Several reports have addressed reconstruction of soft-tissue defects around the knee using a vascular pedicle island flap. Most of these flaps are transferred from the posterior aspect of the lower leg, and others are transferred from the anterior thigh area and are supplied by perforators from the popliteal artery. It is difficult, however, to cover a significant defect of the popliteal fossa area with a vascularized flap. We are aware of few previous studies investigating the possibility of elevating a flap from the posterior thigh region to cover popliteal soft-tissue defects.

We report a rare case of refractory ulceration at the popliteal fossa caused by radiation therapy for a malignant tumor. The ulceration was successfully treated with a long head of the biceps femoris (LHBF) musculocutaneous flap. We hypothesized that a musculocutaneous flap could be elevated and transferred from the posterior aspect of the lower leg and others are transferred from the anterior thigh area and are supplied by perforators from the popliteal artery. It is difficult, however, to cover a significant defect of the popliteal fossa area with a vascularized flap. We are aware of few previous studies investigating the possibility of elevating this flap to the popliteal region.

**Methods:** Five lower extremities of 5 fresh cadaveric specimens were dissected following injection of a silicone compound into the deep femoral artery. We investigated the number, location, and diameter of nutrient branches to the LHBF originating from the deep femoral artery. Based on these results, we treated a 76-year-old woman with a refractory postradiation ulceration at the popliteal fossa associated with popliteal artery obstruction using a 25 × 7 cm LHBF musculocutaneous flap.

**Results:** The mean number of nutrient branches to the LHBF muscle was 3.6, with a mean diameter of 1.9 mm. One to two branches consistently arose from the distal aspect of the posterior thigh. Most branches followed an intramuscular route, giving rise to fine cutaneous branches. The distal border reached by the musculocutaneous flap was located 6.7 cm distal to the bicondylar line. The flap survived completely without complications, and the patient was able to walk with a walking frame postoperatively.

**Conclusions:** The LHBF musculocutaneous flap may offer a reliable treatment option for soft-tissue defects of the popliteal fossa, especially in patients with significant damage to the popliteal artery from trauma or radiation therapy.

**Disclosure:** The authors have no financial interest to declare in relation to the content of this article. The Article Processing Charge was paid for by the authors.
transferred as a propeller flap to cover the popliteal soft-tissue defect when nutrient branches to the LHBF are present and branch at the distal aspect of the LHBF muscle. We describe the use of a novel propeller flap with perforators nourishing the LHBF muscle and the results of our preliminary anatomical study.

Previous studies have revealed that the principal origin of the nutrient artery to the LHBF muscle is the deep femoral artery (DFA). Thus, we investigated the location, number, and courses of the branches from the DFA to the muscle. The distance to the distal border of the popliteal fossa, to which the propeller flap had to reach, was also investigated.

**MATERIALS AND METHODS**

**Anatomical Study**

Five lower extremities of 5 fresh cadaveric specimens were studied. Following injection of a silicone rubber compound (Microfil; Flow Tech, Carver, Mass.) into the DFA, anatomical dissection of the posterior thigh area was carried out. A longitudinal incision was made along a line connecting the pubic symphysis and the medial femoral condyle. The semimembranosus and semitendinosus muscles were retracted medially, and the short and long heads of the biceps femoris muscle were retracted laterally. The DFA was identified at a bifurcation site and dissected distally to identify its arterial branches. Nutrient branches of the LHBF derived from the DFA were exposed.

We investigated (1) the number and location of nutrient branches to the LHBF muscle, (2) the arterial diameter of the branches at the point of entry into the LHBF, (3) the courses of the nutrient branches, and (4) the number of cutaneous perforators. The posterior thigh was divided evenly into 4 areas (areas 1–4), and the locations of arterial branches were determined by measuring their distances from the bicondylar line of the popliteal fossa. We also observed the anatomical relationship between the nutrient branches and the sciatic nerve.

