Asia-Pacific Journal of Sports Medicine, Arthroscopy, Rehabilitation and Technology 30 (2022) 9–13

Contents lists available at ScienceDirect

Asia-Pacific Journal of Sports Medicine, Arthroscopy, Rehabilitation and Technology

journal homepage: www.ap-smart.com

Analysis of the running position of the popliteal artery and branching level of the anterior tibial artery detected by magnetic resonance imaging to avoid vessel injury during surgery around the knee joint

Kosuke Hamahashi [a, *], Genya Mitani [b], Tomonori Takagaki [c], Yasuyuki Sogo [a], Masato Sato [a], Masahiko Watanabe [a]

[a] Department of Orthopaedic Surgery, Tokai University School of Medicine, Japan
[b] Department of Orthopaedic Surgery, Tokai University Oiso Hospital, Japan
[c] Division of Orthopaedic Surgery, Ebina General Hospital, Japan

ARTICLE INFO

Article history:
Received 29 October 2021
Received in revised form
17 May 2022
Accepted 8 July 2022

Keywords:
Vessel injuries
Popliteal artery
Anterior tibial artery
Total knee arthroplasty
High tibial osteotomy

ABSTRACT

Background: Vessel injuries during total knee arthroplasty or high tibial osteotomy are rare but have serious complications. This study aimed to analyze the running position of the popliteal artery (PA) and branching level of the anterior tibial artery (ATA), using magnetic resonance imaging (MRI). This analysis might be helpful in avoiding unnecessary vessel injury.

Methods: In total, 105 patients (41 men and 64 women), whose running position of the PA and branching level of the ATA could be detected by preoperative MRI, were included in this study. We configured zones A, B, C, and D to be 5–10, 15–20, 25–30 and 35–40 mm distal from the lateral tibial plateau in the axial view, respectively. First, the distance between the posterior cortex of the tibia and anterior border of the PA was measured. Second, the PA position from the medial border of the tibia was measured. This measured value was divided by the transverse diameter of the tibia, and multiplied by 100 to obtain the PA position from the medial border of the tibia. Third, the branching level of ATA was measured from the joint line. Subsequently, each value was compared between men (the M group) and women (the W group).

Results: The distance between the posterior cortex of the tibia and the anterior border of the PA was 5.5 ± 1.9, 10.4 ± 2.4, 12.5 ± 2.3 and 12.5 ± 2.3 (mm; mean ± SD) in zones A, B, C, and D, respectively. Comparing both groups, this distance was significantly larger (more separated posteriorly) in zones C and D in the M group. The PA position from the medial border of the tibia was 51.7 ± 6.5, 52.7 ± 8.2, 56.7 ± 10.5 and 66.8 ± 14 (%; mean ± SD) in zones A, B, C, and D, respectively. On comparing the two groups, this position was significantly larger (more laterally shifted) in zone D in the W group. The branching level of the ATA was not detected within 40 mm distal to the joint line in 92 patients (87.6%). However, it was detected within 40 mm (mean 32.5 mm; range 20–38) in 12 patients (11.4%). Among them, 11 were women. Only one woman had an aberrant branching pattern: the ATA bifurcated at the joint level.

Conclusion: The PA positioned closest at the joint level, gradually separated and shifted laterally towards the distal side. The distance between the posterior cortex of the tibia and the anterior border of the PA was closer in women than in men in zones C and D. Although a difference of 2 mm is small, the risk of PA injury can be considered to be higher in women than in men. Furthermore, ATA injury is also a concern during retraction of the tibialis anterior muscle posteriorly, and the descending cut of the tibial tuberosity, particularly in women.

1. Introduction

Vessel injuries during total knee arthroplasty (TKA) or high

* Corresponding author. Department of Orthopaedic Surgery, Surgical Science, Tokai University School of Medicine, 143 Shimokasuya, Isehara, Kanagawa, 259-1193, Japan.
E-mail address: hamako@is.icc.u-tokai.ac.jp (K. Hamahashi).

https://doi.org/10.1016/j.asmart.2022.07.001

tibial osteotomy (HTO) are rare but lead to serious complications.[1–4] The popliteal artery (PA) runs behind the knee joint and usually branches into the anterior tibial artery (ATA) and tibio-peroneal trunk near the inferior margin of the popliteus muscle. The tibioperoneal trunk then bifurcates into the posterior tibial artery and the peroneal artery.[5–7] The risk of vessel injury during surgery around the knee joint is mainly associated with the PA and the ATA. It is indisputable that an appropriate use of a retractor is important to avoid vessel injury. However, analysis of the running position of the PA and branching level of the ATA is helpful in avoiding unnecessary vessel injuries.

