CASE REPORT

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Anatomical variations of the popliteal artery as a risk factor for its laceration during total knee arthroplasty: controversies with illustrative case report

Anatomske varijacije poplitealne arterije kao faktor rizika za njenu laceraciju prilikom totalne artroplastike kolena: kontroverze uz ilustrativni prikaz slučaja

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Abstract

Introduction. Popliteal artery (PA) injury during knee replacement surgery is a rare but extremely serious complication. Most vascular complications during knee surgery can be prevented by a careful preoperative assessment of the patient. **Case report.** We present the case of a 51-year-old woman who was admitted to the hospital to undergo routine total knee arthroplasty (TKA) surgery due to rheumatoid arthritis. The patient underwent surgery *via* standard medial parapatellar approach under spinal anesthesia. A fixed-bearing implant was used. The operation was successfully performed, but after removing the tourniquet, excessive bleeding was encountered, indicating a possible injury to the PA, hence the tourniquet was placed again. Severed PA was noted after exploration of the popliteal region, while the posterior capsule was not damaged. Revascularization with a Dacron vascular graft was performed immediately. On the third day following surgery, the patient had complaints that caused a suspicion of graft occlusion, and she was transferred to the Clinic for Cardiovascular Surgery. Multidetector computed tomography angiography confirmed total occlusion of the popliteal Dacron graft, and surgery was performed. The occluded graft was removed, and a popliteal-tibioperoneal trunk bypass was performed using an autologous great saphenous vein graft. Lateral and posterior fasciotomies were performed as well. At the three-month follow-up examination, the patient remained asymptomatic, with improvement in ankle dorsiflexion function. **Conclusion.** Preoperative assessment can help identify patients who are at the highest risk of complications of PA injury during their TKA. If vascular complications occur, early recognition and immediate intervention by a vascular surgeon are essential for a positive treatment outcome.

Key words:
arthritis, rheumatoid; arthroplasty, replacement, knee; computed tomography angiography; intraoperative complications; popliteal artery; risk factors; treatment outcome.

Apstrakt

Uvod. Povreda poplitealne arterije (PA) tokom operacije zamene zgloba kolena je retka ali izuzetno ozbiljna komplikacija. Većina vaskularnih komplikacija prilikom operacija kolena može se sprečiti pažljivim preoperativnim pregledom bolesnika. **Prikaz bolesnika.** Prikazana je 51-godišnja žena koja je primljena u bolnicu na rutinsku operaciju totalne artroplastike kolena (TAK) zbog reumatoidnog artritisa. Bolesnica je operisana standardnim medijalnim parapatelarnim pristupom u spinalnoj anesteziji. Korišćen je implant sa fiksnim ležajem. Operacija je uspešno obavljena, ali je nakon otpuštanja poveske došlo do prekomernog krvarenja, što je ukazalo na moguću povredu PA, te je poveska ponovo postavljena. Povreda PA je uočena nakon eksploracije poplitealne regije, dok zadnja kapsula nije bila oštećena. Revaskularizacija Dacron vaskularnim graftom je odmah urađena. Trećeg dana nakon operacije, bolesnica je imala tegobe koje su izazvale sumnju na okluziju grafta te je prebačena na Kliniku za kardiovaskularnu hirurgiju. Angiografija multidetetorskom kompjuterizovanom tomografijom je potvrdila totalnu okluziju poplitealnog Dacron grafta i urađena je operacija. Okludirani graft je uklonjen, a poplitealno-tibioperonealni bajpas je urađen korišćenjem autolognog grafta vene safene magne.

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Urađene su i bočne i zadnje fasciotomije. Na tromesečnom kontrolnom pregledu bolesnica je i dalje bila bez simptoma, uz poboljšanje dorzalne fleksije skočnog zgloba. **Zaključak**. Preoperativna ispitivanja mogu pomoći u identifikaciji bolesnika koji imaju najveći rizik od komplikacija povrede PA tokom TAK. Ako dođe do vaskularnih komplikacija, rano prepoznavanje i hitna intervencija vaskularnog hirurga su esencijalni za pozitivan ishod lečenja.

Ključne reči:
artritis, reumatoidni; artroplastika kolena; angiografija, tomografska, kompjuterizovana; intraoperativne komplikacije; a. poplitea; faktori rizika; lečenje, ishod.