**Clinical Case**

A 76-year-old woman underwent marginal resection of a low-grade malignant fibrous histiocytoma at the popliteal fossa of the right knee in 2010. The tumor recurred within 2 years after surgery, and the patient underwent radiation therapy with a total dose of 50 Gy in 22 fractions. The tumor became necrotic following radiation therapy, and a 12 × 4 cm area of ulceration with a depth of 3 cm occurred, exposing underlying bone (Fig. 1). The ulcer was managed conservatively for about 6 months using closed irrigations with povidone-iodine and several debridements. However, the size of the ulcer did not decrease, and the patient was subsequently unable to walk because of pain behind the knee. Contrast-enhanced computed tomography showed a 17-cm-long obstruction of the popliteal artery approximately 8 cm proximal to the knee joint. Blood flow in the lower extremity was preserved by small branches from the descending genicular artery and its collateral circulation (Fig. 2). There were no signs of tumor recurrence, and no infection was found in the popliteal wound area. The patient wished to undergo flap surgery to cover the defect.

**RESULTS**

**Anatomical Study**

The mean number of nutrient branches to the LHBF muscle was 3.6 (range, 3.0–5.0) (Table 1). Branches were consistently found to emerge in areas 2 and 3. The average number of branches was 0 in area 1, 1.7 (range, 1.0–2.0) in area 2, 2.0 (range, 1.0–3.0) in area 3, and 0.2 (range, 0–1.0) in area 4. In total, 94% of the branches (17 of 18) ran distally in an oblique fashion and pierced the LHBF muscle. One branch (6%) ran transversely and penetrated the muscle at the same level as its bifurcation site.

The nutrient branches of the LHBF muscle at the sites of emergence were located at an average of 19 cm (range, 9–28 cm) proximal to the bicondylar line of the popliteal fossa. In the distal aspect of LHBF (areas 1 and 2), the nutrient branches were located 14 cm proximal to the bicondylar line of the popliteal fossa. Most branches (94%) then followed an intramuscular route from the posterior aspect of the muscle. One branch (6%) ran transversely and penetrated the muscle at the same level as its bifurcation site.

The nutrient branches of the LHBF muscle at the sites of emergence were located at an average of 19 cm (range, 9–28 cm) proximal to the bicondylar line of the popliteal fossa. In the distal aspect of LHBF (areas 1 and 2), the nutrient branches were located 14 cm proximal to the bicondylar line of the popliteal fossa. Most branches (94%) then followed an intramuscular route from the posterior aspect of the muscle. One branch passed through the septal plane between the LHBF and the vastus lateralis muscle in area 3 and sent off small nutrient branches at the lateral aspect of the LHBF, terminating as a septocutaneous perforator. With respect to the anatomical relationship between the branches and the sciatic nerve, 9 branches (50%) ran medial to the nerve, 7 (39%) ran lateral to the nerve, and 2 (11%) penetrated through the nerve. In area 2, 3 branches ran medial to the nerve, 3 passed lateral to the nerve, and 1 penetrated through the nerve (Fig. 3). There were numerous fine cutaneous...
branches emerging from the LHBF, and the mean number of cutaneous perforators >0.5 mm in diameter was 1.6 (range, 1.0–2.0). The distal border to which the propeller flap had to reach was located at an average of 6.7 cm distally from the bicondylar line (range, 0–12 cm).

