

the EDB-flap are its small size, healing problems of the donor site, and reduced mobility of the ankle joint.

Anatomical Background

The EDB is a trapezoid-shaped muscle on the dorsum of the foot, lateral to the extensor hallucis longus tendon and deep to the tendons of the long toe extensors. It consists of 4 bellies that originate from ligamentous structures of the tarsal sinus and inserts on each of the long extensor tendons of the 4 medial toes. The size of the conjoined muscles in an adult is about 6×4.5 cm. The EDB muscle has a Mathes and Nahai type II vascular supply.¹² The dominant pedicle is the lateral tarsal artery that runs in a plane deep to muscles. It branches from the Dorsalis Pedis artery at or immediately distal to the extensor retinaculum (Fig. 1). Veins and nerves usually follow the main arterial pedicle.

The aim was to describe our experience of the last 20 years with the use of the EDB as a local muscle flap for coverage of complex small lower limb defects and to delineate its clinical use as well as to analyze donor-site complications.

METHODS

All adult (≥ 18 years) patients who had intervention ICD-10 code ZZR30 (reconstruction with muscle flap) of the lower limb between 1997 and 2017 at the Department of Hand and Plastic Surgery at Linköping University Hospital were screened. All patients who had been reconstructed with a pedicled EDB flap were included, and a retrospective analysis was done using data retrieved from the medical records. The following variables were used: age, sex, co-existing medical conditions, site, dimension of the defects, mechanism of injury, operating time (skin to skin), flap viability and complications, and donor-site

complications. The study was approved by the Regional Ethics Review Board (No. 2018\18–31).

Preoperative Procedure

All patients were examined with preoperative Doppler to identify anterior and posterior tibial vessels in the lower leg. Angiography or computed tomography (CT) angiography was performed in some patients when Doppler assessment was inconclusive or when the trauma to the lower leg was extensive.

Surgical Procedure

With the patient supine, a curvilinear skin incision is made on the dorsum of the foot starting from the lateral malleolus to the first web space, this incision follows the oblique course of the EDB muscle bellies. In the space between the extensor digitorum longus (EDL) and extensor hallucis longus tendons, the lateral tarsal artery is identified just distal to inferior border of extensor retinaculum along with the motor branch of the deep peroneal nerve. These course infero-laterally for approximately 2 cm before passing underneath the proximal edge of EDB.

Dissection starts by creating a plane between EDB muscle and the superficial EDL tendons from medial to lateral taking care not to divide the branches of the superficial peroneal nerve. Elevation of the long extensors is simplified by early division of the extensor retinaculum. The tendons of the EDB are then divided distally where after the muscle is freed off the deep proximal attachment starting from the tarsal bones in the mid foot to its origin in the calcaneus. The neurovascular pedicle can then be dissected proximally, which is facilitated by the ligation of a fairly constant branch to the sinus tarsi. The dorsalis pedis artery is then ligated distal to the origin of the lateral tarsal artery, which