Introduction

The incidence of popliteal artery (PA) injury (PAI) during total knee arthroplasty (TKA) is relatively low, from 0.03% to 0.2%. The consequences of the PAI might be very serious, including limb loss or even death [1, 2]. The most commonly reported vascular complications following TKA were a variety of injuries such as laceration or transection, (false) aneurysm formation, arteriovenous fistula, and thrombosis. PAIs are present in several forms, ranging from acute bleeding to discrete swelling, occurring sometimes several months following TKA. The literature on this topic comprises individual case reports, case series, and surveys that provide information concerning surgeons' experiences of PAI following TKA. A review of the literature has shown multiple risk factors that predispose patients to arterial complications after TKA [3–8]. It is not surprising that the highest risks of PAI are associated with revision arthroplasty or previous injuries of the knee joint affecting the posterior capsule [2, 3, 9, 10]. Revision surgery or surgery near the knee joint compromises the anatomic relationships in the popliteal *fossa,* which may also increase the risk of vascular complications [2, 10–14].

Morphological variations and branching patterns of the PA, as well as the anatomical positions of other structures, such as the popliteal vein, tibial nerve, and common peroneal nerve, are considered risk factors during TKA [8, 15]. In order to minimize the risk of lesions on the PA during TKA, most knee surgeries are performed with the knee at 90° of flexion, as it is believed to be a safe position for the PA. On the other hand, it has been reported that the PA moved closer to the tibia or was not removed when the knee was flexed [16]. The popliteal vessels are found to be at major risk at 90° of knee flexion, as confirmed by other authors [17, 18].

Arthroscopy and TKA are two orthopaedic procedures in which instrumentation is routinely placed near the posterior capsule of the knee. Closer proximity of the PA and the posterior horn of the lateral meniscus was noted as opposed to the medial meniscus, and with respect to the clinically relevant tibial plateau as it crosses the joint line [19–21].

We present a case of the PA lesion caused by indirect injury during TKA, thus highlighting the anatomic relationships as a respectable risk factor. We clarify the patient factors that influence the TKA surgery, such as the PA position to the tibial plateau, the movement of the PA during knee flexion, the influence of the variable branching pattern of the PA, as well as the importance of meticulous surgery, especially in cases in which anatomical relationships of the major vessels to the tibial surface could be affected by comorbidities.

Case report

A 51-year-old female was admitted to the hospital to undergo routine TKA for rheumatoid arthritis (RA). She had symptoms of marked pain, including left leg weakness, limited motion, and left knee instability. She had been suffering from RA for 10 years and from hypothyroidism for 5 years, during which time she had been properly medicated. The patient's medical history included right total hip arthroplasty (5 years ago). She denied lower extremity claudication, vascular disease, or chest pain.

A physical examination prior to primary TKA revealed a moderately obese female (165 cm, 70 kg) with left knee pain, knee deformity (hypertrophic synovial membrane and severe varus), and laxity of the lateral collateral ligament. The range of motion of the knee was from 15° lack of full extension to 90° of flexion. She had no signs of chronic ischemia or thrombosis in the leg. Preoperative radiographs revealed marked depression on the medial tibial plateau and destruction on the medial femoral condyle (probably necrosis). There were osteophytes on the posterior tibia. Preoperative radiographs confirmed the 18° of femorotibial anatomic varus.

The patient underwent surgery under spinal anesthesia, which lasted 100 minutes. Surgery had been performed *via* standard medial parapatellar approach with a tourniquet in place. A SIGMA PS fixed-bearing implant (De Puy – Johnson & Johnson, Warsaw, Indiana, USA) had been used.

The knee position during the operation was between 90° and 100° of flexion. The articular surface of the femur was resected, and the trial implant was inserted. The tibia was pushed forward and held in a position similar to the knee dislocation during the resection of the articular surface. The distal femur was held posteriorly, compressing the posterior capsule. The trial tibial component was inserted to check the position of the knee. The same maneuver was performed during the insertion and fixation of the cemented prosthesis. Bearing in mind that the physical examination revealed severe limitation of the knee movement in RA and a significant varus deformity, it could be assumed that the posterior capsule was thickened, shortened, and lacked elasticity. Damage to the PA might have been caused by the force used to position the tibia for inserting the implant.