Clinical Case
Ultrasound examination revealed 2 cutaneous perforators piercing the LHBF muscle about 14 cm proximal to the knee joint. We planned a surgery to rotate an LHBF musculocutaneous flap as a propeller flap based on the location of these 2 perforators to cover the ulceration. The patient was placed in the prone position under general anesthesia. A 25-× 7-cm musculocutaneous flap was outlined with the distal border located at the proximal edge of the ulceration and with the proximal border located at the level of the ischial tuberosity, which was located at about 18 cm proximal to these perforators. Because the distance between the distal margin of ulceration and location of the perforators was 18 cm, we judged that the outlined flap could cover the whole area of ulceration (Fig. 4). A longitudinal incision was made along the medial border of the LHBF, and dissection was performed along the septum between the LHBF and semitendinosus muscle in a distal-to-proximal direction. A nutrient branch of the LHBF muscle was found running just medial to the sciatic nerve approximately 13 cm proximal to the knee joint. This branch was dissected proximally and carefully preserved. Another nutrient branch was found on the lateral aspect of the LHBF 15 cm proximal to the knee joint. This nutrient branch ran lateral to the sciatic nerve and also penetrated the LHBF. These 2 branches were carefully dissected and separated from the sciatic nerve. The outlined propeller flap was elevated based on the 2 musculocutaneous perforators and rotated 180° clockwise to cover the significant defect of the popliteal fossa (Figs. 4 and 5). (See Video 1, Supplemental Digital Content 1, which displays a 25 × 7 cm propeller flap that was elevated based on the 2 musculocutaneous perforators and rotated 180° clockwise and covered the defect of the popliteal fossa. This video is available in the “Related Videos” section of the full-text article at http://www.PRSGO.com or available at http://links.lww.com/PRS-GO/A56). The location of these perforators (area 2) was comparable to the location reported in anatomical findings.

Blood flow to the flap was confirmed by a pinprick test after the flap was positioned. Primary closure of the donor defect was performed. The entire flap survived completely without any complications.

| Table 1. Perforating Artery of the DFA to the Long Head of the Biceps Femoris Muscle |
|----------------------------------------|------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                                       | Area 1 | Area 2 | Area 3 | Area 4 | Total Area |
| Number                               | 0      | 1.4 ± 0.3 (1.0–2.0) | 2.0 ± 0.3 (1.0–3.0) | 0.2 ± 0.1 (0.0–1.0) | 3.6 ± 0.2 (3.0–5.0) |
| Diameter (mm)                        | 0      | 1.7 ± 0.8 (0.5–2.6) | 2.0 ± 0.8 (1.2–3.0) | 3.1 (3.1) | 1.9 ± 0.8 (0.5–3.1) |
| Location (cm)                        | 0      | 14.0 ± 2.8 (9.0–17.0) | 21.0 ± 2.3 (18.0–24.0) | 28.0 (28.0) | 19.0 ± 4.9 (9.0–28.0) |

*Distance between each perforator and bicondylar line.
(Fig. 6), and the patient was able to walk with a walking frame 1 year postoperatively.

**DISCUSSION**

This is the first report describing the use of a bi-iceps femoris musculocutaneous flap for reconstruction of a defect caused by refractory ulceration at the popliteal fossa. Various flaps from the posterior thigh area are available to provide coverage of ischial or sacral pressure sores.16–18 However, there have been no previous reports on the transfer of a musculocutaneous flap to the knee area as a propeller flap from the posterior thigh area.

The LHBF muscle is nourished by several perforating arteries, including perforators from the DFA, medial circumflex femoral artery, popliteal artery, and vasa nervorum of the sciatic nerve.14 The principal origin of nutrient arteries supplying the LHBF muscle is the DFA.14,15 There are several anatomical studies investigating the distribution of perforators to the biceps femoris muscle and overlying skin. Ahmadzadeh et al15 reported that the cutaneous perforators arising from branches of the DFA could be located, with 65% being septocutaneous and 35% being musculocutaneous. By contrast, Salvador-Sanz et al14 described that the majority of perforator arteries from the biceps femoris muscle followed an intramuscular route (80.5%) and less frequently a septal route (19.5%). In the current cadaver study, most branches (94%) followed an intramuscular route in the LHBF muscle, and the result was comparable to that of Salvador-Sanz et al.14

It is possible in theory to transfer a LHBF propeller flap to cover soft-tissue defects of the popliteal fossa when the DFA consistently sends off perforators at the distal aspect of the LHBF muscle. However, there is a lack of information regarding the exact location of the perforators arising from the DFA and coursing to the LHBF muscle. Despite the limited number of cadaver specimens in our preliminary anatomical study, perforators nourishing the LHBF were consistently found at the distal half of the pos-
terior thigh. Thus, the transfer of this propeller flap to the posterior knee region is reliable. This flap may be able to reach as far as 7 cm distal to the popliteal fossa based on the current simulation of flap rotation using cadaveric specimens.