The incidence of unusual branching of the PA has been reported to be approximately 10%.[8–11] The risk of vessel injury might increase in cases where an aberrant branch arises at or above the knee joint. There are only a few reports that focused on the relation between vessel locations and osteotomy lines in TKA and HTO. This study aimed to analyze the running position of the PA and the branching level of the ATA on magnetic resonance imaging (MRI).

2. Materials and methods

This study was approved by the Institutional Review Board for Clinical Research of our university. The patients and/or their families were informed that data from the case would be submitted for publication, and their consent was obtained.

From 2013 to 2020, 125 patients underwent HTO for osteoarthritis or osteonecrosis at our institution. Among them, 20 patients were excluded because their MRI images were taken within 40 mm below the knee joint. The other 105 patients (41 men, 64 women) were included in this study. The running position of their PA and branching level of their ATA could be detected not less than 40 mm below the knee joint by preoperative MRI. The mean age at the time of operation was 60.9 ± 9.1 years (mean ± SD, range 41–76), body mass index was 26.5 ± 4.4 kg/m^2 (18.9–44), femorotibial angle was 180 ± 3.7° (169–187), and % of mechanical axis was 21.7 ± 15.6 (−16.6–68.8).

We configured zones A, B, C and D to be 5–10, 15–20, 25–30, and 35–40 mm distal from the lateral tibial plateau, respectively, in the coronal view of the MRI (Fig. 1). First, the distance between the posterior cortex of the tibia and the anterior border of the PA was measured by axial view fitting within each zone (Fig. 2). Second, the distance between the medial border of the tibia and the medial border of the PA was measured. The value of that distance was divided by the transverse diameter of the tibia, and multiplied by 100 to obtain the PA position from the medial border of the tibia (Fig. 3). The transverse diameter of the tibia differs substantially between individuals, particularly between men and women. Therefore, we suggest that a percentage parameter might be more appropriate to mark the PA position with respect to the midline. A

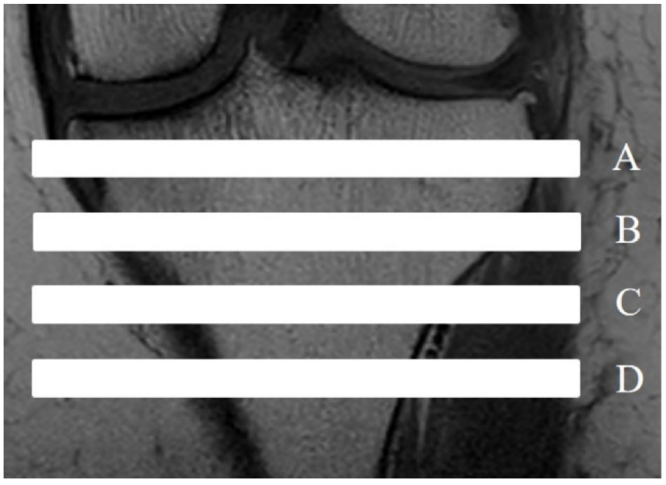

Fig. 1. Configuration of zone A (5–10 mm distal from lateral tibial plateau), zone B (15–20 mm distal), zone C (25–30 mm distal), and zone D (35–40 mm distal) are shown in the coronal view of the MRI.