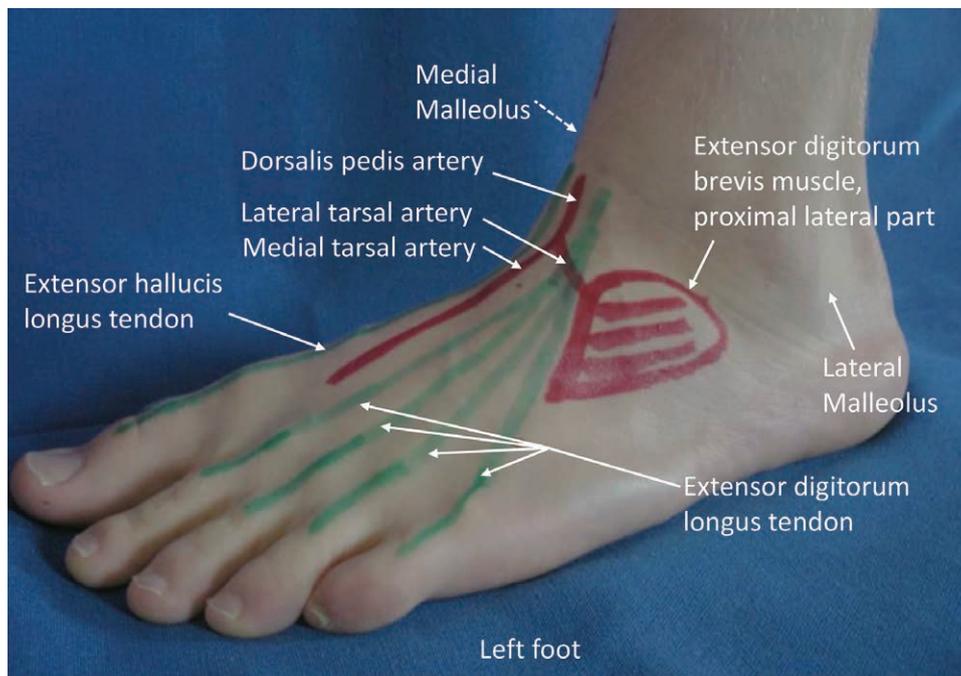


Fig. 1. Anatomical landmarks on the dorsum of the left foot showing surface anatomy of EDB muscle.

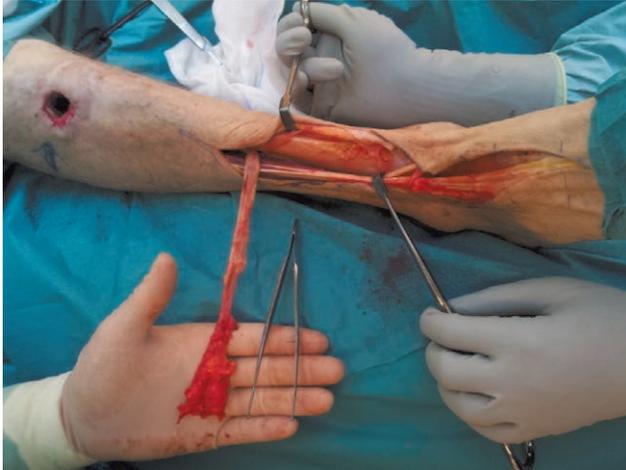


Fig. 2. The area possible to reach with the EDB-flap is substantially enhanced by proximal dissection of the vascular pedicle. A low-grade osteitis in the upper part of the tibia was thus cured in the illustrated example.

will give extra arc of rotation, length, and better mobilization of the flap. The pedicle is dissected proximally, and if an even longer arc of rotation is needed, the extensor retinaculum is divided and the proximal dissection of the pedicle is followed even further. This latter procedure enables the flap to reach even the tibial tuberosity (Fig. 2). After elevation of the flap and pedicle, the extensor retinaculum is reconstructed by single sutures of Polydioxanone (PDS) 3-0, the donor site is sutured in layers. No drains are employed. Finally a skin graft is harvested from available donor site at the ipsilateral thigh with a Zimmer Pneumatic dermatome with thickness 0.01 inch, meshed 1:1.5, and fixed with staples on the surface of the EDB flap.

Postoperative Procedure

The ankle joint and foot are immobilized using a posterior below knee plaster slab for 6 weeks. Thereafter, gradual mobilization is initiated.

Analysis of Data

Descriptive data are presented as median (25th–75th centiles) unless otherwise stated. Probabilities of less than 0.05 were accepted as significant. Distribution was tested with the Lilliefors test for normality. Significance of difference between the groups was assessed using the Mann Whitney *U*, and the chi-square, tests. Logistic regression was used to assess the effect of site (tibia or dorsal foot; Achilles or heel; malleolus), size of the defect, operating time, age, sex, and presence of co-existing medical conditions on flap outcome: viable flap (full success) coded as 0, complications and flap loss (dehiscence, fistulae, partial necrosis, and total necrosis) coded as 1.

RESULTS

A total of 64 patients were included. Figures 3–5 show 3 cases before and after operation, site of defects were dorsal foot, distal tibia, and medial malleolus. Four of the 64 patients had distally based flaps. The soft-tissue defects were associated with fractures in 40/64 (63%) patients. The most frequent reason for flap-surgery (41%) was skin defects without exposed bone, followed by osteomyelitis (27%), skin defects with exposed bone (17%), exposed Achilles tendon (14%), and 1 case with sarcoma (Table 1). The muscle flap was used to reconstruct defects in distal leg and foot in 94% (60/64) of the cases (Table 2) (see table, **Supplemental Digital Content 1**, which displays all the details of patients, <http://links.lww.com/PRSGO/A938>).