We considered the LHBF propeller flap to be the only treatment option for flap coverage in patients with obstruction of the popliteal artery, with the exception of free flaps or cross-leg flaps from a distant area. Moreover, we considered a musculocutaneous flap to be more appropriate than a fasciocutaneous flap for the current patient because there was massive skin and soft-tissue defect of the popliteal fossa with exposure of underlying bones. In cases where the defect is not so deep and does not need augmentation, a fasciocutaneous perforator flap would be enough to cover the popliteal defect. Although musculocutaneous perforators at this area were thin, based on the findings of our anatomical study, elevating the fasciocutaneous perforator flap without muscle that contains branches from the

Fig. 5. A 25×7 cm propeller flap was elevated based on the 2 musculocutaneous perforators and was rotated 180° clockwise (black arrow heads, lateral branch; white arrow heads, medial branch; ※ indicates sciatic nerve).
DFA and transferring the flap in a propeller fashion would be a less invasive technique.

The anatomical relationship between flap perforators and the sciatic nerve should be taken into account during flap elevation. In the current anatomical study, the courses of the branches varied considerably in relation to the sciatic nerve. Half of the branches ran medial to the sciatic nerve, and the other half ran lateral to the sciatic nerve. In the current patient, 2 perforators in the distal aspect of LHBF muscle ran medial and lateral to the sciatic nerve. We included 2 perforators in the flap to improve its circulation because the sciatic nerve was severed at the popliteal fossa. However, the technical principle of rotating a propeller flap is that only one perforator should be included to avoid kinking of the perforator itself. Although we paid attention to minimize kinking of perforators by releasing the perforators at the bifurcating site, the inclusion of 2 perforators in the propeller flap would not have been adequate for preventing kinking of perforators and excessive twisting of the nerve.

Several studies have addressed reconstruction of soft-tissue defects around the popliteal fossa using a vascular pedicle island flap. Anterior thigh flaps, such as the descending genicular artery perforator flap and the reverse-flow anterolateral thigh perforator flap, for reconstructing popliteal soft-tissue defects have been reported and are relatively reliable flaps, but a change in body position is necessary during the surgery. Posterior lower leg flaps, such as the medial sural artery perforator flap and the reverse peroneal artery flap, are versatile but are likely to require a skin graft at the donor site. Moreover, these flaps might not have survived in the present case because the popliteal artery was occluded, and so circulation to such flaps would likely be impaired. A posterior thigh perforator flap based on direct branches of the popliteal artery was reported by Maruyama and Iwahira, and it is possible to elevate perforator flaps supplied by the DFA and the superficial femoris artery. These flaps may offer an attractive option for reconstruction of a popliteal soft-tissue defect, but there is still a lack of information regarding which perforator flaps from the posterior thigh area are consistently transferable to the popliteal area. Further investigation is needed to establish perforator flaps from the posterior thigh area to cover significant defects around the knee.

We used the LHBF musculocutaneous propeller flap as a feasible reconstructive option for a significant soft-tissue defect of the popliteal fossa area, but one clinical case is not enough to assess the safety and reproducibility of the procedure. Nevertheless, this flap may offer a reliable treatment option, especially in patients with significant damage to the popliteal artery and more distal arteries, which is caused by trauma or radiation therapy to the lower extremity. Preoperative ultrasonographic examination is useful for identification of one or more arterial branches that nourish the LHBF and emerge in the skin at the distal aspect of the posterior thigh for safe elevation of the flap.

**CONCLUSION**

The LHBF musculocutaneous flap may offer a reliable treatment option for soft tissue defects of the popliteal fossa, especially in patients with significant damage to the popliteal artery from trauma or radiation therapy.

