OPEN

The Reversed Flow Hemisoleus Propeller Muscle Flap

*Dalia Mohammed Galal Saleh, MD, Ayman A. Shaker, MD,
Mahmoud Alrefahi, MD, and Mina Agaiby Estawrow, MD*

Background: Soleus muscle flap can be used in different modifications to reconstruct lower limb defects. It can be proximally based, distally based, island or reversed flow flap. The first description of the soleus muscle as an island flap supplied by one distal perforator was reported by Yajima et al (*Plast Reconstr Surg*. 1995;96:1162–1168). However, its use as a propeller flap supplied by the distal perforators and rotated for more than 90 degrees was not described yet.

Obejectives: The aims of the study are to study the detailed vascular anatomy of the distal perforators of the soleus muscle flap and to demonstrate the applicability of using it as a propeller flap.

Patients and Methods: A total number of 42 patients were included in this study. These patients had various distal leg and foot defects. All patients were assessed preoperatively by Doppler study and computed tomography angiography to define the vascular status of the leg. The muscle was raised as a reversed flow flap, based on 1 or more distal perforators and its feeding vessel (posterior tibial artery) after being dissected and divided proximally. The muscle was rotated for more than 90 degrees to reach distal leg defects and approximately 180 degrees to reach the foot defects.

Results: All flaps survived completely with good and durable coverage. The vascularity of the limb was not affected in all patients. There was no functional donor site morbidity.

Conclusions: The reversed flow hemisoleus muscle flap supplied by the distal perforators and the posterior tibial artery has a great arc of rotation that can cover all distal leg, ankle, and foot defects. Therefore, it can be used as alternative to free flap in lower extremity reconstruction. A new nomenclature is suggested for this flap which is the propeller hemisoleus muscle flap.

Key Words: lower limb reconstruction, soleus muscle flap, free flaps, propeller flap

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The soleus muscle flap can be used in different modifications to reconstruct lower limb defects. It can be either proximally or distally based, island or reversed flow flap. The distally based one is the worst because it has a failure rate that reaches up to 50% in the articles by Magee et al (1980),[1] Mathes and Nahai (1982),[2] Tobin (1985),[3] and Yajiama et al (1988).[4]

The first description of the soleus muscle as an island flap supplied by one distal pedicle was reported by Yajima et al (1995).[5] This flap can be also based on any number of pedicles arising from the posterior tibial artery. However, its arc of rotation is limited to cover the whole shaft of the tibia down to the ankle region (Zakaria, 2010).[6]

Another modification for the soleus muscle flap is its use as a reversed flow flap supplied by the posterior tibial artery itself (Guyuron et al, 1982).[7] This modification was used successfully by Shaker et al (2002)[8] for coverage of distal leg defects and all foot defects. The main advantages of this flap were the high success rate in contrary to the distally based hemisoleus flap, which has a high failure rate. The second advantage is that it has the capability of reaching distal leg and any foot defects. However, it has the great disadvantage of scarifying a major leg blood vessel, and for this reason, it did not gain much popularity.

In this article, we are going to extend the use of this flap by increasing its arc of rotation and trying to overcome its major disadvantage, which is scarifying the posterior tibial artery.

PATIENTS AND METHODS

This series included 42 patients, and it was conducted at Ain Shams University Hospitals, Nasr Institute, and Nasr City Insurance Hospital through the period from July 2014 to December 2017. Of these 42 patients, there were 31 males and 11 females. The age ranged from 6 to 65 years. Four of them were diabetic and six were smokers. The etiological factors of the defects were trauma, neurotrophic ulceration, postvacuities gangrene, and diabetic ulceration. Fifteen of the patients had defects of the lower third of the leg, ankle, or malleolar region. In this group, the original plan was to cover the defect by distally based hemisoleus supplied by the distal perforators. However, the preoperative conducted Doppler study confirmed the absence of sufficient pedicles to maintain the flap viability, and the procedure was replaced by the reversed flow hemisoleus flap. The other 27 patients had different foot defects. In this group, the plan was to use the reversed flow hemisoleus flap from the start as these defects were beyond the arc of rotation of the distally based flaps. The sites and the number of the defects are shown in Table 1.