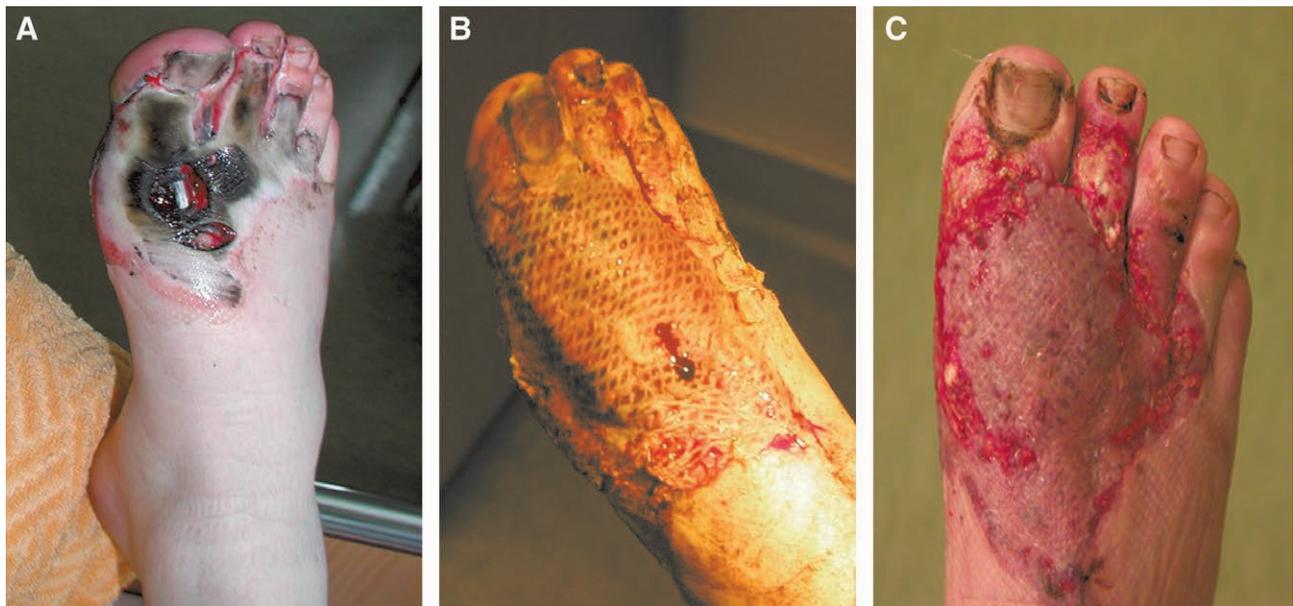


Fig. 3. A, Shows a friction injury in a 22-year-old male patient before operation. B, Shows 4 days after operation with a distally based EDB muscle flap covering a 5 × 5 cm defect and additional skin graft on the adjacent wound. C, Shows the flap 3 weeks after operation. No co-existing medical conditions were recorded.