**ACKNOWLEDGMENTS**

We thank Prof. Dr. Pasuk Mahakkanukrauh for extensive help in the current anatomical study and Dr. Kobata Yasunori, Dr. Yasuaki Nakanishi, Dr. Kenichi Nakano, and Dr. Akira Kido for valuable assistance with clinical treatment.

**REFERENCES**

1. El-Sherbiny M. Pedicled gastrocnemius flap: clinical application in limb sparing surgical resection of sarcoma around the knee region and popliteal fossa. *J Egypt Natl Canc Inst*. 2008;20:196–207.
2. Feldman JJ, Cohen BE, May JW Jr. The medial gastrocnemius myocutaneous flap. *Plast Reconstr Surg*. 1978;61:531–539.
3. Xie XT, Chai YM. Medial sural artery perforator flap. *Ann Plast Surg*. 2012;68:105–110.
4. Ikeda K, Morishita Y, Nakatani A, et al. Total knee arthroplasty covered with pedicle peroneal flap. *J Arthroplasty*. 1996;11:478–481.
5. Schneider LF, Kaplan KA, Mehrara BJ. Pedicled peroneal artery flap for popliteal fossa reconstruction. *J Plast Reconstr Aesthet Surg*. 2014;67:282–284.
6. Yoshimura M, Shimada T, Imura S, et al. Peroneal island flap for skin defects in the lower extremity. *J Bone Joint Surg Am*. 1985;67:935–941.
7. Ruan H, Cai P, Fan C, et al. Antegrade extended peroneal artery perforator flap for knee reconstruction. *Ann Plast Surg*. 2010;64:451–457.
8. Hayashi A, Maruyama Y. The medial genicular artery flap. *Ann Plast Surg*. 1990;25:174–180.
9. Maruyama Y, Iwahira Y. Popliteo-posterior thigh fasciocutaneous island flap for closure around the knee. *Br J Plast Surg*. 1989;42:140–145.
10. Tang ML, Liu XY, Ren JW, et al. The sartorius myocutaneous island flap. *Surg Radiol Anat*. 1993;15:259–263.
11. Yıldırım S, Avci G, Akan M, et al. Anterolateral thigh flap in the treatment of postburn flexion contractures of the knee. *Plast Reconstr Surg* 2003;111:1630–1637.

12. Sananpanich K, Athakomol P, Luivotoonvechkij S, et al. Anatomical variations of the saphenous and descending genicular artery perforators: cadaveric study and clinical implications for vascular flaps. *Plast Reconstr Surg* 2013;131:363e–372e.

13. Demirseren ME, Efendioglu K, Demiralp CO, et al. Clinical experience with a reverse-flow anterolateral thigh perforator flap for the reconstruction of soft-tissue defects of the knee and proximal lower leg. *J Plast Reconstr Aesthet Surg* 2011;64:1613–1620.

14. Salvador-Sanz JF, Torres AN, Calpena FT, et al. Anatomical study of the cutaneous perforator arteries and vascularisation of the biceps femoris muscle. *Br J Plast Surg* 2005;58:1079–1085.

15. Ahmadzadeh R, Bergeron L, Tang M, et al. The posterior thigh perforator flap or profunda femoris artery perforator flap. *Plast Reconstr Surg* 2007;119:194–202.

16. James JH, Moir IH. The biceps femoris musculocutaneous flap in the repair of pressure sores around the hip. *Plast Reconstr Surg* 1980;66:736–739.

17. Tobin GR, Sanders BP, Man D, et al. The biceps femoris myocutaneous advancement flap: a useful modification for ischial pressure ulcer reconstruction. *Ann Plast Surg* 1981;6:396–401.

18. Hurteau JE, Bostwick J, Nahai F, et al. V-Y advancement of hamstring musculocutaneous flap for coverage of ischial pressure sores. *Plast Reconstr Surg* 1981;68:539–542.