Operative Technique

Preoperative assessment should confirm the presence of both the posterior tibial and dorsalis pedis arterial pulses. Doppler examination was done to locate the posterior tibial artery pedicles supplying the muscle. In doubtful cases, computed tomography angiography was needed.

TABLE 1. Showing the Sites and the Number of the Defects

The Site of the Defect	The Number (42)
Lower 1/3 leg, ankle, and medial malleolus	15 patients
Heel	12 patients
Heel extending into the instep area	4 patients
Dorsum of the foot	8 patients
Dorsum of the foot extending into the ankle.	3 patients

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From the Department of Plastic, Burn, Reconstructive and Maxillofacial Surgery, Ain Shams University, Cairo, Egypt.
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Reprints: Mina Agaiby Estawrow, MD, El Demerdash Hospital, 56 Ramsis St, Behind El Nour Mosque, Abbasseya, Cairo, Egypt. E-mail: agboo2010@med.asu.edu.eg.

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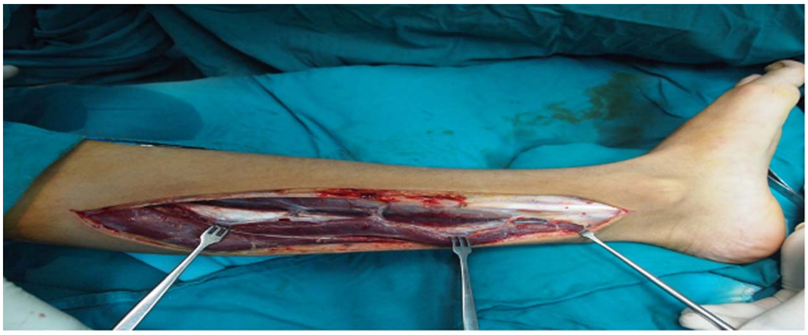

FIGURE 1. Identification of the posterior tibial artery perforators.

The flap was raised under general or spinal anesthesia under tourniquet. Through a medial approach, all the distal and proximal pedicles of the posterior tibial artery supplying the muscle were exposed and identified (Fig. 1). After locating the sites of the distal pedicles, the arc of flap rotation is tested to detect whether the flap can be raised on the distal pedicles or the posterior tibial artery itself. Because of the absence of sufficient number of nearby pedicles or traumatization of these pedicles, which was already confirmed by Doppler study or because of more distal location of the defect in the foot, all the flaps should be raised on the posterior tibial artery and its more proximal pedicles. These pedicles should be dissected to their origin from the posterior tibial artery. The artery should be dissected carefully from the posterior tibial nerve to the most proximal reliable pedicle that has to be included in the flap. Care is taken to prevent jeopardizing the blood supply to the tibial nerve and to maintain the continuity between the flap and the vessel. All the branches from the posterior tibial artery to the surrounding muscles were ligated or cauterized by bipolar. A microvascular clamp was applied on the posterior tibial artery proximal to the planned included perforator and the tourniquet was released to assess the flap viability and ensure the vascularity of the limb before division of the artery (Fig. 2). After confirming the viability of the limb, the artery was doubly ligated and divided. The hemisoleus muscle flap was raised down to the ankle at the site of anastomosis between the anterior and posterior tibial arteries, which will be the arc of flap rotation. The insertion of the muscle was detached from the tendon achilis, and the flap was converted into a pure island one (Fig. 3).

If there was more than one pedicle in the flap, selective clamping of these pedicles was done to ensure that one pedicle is sufficient to maintain the flap viability. These pedicles could be ligated to increase the reach of the flap. The flap was then rotated 90 to 180 degrees to reach its destination. The exposed tibial nerve was covered by the adjacent muscles. The flap covered the defect after dealing with any underlying bone problem and the donor site was closed directly with insertion of tube drain.