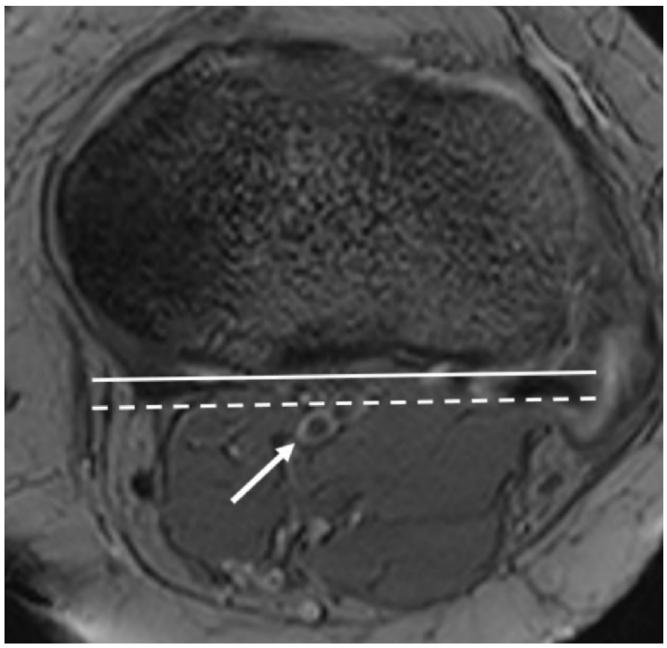

Fig. 2. Distance between posterior cortex of the tibia and anterior border of the PA (arrow) was measured between solid line and dotted line (this slice was fitting within zone A). Solid line; tangential line to posterior cortex of the tibia. Dotted line; tangential line to anterior border of the PA parallel to the solid line. PA; popliteal artery.

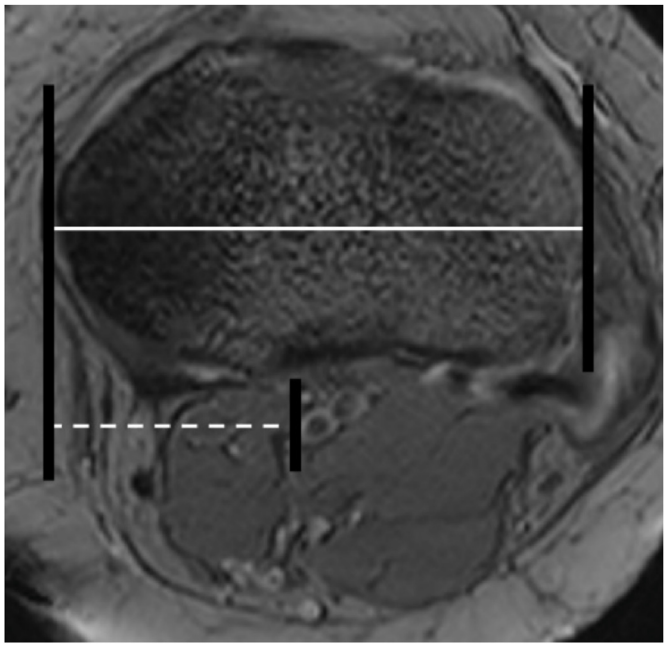

Fig. 3. The PA position from medial border of the tibia is shown (same slice as Fig. 2); The distance between the medial border of the tibia and the medial border of the PA (dotted line) is divided by transverse diameter of the tibia (solid line), and multiplied by 100. PA; popliteal artery.

Table 1
Distance between the posterior cortex of the tibia and the anterior border of the popliteal artery.

	All n = 105	M group n = 41	W group n = 64	*p* value
Zone A	5.5 ± 1.9	5.2 ± 1.9	5.7 ± 1.9	0.21
Zone B	10.4 ± 2.4	10.1 ± 2.6	10.6 ± 2.3	0.29
Zone C	12.5 ± 2.3	13.6 ± 2.4	11.7 ± 2.0	<0.05
Zone D	12.5 ± 2.3	13.7 ± 2.3	11.7 ± 2.0	<0.05

Data are presented as mean ± SD (mm). The p value was calculated using the Student's t-test (comparison between the M and W groups).

Table 2
Relative popliteal artery position from the medial border of the tibia.