The tourniquet was released after 87 minutes, prior to implantation of the bearing component to ensure hemostasis. Excessive bleeding was encountered, indicating injury to the PA. The bleeding was stopped by repositioning the tourniquet. Due to this, the general surgeon was immediately alerted, surgery was completed, and the patient was introduced to

general anesthesia and placed into the prone position. The patient underwent immediate exploration without prior investigation. The popliteal region was explored *via* the straight posterior incision. Intraoperatively, the general surgeon noted the extremely thin and fragile PA, which was completely severed and retracted. The posterior capsule was not damaged. Revascularization with a Dacron vascular graft was performed using systemic heparinization. The tourniquet was released after 150 minutes (encountering the prior intervention). The regular thromboembolic arthroplasty prevention protocol, which included subcutaneous injection of fraxiparine twice daily for 5 days (determined based on the patient's body weight), was administered.

Postoperatively, the peripheral arterial pulse on the *dorsalis pedis* artery was palpable, and the temperature and coloration of the lower leg were normal. The orthopedic surgeon examined the patient daily and did not notice anything that could indicate any circulatory problem in the left leg and foot. The patient experienced severely decreased sensation in the right foot and calf, along with no significant weakness of ankle dorsiflexion, which was related to the tourniquet utilization time. On the third day following surgery, the patient began experiencing the absence of palpable peripheral pulses (pedal and posterior tibial) and coolness of the left lower limb, with complaints of numbness and tingling below the knee and rest pain in the calf. Based on medical history, the patient was diagnosed with graft occlusion and was immediately transferred to the clinic for cardiovascular surgery. Vascular examination revealed a livid left foot, very cold on palpation, without dorsal flexion movement ability. Multidetector computed tomography angiography revealed total occlusion of the popliteal Dacron graft, and emergency reconstruction was indicated (Figures 1 and 2). The occluded graft was resected, and a popliteal-tibioperoneal trunk bypass

Fig. 1 – Multidetector computed tomography angiography – lateral view of the occluded popliteal Dacron graft.