In 10 selected patients with compromised vascular supply like diabetic or heavy smokers' patients, the continuity of the posterior tibial artery was restored by an interposition saphenous vein graft harvested from the contralateral healthy limb. This was done by applying a microvascular clamp on the proximal part of the posterior tibial artery instead of being ligated and anastomosing it to one end of the graft. The distal divided end of the posterior tibial artery was dissected for a short distance that allows it to be rerouted proximally to be anastomosed to the other end of the vein graft (Figs. 4, 5).

Immediate skin grafting was done in 6 cases and was delayed for 1 to 4 weeks in the other 36 cases. During grafting, the superficial tendinous surface and a variable thickness of the muscle were shaved until it will be leveled with the normal surrounding tissue. Thirty patients were followed up for at least 3 years after surgery.

RESULTS

The flap was raised within the allowed tourniquet time (approximately 2 hours) in all patients but in patients who needed interposition grafting of the posterior tibial artery the operative procedure took about 4 hours. In the 15 patients with distal leg defects, no distal pedicles could be identified because of anatomical variation or traumatization by the accident or the associated orthopedic work for fixing the underlying bony problems. In such cases, the flaps were based on 1 or more of the proximal pedicles, which were present in all patients and located at approximately 7 to 12 cm distal to the medial tibial condyle. In the other 27 patients, the flaps were based on 2 or more pedicles, one large proximal and a smaller distal one. All the flaps survived completely with durable soft tissue coverage (Figs. 6–8).

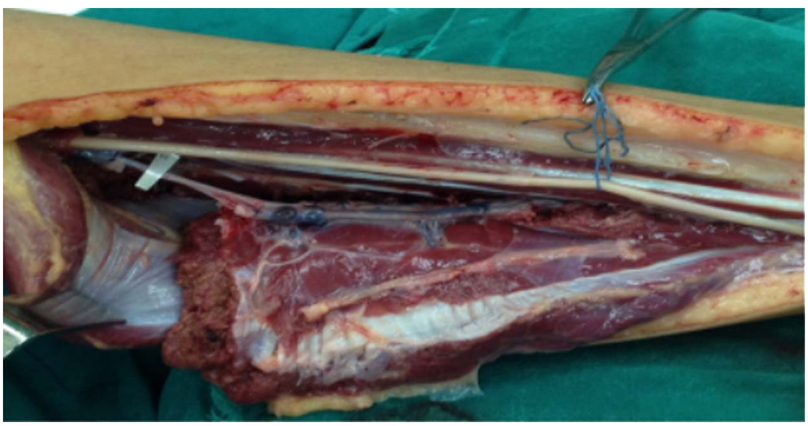

FIGURE 2. Intraoperative clamping of the posterior tibial artery.

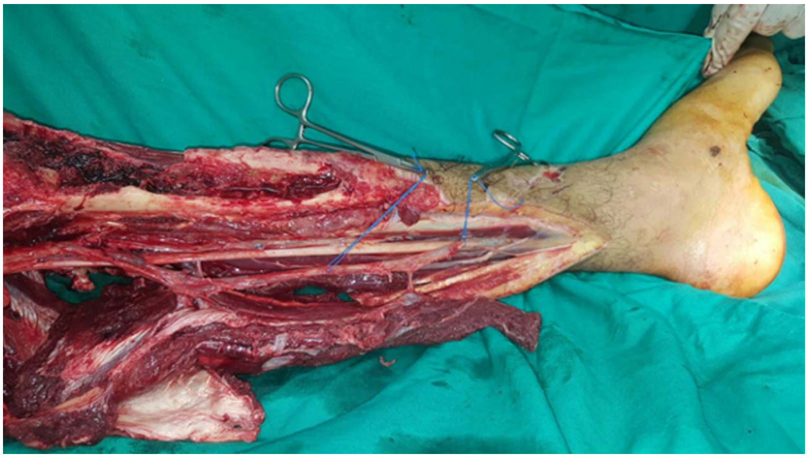

FIGURE 3. Division of the muscle insertion converting it into a pure island flap.