	All n = 105	M group n = 41	W group n = 64	*p* value
Zone A	51.7 ± 6.5	51.7 ± 5.8	51.7 ± 7.0	0.98
Zone B	52.7 ± 8.2	51.9 ± 6.9	53.3 ± 8.9	0.39
Zone C	56.7 ± 10.5	54.6 ± 8.7	58.0 ± 11.4	0.09
Zone D	66.8 ± 14.0	62.2 ± 12.9	69.8 ± 14.0	<0.05

Data are presented as the mean (%) ± SD. The p value was calculated using the Student's t-test (comparison between the M and W groups).

value of >50% indicates the PA position to be lateral to the midline, as opposed to <50% that indicates the PA position to be medial to the midline. Third, the branching level of the ATA was measured from the joint line. Furthermore, each value was compared between men (the M group) and women (the W group). Statistical analyses were performed using SPSS Statistics software (version 22; IBM, Armonk, NY, USA). Variables were compared between the two groups using the Student's t-test. A p value of <0.05 was considered statistically significant.

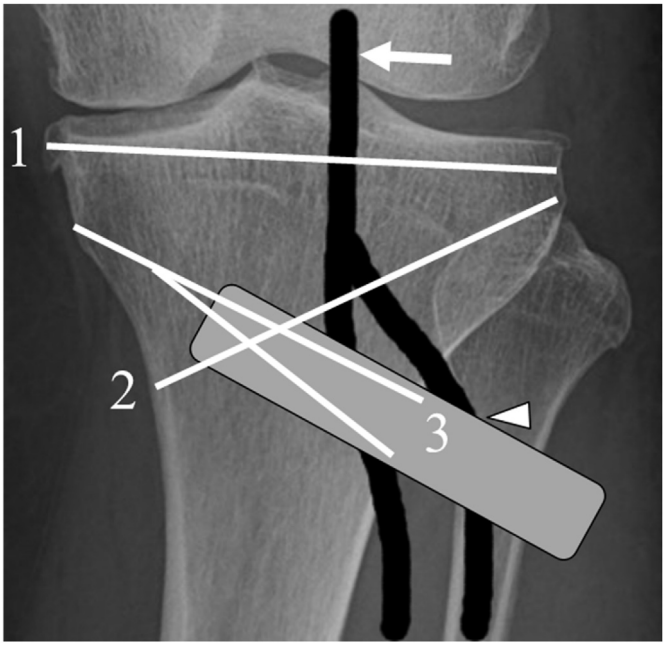

Fig. 4. The osteotomy line (white) of each procedure. Standard position of the popliteal artery (arrow) and high origin of the ATA are drawn in black bold line. Line 1; total knee arthroplasty, line 2; medial opening wedge high tibial osteotomy, line 3; hybrid closed wedge high tibial osteotomy. Crush injury of the ATA (arrow head) is considered as a concern while the tibialis anterior muscle is forcefully compressed by the retractor (gray square). ATA; anterior tibial artery.

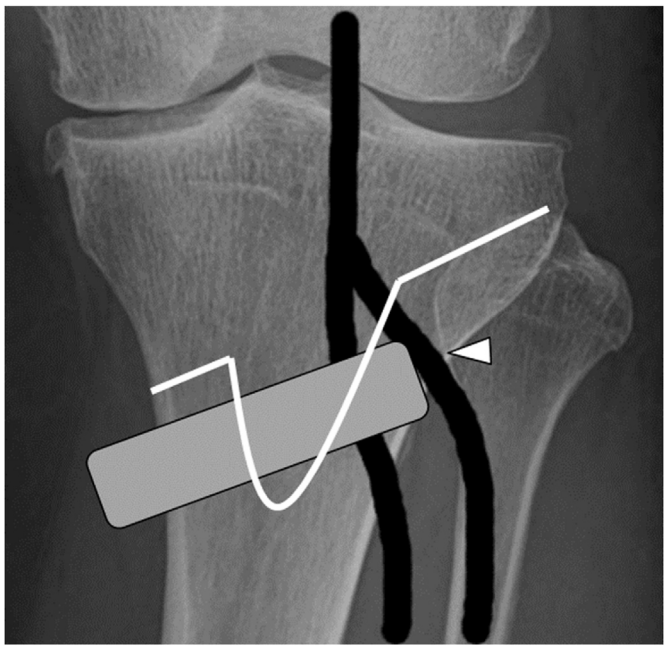

Fig. 5. The ATA injury (arrow head) is considered as a concern during distal tibial tuberosity osteotomy in medial opening wedge high tibial osteotomy (white line) in case of high origin of the ATA (gray square; saw blade). ATA; anterior tibial artery.