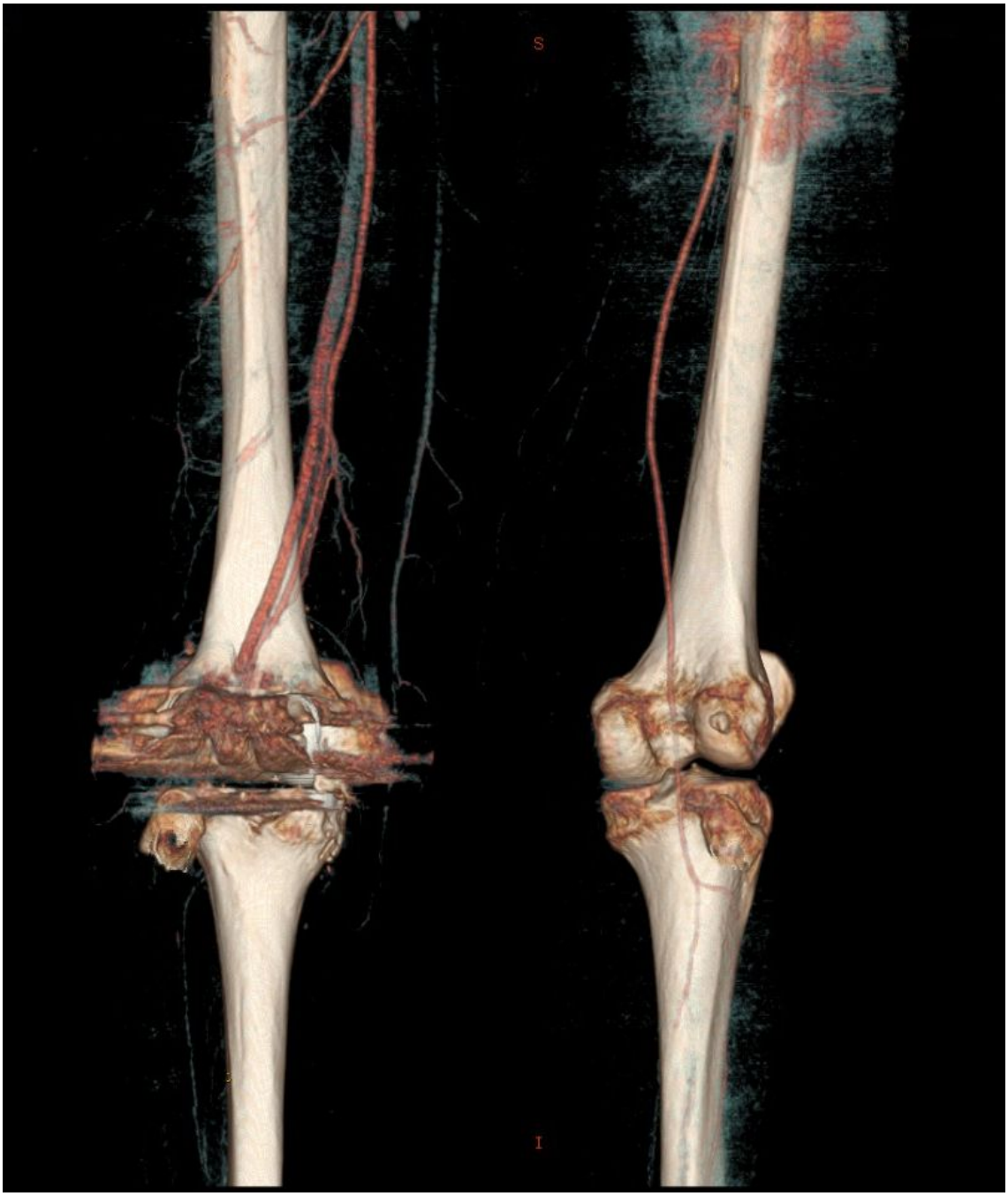

Fig. 2 – Multidetector computed tomography angiography – posterior view of the occluded popliteal Dacron graft.

was performed using an autologous great saphenous vein graft. Both anastomoses were performed in the terminal-lateral method using a 6–0 polypropylene continuous suture. Both lateral and posterior fasciotomies were performed as well.

Necrectomy of the wound, secondary seam, and cover of the skin defect with Thiersch's grafts were performed in the later postoperative course. The wound on the front side healed primarily. There were no signs of infection, the peroneal nerve was partially recovered, and the patient was able to walk with a cane. At a three-month follow-up examination, the patient remained asymptomatic without pain or swelling. The examination indicated evidence of improved function of ankle dorsiflexion.

Discussion

TKA and high tibial osteotomy are common orthopaedic operations with rare vascular complications. The incidence of reported complications is 0.03–0.5%, but they probably occur more commonly than is suggested by the literature [4, 5, 22, 23]. The PA is especially at risk during the following situations: the removal of osteophytes from the proximal aspect of the posterior femoral condyles, the release of

the posterior capsule, and the resection of the proximal tibia with an oscillating saw [24].

Analyzing national data over 14 years in the USA, Dua et al. [5] noted that 93% of patients underwent TKA that was complicated by PAI and had osteoarthritis as their primary diagnosis. In addition, 65% were female and the average age was 61.7 ± 12.3 years. Tearing of the PA during standard surgical manoeuvres might be related to peripheral vasculopathy caused by hypothyroidism in older patients [25, 26].

PAI has two mechanisms – direct and indirect. Direct trauma may cause intraoperative hemorrhage, pseudoaneurysm, or arteriovenous fistula, while indirect trauma may cause intimal damage, atheromatous plaque disruption, or both [5, 9, 13, 14]. A review of the literature demonstrated that direct trauma is the most common mechanism in up to 78% [9, 22, 23, 27]. Pal et al. [9] presented nine cases of PAI following TKA. Seven (78%) were due to direct injury (three arterial lacerations, two pseudoaneurysms, and one arteriovenous fistula), and two (22%) were due to indirect trauma (thrombosis). Identical results were published by Bernhoff et al. [23] as a nationwide study of PAI during knee arthroplasty in Sweden (78% were due to penetration and 22% due to blunt trauma). They identified three different presentations of injury: bleeding in 44%, ischaemia in 21%, and false aneurysm formation in 35%. Compared to what can be found in the literature, the mechanism of the PAI in our case was common – during the removal of osteophytes and release of the posterolateral capsule. We could not exactly discover the obvious reasons for damage, but direct laceration with an oscillating saw or some other instrument was excluded because the posterior capsule remained intact. The fact that the joint capsule remained intact presumes an indirect trauma. The injury presented with excessive bleeding after deflating the tourniquet, which was the most common clinical presentation in the literature.