Only one flap suffered from sloughing of the lateral distal part, and it was managed by debridement of this part and skin grafting later (Fig. 9).

Two flaps remain bulky after surgery (Fig. 10) and need debulking procedures. Immediate skin grafts were done in 6 patients. In 28 patients, it was done 1 week after the flap procedure. In the remaining 8 patients, it was delayed for a variable time until 4 weeks after surgery. Skin graft take was 100%. None of our patients experienced functional loss or deficit. There were no symptoms or signs of acute or chronic ischemic manifestations or affection of the venous system in the 3-year follow-up of our patients.

DISCUSSION

According to Mathes and Nahai (1982),[2] the soleus muscle flap is classified as type II vascular pattern with dominant (major) proximal vascular pedicle and secondary (minor) vascular pedicles. It can be used as proximally based, distally based, island or reversed flow flap for coverage of many leg defects. The proximally based one is based on the dominant proximal pedicle, and it can cover upper and middle lower third leg defects.

The first description of the soleus muscle as an island flap supplied by one distal pedicle was reported by Yajima et al (1995).[5] This flap can be also based on any number of pedicles arising from the posterior tibial artery. However, its arc of rotation is limited to cover the whole shaft of the tibia only down to the ankle region (Zakaria, 2010).[6]

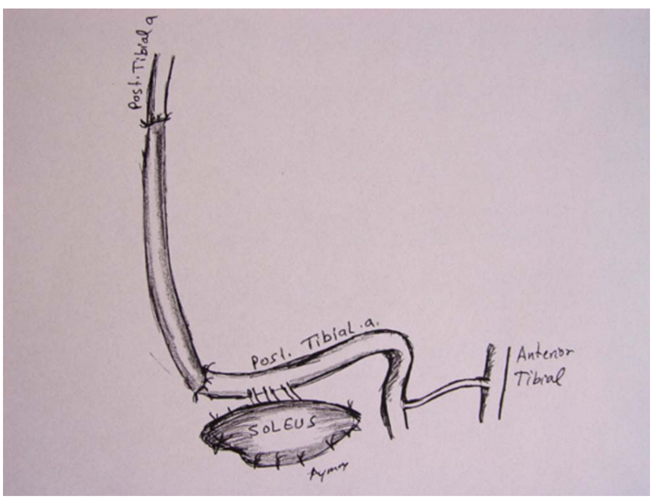

FIGURE 4. Diagram showing the interposition saphenous vein graft to restore the continuity of the posterior tibial artery.

The distally based hemisoleus muscle flaps are not always reliable and associated with high failure rate 21% to 50%, Townsend (1978),[9] Magee et al (1980),[1] Mathes and Nahai (1982),[2] Tobin (1985),[3] Yajima et al (1988),[4] and Shaker (1998).[10] This is due to variations of the vascular anatomy of the distal minor pedicles, Townsend (1978),[9] Magee et al (1980),[1] Tobin (1985),[3] and Yajima et al (1988).[4] In a series of 24 patients published by Shaker (1998),[10] he found that in 50% of the patients, the second most distal pedicle that the flap has to be based on it is located at a distance of 15 cm or more proximal to the medial malleolus. This means that to allow the flap to reach its destination, this pedicle must be divided and hence the high failure rate (21% loss of the flaps).