3. Results

The distance between the posterior cortex of the tibia and anterior border of the PA is shown in Table 1. Compared with the W group this distance was significantly larger (more separated posteriorly) in zones C and D in the M group (Table 1).

The PA position from the medial border of the tibia is shown in Table 2. Compared with the M group, the distance was significantly larger (more laterally shifted) in zone D in the W group (Table 2).

The branching level of the ATA was not detected within 40 mm distal to the joint line in 92 patients (87.6%). However, it was detected within 40 mm (mean 32.5 mm; range 20–38) in 12 patients (11.4%). Among them, 11 were women. Only one woman had an aberrant branching pattern; the ATA bifurcated at the joint level. The branching of the popliteal artery was categorized according to the classification by Kim et al.[12] It was considered type 2-A (the ATA is the first branch arising at or above the knee joint).

4. Discussion

In this study, we configured each zone according to the potential risk of vessel injury during osteotomy. Zone A presumed osteotomy level at TKA; zones B, C, and D were at medial opening wedge (MOW) HTO[13] and lateral hybrid closed wedge (LCW) HTO[14] (Fig. 4). As a result, the distance between the posterior cortex of the tibia and the anterior border of the PA was closest in zone A. It was suggested that the risk of PA injury was highest during tibial osteotomy in TKA. In zones C and D, the PA gradually separated posteriorly and shifted laterally compared with zone A. During osteotomy, caution must be exercised to avoid moving excessively posterior in the mid-part to the hinge point at MOWHTO. Lee et al.[15] reported that the distance between the posterior cortex of the osteotomy line and popliteal artery was 13–14 mm, 3 cm below the joint line on sagittal plane MRI. These results are comparable to those of the present study.

We should recognize that the risk of PA injury during osteotomy differs between MOWHTO and LCWHTO because the PA shifted

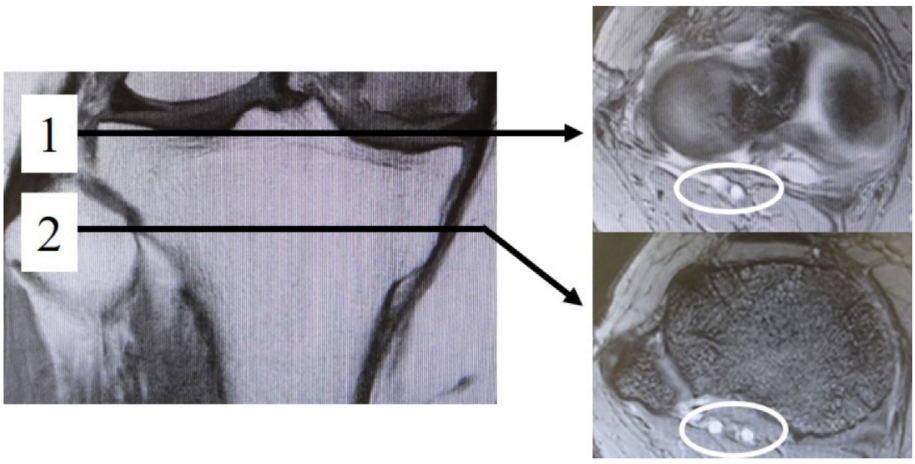

Fig. 6. Aberrant branching pattern of type 2-A (circle) has the anterior tibial artery (left) as a first branch, running side-by-side with tibio-peroneal trunk (right). Line 1; joint level, line 2; 20 mm distal from joint line.

most laterally in zone D. Caution must be exercised during osteotomy from the start point to the mid-point in LCWHTO. However, the risk of PA injury could be decreased by using a retractor appropriately, because the PA running position is closer to the operative field than it is in MOWHTO. However, the branching level of ATA was detected within 40 mm in 12 patients (11.4%). Crush injury to the ATA was considered as a concern while the tibialis anterior muscle was forcefully compressed by the retractor in patients with a high branching level of the ATA (Fig. 4).