Our patient was a young female with no risk factors for vascular impairment reported in the literature, such as smoking, hypercholesterolemia, or hypertension. She had been suffering from RA for 10 years and from hypothyroidism for 5 years, during which time she had been properly medicated. During the preoperative physical examination, she had good palpable pulses of the *dorsalis pedis* artery and a good capillary refill of the foot. Given that adequate care was taken throughout the procedure, including the manipulation of the knee, the use of the oscillating saw, and the placement of the posterior blunt retractor, it appears that an external factor caused this vascular complication. We present the anatomical description of the PA variant location to help explain this case.

PA descends obliquely as a continuation of the femoral artery from the opening of the adductor magnus medially to the crural interosseous space laterally, where it is divided into anterior and posterior tibial arteries. As the artery traverses the popliteal *fossa*, inclining obliquely from the medial condyle of the femur to the distal border of the popliteus muscle, it crosses the knee joint line, closely opposed to the posterior capsule of the knee, placing it at risk of injury during the knee surgery [27]. The PA has variant patterns in the number of terminal branches and in the length of the tibioperoneal trunk. The widely used PA variant classification was created by Kim et al. [19], distinguishing three types and ten subtypes. The main categories were formed by the location at which the anterior tibial artery (ATA), posterior tibial artery, and fibular artery branched from the PA. ATA lesions are more frequent due to the type II-B anatomic variant, in which the ATA is in direct contact with the posterior tibial cortex and may be damaged by the saw or the retractors. Our patient has the I-B variant pattern of the PA (Figure 3). The incidence of that variant is the second most frequent in most studies and varies from 2% to 5.46% [8, 19].

Avoiding the vascular injury of the PA has included numerous variations in its positioning to the joint line and its relation to the posterior tibial cortex, posterior capsule, and other neurovascular structures. Most authors have concluded that the PA is the most lateral structure at the level of the tibial plateau, in 94.3–95% of cases [20, 28]. Keser et al. [20] reported the PA localization on the central axis in 5.7% of cases, stressing that such a position could increase the risk of PAI. They did not report PA on the medial side of the central axis of the knee joint. Rubash et al. [17] performed a cadaver study to propose a clock system to be used to guide the surgeon in selecting a safe location during the screw placement. They determined the anatomical relationships of major vessels to the tibial surface, which was compared to a clock face. The PA and ATA were found to be at risk in a zone between the twelve o'clock and two o'clock positions, which is the central and lateral area. Standard medial parapatellar approach, avoiding the "danger zone", was performed on our patient.

An anatomical description of the PA usually refers only to the extended knee. The general position seems to be when the knee flexion releases tension on the PA and displaces it posteriorly, away from the joint capsule. Bartlett et al. [29] conducted a study on injuries of the popliteal vessels and evaluated their incidence, anatomical factors, and the influence of surgery. They concluded that PA came close to the tibia as the knee was flexed, being at risk of PAI. Cadaver studies confirmed that the flexed knee does not always guarantee safety [15, 18]. A larger cut, removing more bone, will further decrease the distance from the cut surface of the tibial plateau to these vulnerable structures. It seems that anatomic variation in the relative depths of the vital structures exists.

Early detection and repair of arterial injuries during TKA often improve outcomes [4, 9, 23, 27, 30]. In their nationwide study, Bernhoff et al. [23] reported that six of seven patients with complete recovery had an early diagnosis of PAI and immediate treatment. The urgency of vascular treatment varies in the literature, from four hours for good outcomes [30] to five days for limb salvage [2]. Our patient achieved a complete recovery, which could be associated with the fact that PAI was intraoperatively recognized and repaired.