The reversed flow hemisoleus flap was another modification originally described by Guyuron et al (1982).[9] They advocated raising the flap on the posterior tibial artery itself after ligating it proximally and using the retrograde flow through the distal anastomosis with the anterior tibial artery. This method will not only increase the survival rate of the flap due to inclusion of more proximal pedicles, but also it will increase the arc of flap rotation to reach more distal defects. In a series of 20 patients, the reversed flow hemisoleus flap was used to cover distal third leg and all foot defects with a success rate 100% (Shaker et al, 2002).[8] This modification can be an alternative for distally based hemisoleus flap in case of more proximal location of the distal pedicles or injury of these pedicles due to severe bone comminution. The only disadvantage of the technique is the sacrifice of the posterior tibial artery as being one of the major vessels of the leg, and for this reason, this flap did not gain much popularity (Koshima et al, 1992).[11]

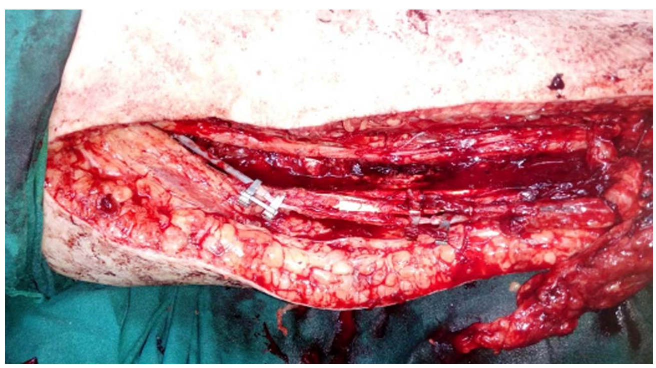

FIGURE 5. Intraoperative view for the interpositional vein graft restoring the continuity of the posterior tibial artery.

FIGURE 6. Patient with crush injury of the left leg. A, Intraoperative view after wound debridement. B, Flap elevation. C, Flap covering the defect and donor site closure. D, Muscle flap after skin graft.

To increase the arc of flap rotation to reach more distal defects, 2 further modifications were done in this work. The first one was conversion of the flap into a pure island one by dividing the insertion of the flap into the remaining part of the tendon achilis. The second modification was to try to base the flap on only one pedicle and dissecting it to its origin from the posterior tibial artery, thus converting it into a propeller flap.

FIGURE 7. Patient with unstable scar of the left heel. A, Preoperative view. B, Intraoperative view showing the flap covering the defect with donor site closure. C, Late postoperative view.

FIGURE 8. Patient with mangled left foot. A, At the time of the trauma. B, After debridement and bony work. C, Muscle flap covering the defect. D, After skin grafting. E, One year after surgery.

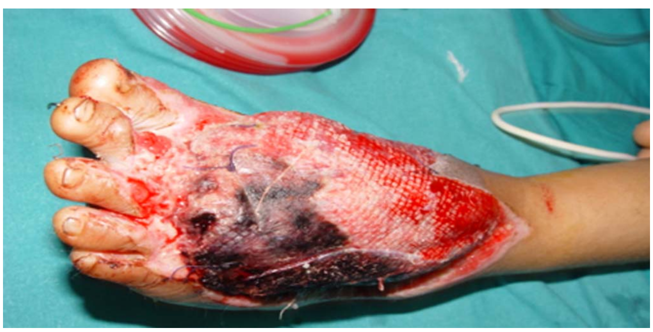

FIGURE 9. Showing sloughing of the lateral distal part of the flap.

FIGURE 10. Showing a bulky flap.

The term propeller flap was first reported by Hyakusoku et al (1991)[12] for description of adipocutaneous flap based on a central subcutaneous pedicle, with a shape resembling a propeller that was rotated 90 degrees. Hallock (2006)[13] reported a fasciocutaneous flap that was similar in shape to the one described by Hyakusoku et al,[12] but it was based on a skeletonized perforating vessel and rotated 180 degrees on an eccentric pivot point. Teo (2006)[14] was the one who gave the greatest contribution to the surgical technique and the application of the perforator propeller flaps.