Distal tibial tuberosity osteotomy in MOWHTO[16–18] has become mainstream in recent years. However, during the descending cut of the tibial tuberosity, ATA injury is a concern (Fig. 5). A higher branching level of the ATA was observed in our study. Of note, 11 out of 12 patients were women. Sex differences in lower leg length might influence branching level. Furthermore, the distance between the posterior cortex of the tibia and the anterior border of the PA was closer in women than in men in zones C and D. At that level, the PA runs behind the popliteus muscle. Sex differences in popliteal muscle thickness might have influenced the distance. Although the difference of 2 mm is small, we should consider that the risk of vessel injury was higher in women than in men.

As previously mentioned, the PA usually branches into the ATA and tibioperoneal trunk near the inferior margin of the popliteus muscle. The tibioperoneal trunk then bifurcates into the posterior tibial and peroneal arteries. According to previous reports, almost 90% of cases had this branching pattern, which was categorized as type 1 (normal branching pattern), while the remaining 10% had aberrant branching patterns.[5–11] Aberrant branch arising at or above the knee joint is categorized as type 2 (high division of the PA). Among them, type 2-A has the ATA as the first branch, running side-by-side with the tibioperoneal trunk at the osteotomy level of TKA or HTO.[12] Therefore, the risk of vessel injury increases two-fold. In this study, only one patient had an aberrant branching pattern (Fig. 6). However, the incidence of type 2-A pattern was reported to be approximately 3–5% in previous reports.[19] Furthermore, the other type of high-origin ATA has been reported to pass beneath the popliteus and is in direct contact with the posterior tibial cortex.[20,21] This type of aberrant branching pattern needs to be given maximum attention. We experienced the same aberrant branching pattern in patients with rheumatoid arthritis who underwent TKA at our institution (not included in this study). We identified this aberrant branching pattern preoperatively, thus avoiding unnecessary vessel injury by paying enhanced attention to the operative procedure.

This study has several limitations. First, a maximum of 5 mm difference was observed despite the plane of measurement being from the same zone in each patient. This limitation could not be excluded due to the retrospective nature of the study. Second, the patients flexed their knees 20°−30° during MRI examination in this study, and their knees did not remain in an extended position. We suggest that our results approximately represent the actual artery position during tibial cutting in TKA. The PA moves posteriorly during knee flexion.[22–24] Therefore, surgeons should have considered this fact during knee extension. Third, we could not assess interobserver variability because all measurements were performed only once by a single operator.

In conclusion, we retrospectively evaluated PA position and aberrant branching patterns detected by MRI. The PA was positioned closest at the joint level, gradually separated and shifted laterally toward the distal side. The distance between the posterior cortex of the tibia and the anterior border of the PA was closer in women than in men regarding zones C and D. Although the difference of 2 mm was small, we should consider that the risk of PA injury might be higher in women than in men. Furthermore, ATA injury is also a concern during retraction of the tibialis anterior muscle posteriorly, and the descending cut of the tibial tuberosity, particularly in women. It is indisputable that an appropriate use of a retractor would be important to avoid vessel injury.

Ethics statement

This study was approved by the Institutional Review Board for Clinical Research of our university (21R306).

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

Acknowledgements

We thank the reviewers for their valuable comments and suggestions. We also thank Dr. Toshihiro Noguchi and Takehisa Suzuki for their helpful contributions to our study.