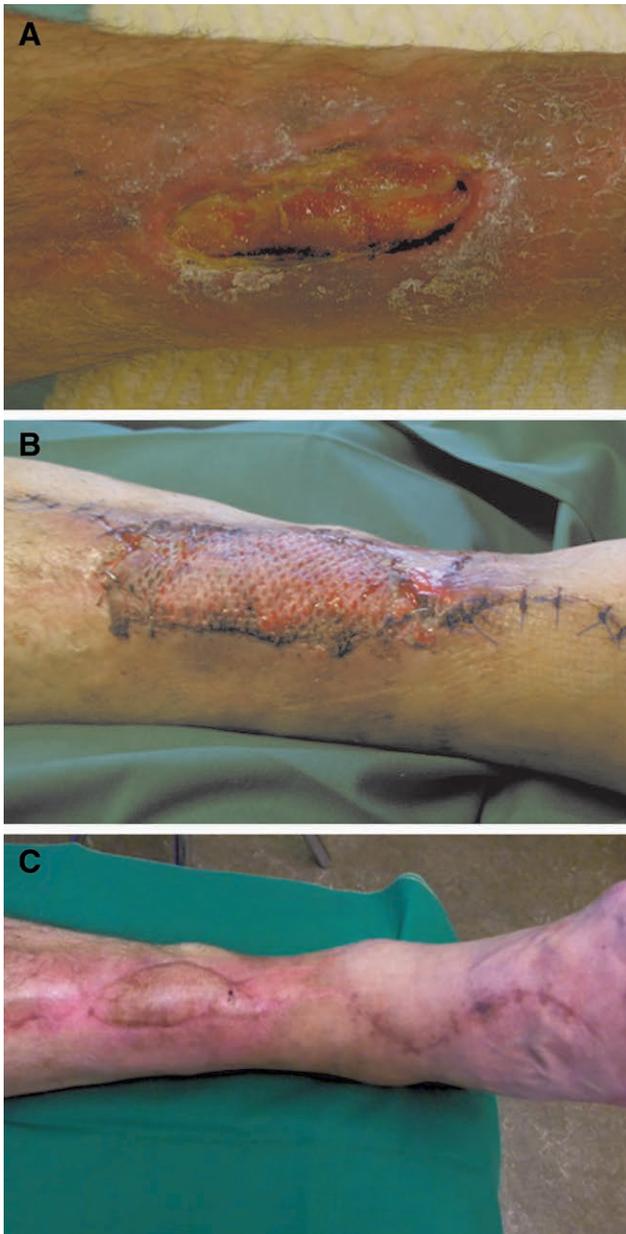


Fig. 4. A, Shows a chronic wound with a 7×4 cm defect in a 55-year-old male patient before operation. B, Shows 1 week after operation with a proximally based EDB muscle flap. C, Six months after operation. No complications were recorded and the only co-existing medical condition was epilepsy.

The EDB flap reconstruction was successful in 47/64 patients (73%), 1 patient developed a fistula under the flap, 4 had dehiscence of the suture line, 5 had partial flap loss, and 7 had total flap loss. Additionally, 3 had a skin graft failure while the flap survived (Table 3). Thirteen of the patients developed donor-site complications of which delayed healing was the most common (n = 9), followed by dehiscence (n = 2), and fistulae (n = 2; Table 3). The differences between the full success group and those with complications are shown in Table 4. The proportion of patients with cardiovascular conditions was greater in the group with complications. Defects of the malleolar region