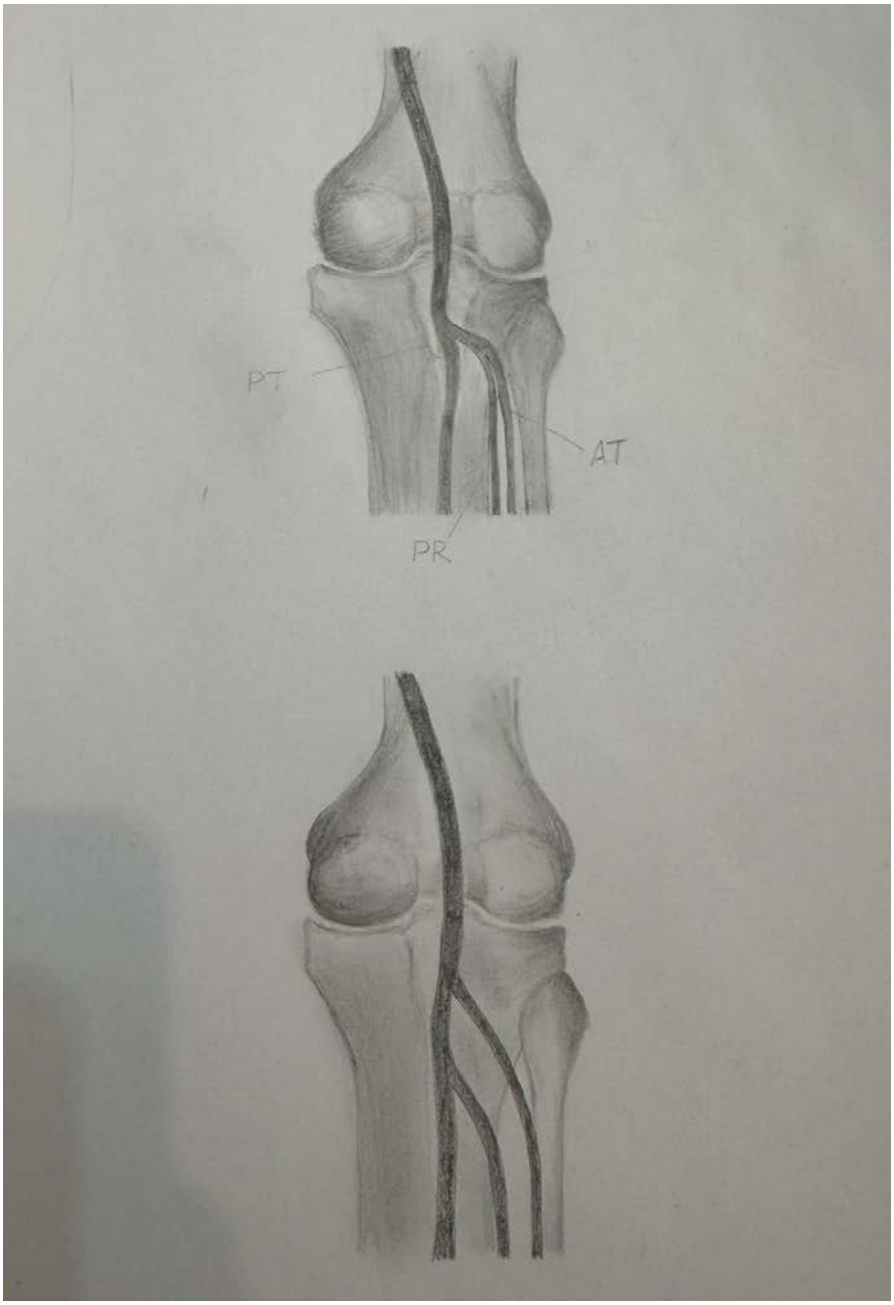

Fig. 3 – Anatomic classification of popliteal artery by Kim et al. [19]: I-B variant. PT –posterior tibial artery; PR – peroneal artery; AT – anterior tibial artery.

Conclusion

Anatomical variation of the popliteal artery should be considered to identify patients at the highest risk of arterial complications during their total knee arthroplasty. Comorbidities such as rheumatoid arthritis or revision surgery could fix the popliteal artery against the posterior capsule by firm connective tissue septa, compromising its movement during the knee flexion or extension.

If an acute vascular complication occurs, early recognition of ischemic arterial complications and rapid diagnosis decreases the period of ischemia. In cases of iatrogenic popliteal artery injury, initial interventions are commonly performed because of faster reperfusion time.

However, the vascular surgeon is the only one able to perform the autologous venous graft/bypass surgery to improve the functional outcome and prevent serious consequences.

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Conflict of interest

The authors declare no conflict of interest.

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