References

1. Sundaram K, Udo-Inyang I, Mont MA, Molloy R, Higuera-Rueda C, Piuzzi NS. Vascular injuries in total knee arthroplasty: a systematic review and meta-analysis. *JBJS Rev*. 2020;8, e0051.
2. Ko LJ, DeHart ML, Yoo JU, Huff TW. Popliteal artery injury associated with total knee arthroplasty: trends, costs and risk factors. *J Arthroplasty*. 2014;29:1181–1184.
3. Woodacre T, Ricketts M, Evans JT, et al. Complications associated with opening wedge high tibial osteotomy-A review of the literature and of 15 years of experience. *Knee*. 2016;23:276–282.
4. Tunggal JA, Higgins GA, Waddell JP. Complications of closing wedge high tibial osteotomy. *Int Orthop*. 2010;34:255–261.
5. Kil SW, Jung GS. Anatomical variations of the popliteal artery and its tibial branches: analysis in 1242 extremities. *Cardiovasc Intervent Radiol*. 2009;32:233–240.
6. Day CP, Orme R. Popliteal artery branching patterns - an angiographic study. *Clin Radiol*. 2006;61:696, 299.
7. Oner S, Oner Z. Popliteal artery branching variations: a study on multidetector CT angiography. *Sci Rep*. 2020;10:8147.
8. Celtikci P, Ergun O, Durmaz HA, Conkbayir I, Share Hekimoglu B. Evaluation of popliteal artery branching patterns and a new subclassification of the 'usual' branching pattern. *Surg Radiol Anat*. 2017;39:1005–1015.
9. Calisir C, Simsek S, Tepe M. Variations in the popliteal artery branching in 342 patients studied with peripheral CT angiography using 64-MDCT. *Jpn J Radiol*. 2015;33:13–20.
10. Demirtaş H, Değirmenci B, Çelik AO, et al. Anatomic variations of popliteal artery: evaluation with 128-section CT-angiography in 1261 lower limbs. *Diagn Interv Imaging*. 2016;97:635–642.
11. Yanik B, Bulbul E, Demirpolat G. Variations of the popliteal artery branching with multidetector CT angiography. *Surg Radiol Anat*. 2015;37:223–230.
12. Kim D, Orron DE, Skillman JJ. Surgical significance of popliteal arterial variants. A unified angiographic classification. *Ann Surg*. 1989;210:776–781.
13. Takeuchi R, Ishikawa H, Aratake M, et al. Medial opening wedge high tibial osteotomy with early full weight bearing. *Arthroscopy*. 2009;25:46–53.
14. Takeuchi R, Ishikawa H, Miyasaka Y, Sasaki Y, Kuniya T, Tsukahara S. A novel closed-wedge high tibial osteotomy procedure to treat osteoarthritis of the knee: hybrid technique and rehabilitation measures. *Arthrosc Tech*. 2014;3:e431–e437.
15. Lee YS, Lee BK, Kim WS, Choi JS, Baek JR, Moon CW. Sagittal and coronal plane location of the popliteal artery in the open-wedge high tibial osteotomy. *Knee Surg Sports Traumatol Arthrosc*. 2014;22:2629–2634.
16. Akiyama T, Osano K, Mizu-Uchi H, et al. Distal tibial tuberosity arc osteotomy in open-wedge proximal tibial osteotomy to prevent patella infra. *Arthrosc Tech*. 2019;8:e655–e662.
17. Gaasbeek RDA, Sonneveld H, Van Heerwaarden RJ, Jacobs WCH, Wymenga AB. Distal tuberosity osteotomy in open wedge high tibial osteotomy can prevent patella infera: a new technique. *Knee*. 2004;11:457–461.
18. Longino PD, Birmingham TB, Schultz WJ, Moyer RF, Giffin JR. Combined tibial tubercle osteotomy with medial opening wedge high tibial osteotomy minimizes changes in patellar height: a prospective cohort study with historical controls. *Am J Sports Med*. 2013;41:2849–2857.
19. Oztekin PS, Ergun E, Cıvgın E, Yigit H, Kosar PN. Variants of the popliteal artery terminal branches as detected by multidetector CT angiography. *Open Med*. 2015;10:483–491.
20. Klecker RJ, Winalski CS, Aliabadi P, Minas T. The aberrant anterior tibial artery: magnetic resonance appearance, prevalence, and surgical implications. *Am J Sports Med*. 2008;36:720–727.
21. Tindall AJ, Shetty AA, James KD, Middleton A, Fernando KW. Prevalence and surgical significance of a high-origin anterior tibial artery. *J Orthop Surg*. 2006;14:13–16.
22. Choi CH, Lee WS, Jung M, et al. Adequate protection rather than knee flexion prevents popliteal vascular injury during high tibial osteotomy: analysis of three-dimensional knee models in relation to knee flexion and osteotomy techniques. *Knee Surg Sports Traumatol Arthrosc*. 2020;28:1425–1435.
23. Kim J, Allaire R, Harner CD. Vascular safety during high tibial osteotomy: a cadaveric angiographic study. *Am J Sports Med*. 2010;38:810–815.
24. Shiomi J, Takahashi T, Imazato S, Yamamoto H. Flexion of the knee increases the distance between the popliteal artery and the proximal tibia: MRI measurements in 15 volunteers. *Acta Orthop Scand*. 2001;72:626–628.