To our knowledge, this term was not applied for any muscle flap; however, we are suggesting nominating this flap the reversed flow hemisoleus propeller muscle flap. Our newly described flap shares the original concept of the "propeller flaps" in being able to rotate on its vascular axis for 90 to 180 degrees to cover a defect. However, it is different from the traditional propeller flaps in 3 aspects. The first is that it is not based on only one pedicle, but it may be based on more than one pedicle and its source vessel. This pedicle is not necessary to be in the center of the flap, but it may be eccentric in position. The second aspect is that it is supplied through the proximal pedicles, which are bigger in diameter and more reliable than the distal ones. The third aspect is that the pivot point of its rotation is not around the perforator but around the site of anastomosis between the anterior and posterior tibial arteries at the ankle, which makes the flap not liable to torsion or kinking. For these reasons, we did not have any flap loss even with flap rotation for 180 degrees. This makes our flap superior to other perforators-based propeller flaps in which further rotation for a maximum of 180 degrees is associated with torsion and kinking of the pedicle and flap loss in many patients (Pignatti et al, 2011),[15] we are also suggesting to apply the concept of including source vessels to the traditional propeller fasciocutaneous flaps to extend their arch of rotation for more distal leg and foot defects and to improve their survival rates.

However, this flap has the great disadvantage of scarifying the posterior tibial artery, which is one of the major blood vessels of the leg. Koshima et al (1992)[11] believe that it is the main feeding artery of the foot, and they did not accept this. For the same reason, the technique was criticized by Fayman et al (1987)[16] and the flap did not gain much popularity. However, dividing the posterior tibial artery is not a big issue for many reasons. Many reports for free flaps in the lower extremity are scarifying the posterior tibial vessels by doing end-to-end anastomosis with these vessels. According to Cormack and Lamberty (1986),[17] the peroneal artery and not the posterior tibial artery is the main vessel of the limb and is never absent. Furthermore, this vessel is the least affected by arteriosclerosis in the lower leg (Haimovici, 1967).[18] In 2 large series with long-term follow-up published by Liu et al (1990)[19] and Wu et al (1993)[20] on the use of the reversed flow posterior tibial artery fasciocutaneous flaps, they did not have any symptoms of acute ischemia, circulation problems, or cold intolerance.

To minimize the donor site morbidity that may result from transection of the posterior tibial artery and criticize the use of such flap according to some authors, we did another modification in some selected cases with relative impaired vascularity in diabetic patients and smokers. The idea is to restore the continuity of the posterior tibial artery by interposition vein graft. This will not only restore the continuity of the artery, but also it supercharges the flap. It will have a dual blood supply, the first one is the antegrade flow coming through the reconstituted posterior tibial artery and the second one is a retrograde flow coming through the anastomosis with anterior tibial artery at the ankle region. In all our patients, we did not have any symptoms or signs of acute or chronic ischemic manifestations in the long-term follow-up.

This flap has a very high success rate, and it can cover many soft tissue defects of the lower third of the leg and the foot, which presents a challenging problem to the reconstructive surgeon. Being a muscle flap, it provides good bulk and vascularity that combats infection in cases of osteomyelitis (Mathes, 1984).[21] It has less donor site scarring in comparison with fasciocutaneous flaps that have ugly scarring especially in female patients. It adds a lot to the armamentarium of plastic surgeon, and it can be used as an alternative for free flap reconstruction of the lower extremity. However, free tissue transfer had solved many lower extremity defects, yet the long anesthetic time with its risks, the need for special skills and instruments, and the possibility of failure should be put into consideration.

CONCLUSIONS

In this article, the reversed flow hemisoleus muscle flap proved its effectiveness in management of challenging defects in lower third of the leg and foot. Three modifications were done to differentiate it from the classic reversed flow hemisoleus flap, 2 of them to increase the arc of flap rotation and increase its reliability and success rate. The third one to overcome the well and known major disadvantage of the flap, which is the sacrifice of the posterior tibial artery. For the first time, a new nomenclature is suggested for this flap, which is the reversed flow hemisoleus propeller muscle flap. The flap looks like the propeller in its way of rotation, yet it is different from the traditional fasciocutaneous flaps in many aspects. Our recommendation is to expand the use of this flap in lower extremity reconstruction. The second recommendation is to use the same concepts for the traditional propeller flaps to increase its use in lower limb reconstruction.

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