B).

The retro-patellar arch provided descending vessels that predominantly supplied the middle-third, and smaller ascending vessels to the proximal attachment (Figs. 1B and 2). Preparation in sagittal section demonstrated that descending branches from this arch also supplied the tibial periosteum deep to the infra-patellar bursa. As with the parate-
non, Hoffa’s fat pad contains many arterial vessels of which only approximately half continue to supply the PT. Other small branches originating directly from the ATRA and SMGA contributed to the supply of the posterior side’s lateral and medial thirds. Under the dissecting microscope, deep intra-tendinous communication was observed between the anterior and posterior arterial trees, however these vessels were minor compared with the large longitudinal anastomoses that were superficial on the tendon surface (Fig. 1A and 1B).

DISCUSSION

There have been no previous studies that have demonstrated the arterial supply of the PT radiographically, with the current study achieving this and able to demonstrate the microscopic vascular anatomy of this tendon. Previous studies have largely focused on the anastomoses that occur in the peritendinous tissue and the course of the extrinsic vasculature (Soldado et al., 2002). In the current study, the use of angiographic techniques enables the three dimensional appreciation of both the extrinsic and intrinsic arterial territories of the PT, through multi-planar and cross-sectional studies and well as post-radiographic dissection studies. This provides a new perspective that allows for a more clear understanding of the PT’s arterial supply, and the discussion of several significant clinical implications.

Our study supports previous evidence of three lateral pedicles originating from the SLGA, ILGA, and ATRA, and the supply of the retro-patellar arch by
the ILGA with additional contribution from the SLGA (Soldado et al., 2002). The medial pedicles have been described with some variability in the literature, with one study highlighting the importance of the DGA in providing two pedicles, whilst suggesting the SMGA did not provide a tendon pedicle (Soldado et al., 2002). Another study reports the SMGA and DGA to form the main superior pedicles (Kirschner et al., 1996). The present study demonstrates that in 50% of specimens both of these arteries contribute medially to the retro-patellar arch, and that in 50% of specimens only the maDGA supplies the retro-patellar arch. Both the maDGA and SMGA were also found to consistently contribute to the antero-proximal tendon, which was otherwise mostly supplied by the ILGA.

Whether the human tendon graft can revascularize as a cruciate ligament is contentious. There has been only one documented anatomical study on cadavers with previous cruciate reconstruction using allografts, which demonstrated revascularization in nearly the entirety of the neo-ligament (Malinin et al., 2002). Other knowledge is deduced from post-surgical biopsy studies of the human graft, with both evidence of revascularization (Malinin et al., 2002) and also reports of the “avascular graft” (Arnoczky et al., 1982). Several animal studies indicate that there is an ordered sequence leading to the revascularization of the graft, from the ensheathing of a synovial envelope to the ingrowth of vessels from the femoral attachment, infra-patellar fat pad, and posterior joint (Sckell et al., 1999; Yoshikawa et al., 2006). Vascular endothelial growth factor expression has also been demonstrated in the animal neo-cruciate ligament (Yoshikawa et al., 2006). In

![Fig. 2. Radiograph of the patellar tendon vasculature, with this specimen sectioned into anterior and posterior halves. The schematics are views of the external tendon surfaces with labeled genicular arteries (SLGA, superior lateral; ILGA, inferior lateral; SMGA, superior medial; IMGA, inferior medial; maDGA, musculo-articular part of descending; ATRA, anterior tibial recurrent). Upper: The anterior half receives supply from five genicular arteries, with anastomoses near the proximal and distal attachments, and in the central area. Lower: The posterior half exhibits a well-developed retro-patellar arch between the maDGA and ILGA arterial pedicles. A few branches ascend to supply the posterior half’s proximal attachment, but the richest supply is seen descending in the central third which continues to anastomose with vessels from the ATRA and SMGA.](image)
the specimens of the present study, the middle-third of the PT contained a greater number of arterial vessels compared to the lateral and medial thirds, with vessels descending from the retro-patellar arch to course longitudinally with the tendon fibers. As studies with other tissues indicate, angiogenesis occurs from a pre-existing endothelium (Folkman, 1985; Yoshikawa et al., 2006), and as such the richer vascular bed of the middle-third PT may theoretically act as a better scaffold for revascularization and ingrowth as a graft.

Our anatomical findings suggest that the insult to both the intrinsic and extrinsic vasculature after middle-third PT harvest, may significantly interrupt the blood supply to the residual tendon. PT rupture is a rare but significant surgical complication of middle-third PT harvest, with one case-report suggesting that devascularization may be a cause (Marumoto et al., 1996). Certain techniques of open ACL reconstruction and total knee arthroplasty involve partial or total resection of the fat pad. Several studies suggest that when Hoffa's fat pad is preserved, it plays a key role in the regeneration of the middle-third defect (Sanchis-Alfonso et al., 1996; Atkinson et al., 1998; Sanchis-Alfonso et al., 1999), in addition to the contribution from the anterior paratenon (Sanchis-Alfonso et al., 1999). However, it has been shown in the animal model that when the fat pad is preserved (albeit with incision) during PT harvesting, there are proliferative changes in the remaining tendon and a fibrotic thickening of Hoffa's fat pad. It is therefore suggested that these processes may be implicated in the pathogenesis of infra-patellar contracture syndrome and anterior knee pain (Atkinson et al., 1998, 1999). In theory, removal of parateninous tissue (e.g., Hoffa's fat pad) in addition to harvest of the middle-third PT, may correspond to removal of important arterial anastomoses and supply-

**Fig. 3.** A: Arterial territory of the anterior surface of the patellar tendon. The supply of the anterior side was found to be consistent in all specimens, with one type of conformation depicted. B: Arterial territory of the posterior surface of the patellar tendon. Two types of conformation are depicted for the posterior side. Type I derives the main supply from a two-artery retro-patellar arch (50% of specimens), whereas Type II derives the main supply from a three-artery retro-patellar arch with a further accessory artery (50% of specimens). Main arteries: superficial femoral (yellow); descending genicular (purple); popliteal (red); and anterior tibial (blue).
ing vessels, and this may compromise the PT’s regenerative ability. Other knee approaches that endanger this vasculature include double para-patellar incisions, lateral retinacular release and posterolateral corner repair, as appreciated in other publications (Vialle et al., 1997; Soldado et al., 2002). The surgeon need have an awareness of the course of the tendon pedicles, and have caution when exposing the surroundings of the PT during such procedures.

**CONCLUSION**

The finer details of the intrinsic and extrinsic arterial supply of the PT have been demonstrated in the current study. The use of angiographic techniques, not previously described, present radiographic evidence of the pedicles and the intra-tendinous course of their branches, and we have ultimately described this supply by arterial territories. The consistent findings between all specimens, demonstrating the tendon vessels arising from three main sources, show that the anterior side is consistently supplied by the ILGA proximally, and that the supra-tubercular arch distally forms from the ATRA and the IMGA. The pedicles to the retro-patellar arch were variable, with two configurations identified and described. This study invites further investigation of the PT vascularity to strengthen our understanding of the anatomical variability.

These findings have implications for current reconstructive and orthopedic techniques, including supporting the conventional use of the middle-third PT for cruciate ligament reconstruction, and highlighting the vessels that may be endangered in surgical approaches to the knee.

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**REFERENCES**