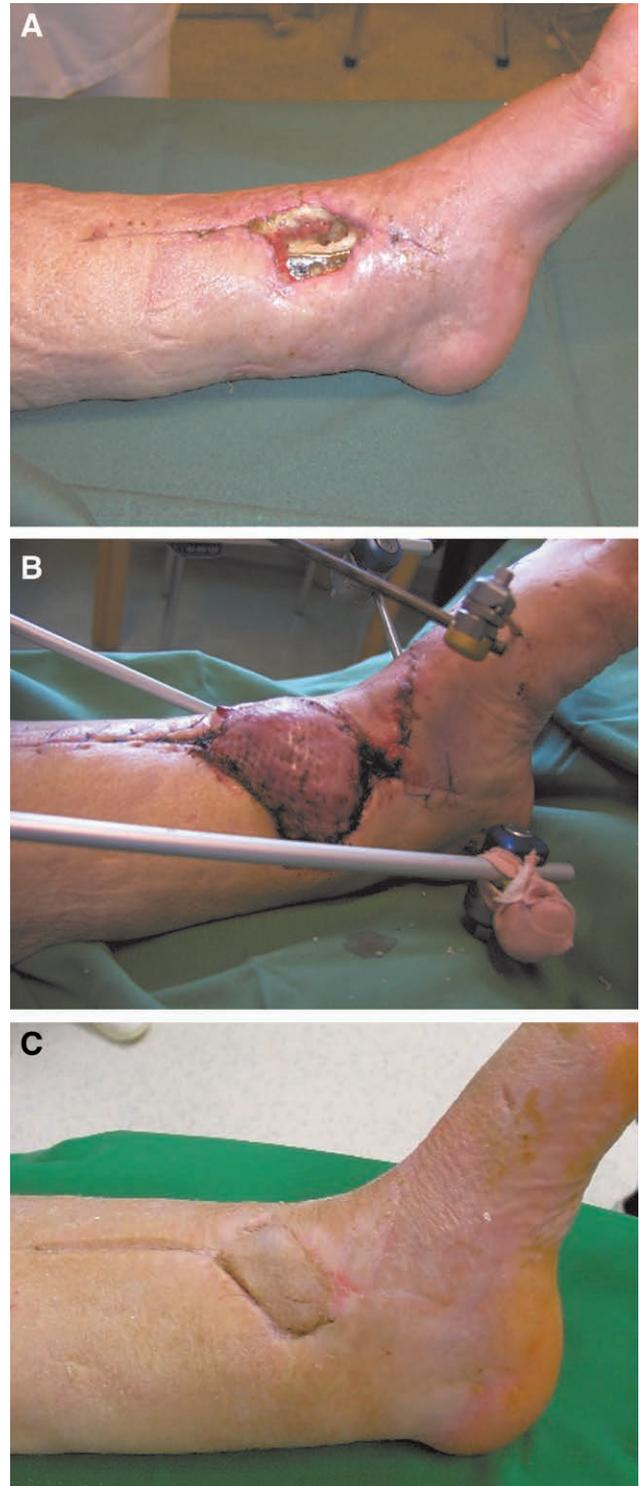


Fig. 5. A, Shows an exposed tibial plate in a 4×5 cm defect in a 65-year-old female patient before operation. B, Shows 2 weeks after operation with plate removal, bone debridement and external fixation, and a proximally based EDB muscle flap. C, Shows the result 11 months after operation. No complications or co-existing conditions were recorded.

was the site with highest frequency of complications while tibia and dorsum of the foot had the lowest frequency.

Table 1. Indication for EDB-flap Surgery

Skin defect without exposed bone	26
Osteomyelitis	17
Skin defects with exposed bone	11
Exposed tendon Achilles	9
Other	1

Table 2. Site of Injury

Distal tibia	23
Medial malleolus	10
Achilles	10
Lateral malleolus	7
Heel	6
Dorsal foot	4
Proximal tibia	4

Table 3. Complications and Flap Loss

Complications	Recipient Site	Donor Site
Total necrosis	7 (11)	
Partial necrosis	5 (8)	
Wound dehiscence	4 (6)	2 (3)
Skin graft failure	3 (5)	
Fistula	1 (2)	2 (3)
Delayed healing		9 (14)

n and (%) of 64

Table 4. Details of Patients Grouped by Flap Outcome

Variables	All	Success	Complications and Flap Loss	P
No. patients	64	47	17	
Male sex	42 (66)	31 (66)	11 (65)	0.93
Age (y)	60 (49–70)	56 (46–68)	62 (60–70)	0.05
Site of injury				0.01
Tibia or dorsal foot	31	27	4 (13)	0.02*
Achilles or heel	16	12	4 (25)	0.87*
Malleolus	17	8	9 (53)	0.004*
Size (cm ²)	12 (5–21)	15 (6–25)	9 (5–20)	0.25
Operating time—skin to skin (min)	100 (75–145)	105 (79–153)	82 (74–135)	0.13
Tourniquet time (min)	75 (60–93)	80 (61–100)	73 (41–77)	0.12
No with donor-site complication	13 (20)	7 (15)	6 (35)	0.07
No with co-existing medical condition	27 (42)	16 (34)	11 (65)	0.05
No with diabetes mellitus	6 (9)	4 (9)	2 (12)	0.78
No with cardiovascular condition	15 (23)	6 (13)	9 (53)	0.002
No with other medical condition	14 (22)	10 (21)	4 (24)	1.00

Data are median (25–75 centiles) or n (%) unless otherwise stated. Mann Whitney *U* test and chi-square for the difference between the outcome groups. Four patients had both a cardiovascular condition and either diabetes mellitus or another medical condition.

*Post hoc 2×2 chi-square for the difference between 1 site and the other 2 taken together.

Table 5. Multivariable Logistic Regression for Complications and Flap Loss

Variables	Coefficient	P	OR	95% CI
Age	0.01	0.66	1.01	0.96–1.07
Sex	0.18	0.83	1.20	0.23–6.14
Cardiovascular condition	1.86	0.02	6.45	1.28–32.57
Site of injury				
Tibia, dorsal foot			1.00	
Achilles, heel	0.40	0.65	1.50	0.26–8.62
Malleolus	1.95	0.03	7.06	1.21–41.20
Constant	-3.14	0.07		

Viable flap (full success) coded as 0, complications and flap loss (dehiscence, fistulae, partial necrosis, and total necrosis) coded as 1. Model pseudo R² 0.24, P = 0.006, n = 56 (age and cardiovascular condition were inter-correlated, pseudo R² 0.18, coefficient 0.09 by each year, P = 0.005).

There was further a tendency for more complications with older age.

Simple logistic regression showed that malleolar site of injury [odds ratio (OR), 7.6; P = 0.005, compared with the reference group tibia and dorsal foot], and presence of cardiovascular condition (OR, 7.3; P = 0.003), were associated with flap complications and flap loss.

Multivariable regression (adjusting for age and sex, and stepwise forward testing combinations of the other variables) showed that site of injury and cardiovascular condition were the differences between the 2 groups that were verified (significantly contributing to the model; Table 5).

DISCUSSION

Sixty-four patients were operated using the EDB flap to reconstruct defects of the lower leg and foot with median size of 12 cm². The 25th to 75th percentile of defect size was between 5 and 21 cm². Total flap-failure was seen in 7 cases (11%) while 10 cases (16%) had partial loss of the flap. Malleolar defects and cardiovascular disease were factors associated with flap failure (either partial or total). We have used the EDB flap for different defects in different regions of the lower leg and even mid- and proximal parts of the tibia, which we think confirms the versatility

of the pedicled EDB-flap in the reconstruction of lower leg defects.

Reconstruction of complex defects of the lower leg and the foot is a continuous challenge for reconstructive surgeons due to poor blood supply, thin skin, and thick bony prominences and sparse muscle volume.¹³ The choice of reconstruction method depends on the nature of the defect, mechanism of trauma, and site of injury as well as surgeon preferences and capabilities. Free micro-vascular tissue transfer is in many parts of the world a popular, useful, and reliable method for the reconstruction of lower leg defects, in particular as experience with these techniques has increased globally.¹ However, a high level of training, expertise, and experience is needed apart from higher costs than with local or pedicled flaps.¹⁴ Local solutions such as reversed flow island flaps, perforator flaps, keystone flaps, and local muscle or skin flaps are available options and in many hands easier to perform.¹⁵ A total assessment of the patient's need of coverage in relation to local factors as well as age and comorbidities is crucial. If considering the use of an EDB-flap, the effects of the sacrifice of a main artery, that is, anterior tibial/dorsalis pedis artery must always be evaluated in relation to future complications. Distally based sural flaps are also widely used in reconstruction of lower leg defects.^{16–18} A cross-leg flap could be considered as an old-fashioned and last resort method but certainly is still a reconstructive option. The morbidity and severe patient discomfort associated with this technique has reduced its popularity considerably.¹⁹ As shown previously, the EDB-flap can be considered a good reconstructive option for small defects in the lower leg and foot region,^{8,11,20} which also we have confirmed in this study. The small size and the thin contour of the flap in addition to the relative simplicity of harvesting are advantages that in some instances make the flap superior when compared with free tissue transfer or other local flap options. Also, in older age groups or in patients with significant comorbidities where free tissue transfer and perforator flaps could be deemed more risky, the EDB can provide a good solution (Fig. 5). The ability to reconstruct defects in complicated areas such as the distal third of the tibia, the heel and Achilles tendon and malleoli is valuable. We have, moreover, in this study also used the flap to reconstruct defects even of the proximal tibia, which confirms the extreme versatility of the EDB flap. In this group (proximal tibia defects), no flap loss was recorded. We further found the EDB-flap particularly useful in the treatment of osteomyelitis with fistulation where parts of, or some of, the muscle bellies also could be used to fill out smaller revised bone cavities.

Success, Failure Rates

In our study, the rate of complete reconstructive failure was about 11%, which is comparable with other studies using EDB^{11,13} and other flap techniques for reconstruction of lower leg defects.^{21–26} However, our study group was considerably larger than in other reports. Our finding that cardiovascular co-existing medical condition was a risk factor for reconstructive failure might not come as a complete surprise.

The cumulative rate of partial and total necrosis after using perforator-pedicled propeller flaps for lower extremity defects has in a recent review been reported to be 13.5%,²⁶ which is lower than the corresponding number (18.8%) in our study, although the numbers change to 17.5% if case studies of less than 5 patients are excluded from the review²⁶ to avoid positive reporting bias on account of handicapped cases. The complete success in our study (73%) was similar to that of 70%, which was reported by Yasir et al.,²¹ although, none of the 8 patients in that study who were 50 years and older had flap necrosis,²¹ suggesting that perforator flaps can be one of the first choices for reconstruction in elderly patients.

The reversed sural flap with modifications (extended distally based) and medial sural artery perforator flap^{23,25} have reported necrosis rates of 10–15% of patients included in the study. However, the donor-site morbidity of this flap is well known, but its capacity to reconstruct bigger defects is an advantage.

According to the review by Reddy and Stevenson,¹ the reconstruction of distal lower leg defects are mainly accomplished using free tissue transfer. However, local fasciocutaneous flaps have been gaining some popularity nowadays. In a study by Kang et al.,²⁷ the total failure rate for free tissue transfer was only 3.5%, however, including partial necrosis the percentage increase to 15%, which is similar to the other described studies and to this study as well. The main advantage of free tissue transfer is the lower local donor-site morbidity compared with local flaps and the capacity to reconstruct larger defects.

Malleolar defects had the worst outcome in our study. Chattar-Cora and Pederson⁹ reported 2 flap failures of totally 9 EDB done to reconstruct a malleolar defect, Koul et al.²⁸ 1 of 4, Pai et al.¹³ none of 5, which by crude numbers is considerably better than our outcome in this site. However, in those studies, patient mean age was 49, 33, and 39 years in the malleolus subgroups, whereas it was 65 years in our study, which could explain the difference in outcome. The mean age in our study is notably higher than mean age in many studies,²⁷ which is characteristic of our Swedish patient population. This makes the EDB technique particularly useful in this part of the world due to the higher complication rate associated with both microsurgical and propeller techniques in the same age group.

The EDB is technically not particularly challenging, and the median operating time in this study was 100 minutes, which indicates that the operation in experienced hands is a short procedure with comparable complication rate to other techniques.

Anticipated Negative Effects after EDB-harvest

The reported complications after the use of EDB-flaps in other studies are few.^{11,13} Donor-site morbidity was 20% (13/64) in our study, which is within the range that of previous publications of 10–45%.^{9,11,13,28} The donor-site morbidity on the dorsum of the foot of the EDB muscle flap is considered to be limited except for possible effects of loss of blood supply from the dorsalis pedis artery to the foot.^{13,29} According to the publication by Chattar-Cora and Pederson,⁹ none of the patients reported difficulty with

ambulation after EDB flap surgery. Koul et al.²⁸ described that 2 of the patients had persistent sensory loss of the skin over the deep peroneal nerve distribution area. Ghareeb²⁹ found hypertrophic donor-site scars in 4 cases of their 14 EDB flaps, and that 1 patient had pain after walking, whereas 4 had other sensation abnormalities at the donor site at long-term follow-up. It can be expected that loss of the synergistic effects of the EDB, and the Extensor hallucis longus and EDL could affect extension of the toes in conjunction with extensive scarring of the dorsum of the foot. Most of the studies have not studied long-term effects after these operations and the frequency of these complications in detail is not known.

Limitations of the Study

The retrospective design of the study resulted in difficulty to assess longer term postoperative results in detail. We have relied on the patients' medical records. There was an overrepresentation of negative records due to the increased focus generated as a complication results in more frequent visits and more notes. The long time-range of this study is a limitation due to changes over time in the instrumentation and increased surgeon experience with this technique. A small number of experienced reconstructive surgeons operated all these patients over a long period of time. There is now a need for further follow-up of this group of patients with regard to long-term results and donor-site morbidity.

CONCLUSIONS

The pedicled EDB-flap has proven to be a versatile and safe reconstructive option in the reconstruction of small defects in the lower leg and foot; however, long-time follow-up is recommended.

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