British Journal of Plastic Surgery (1987) **40**, 20–26

The distally based split soleus muscle flap

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Summary—A refinement of the previously described distally based soleus muscle flap is proposed. The essential features of the flap are mobilisation of the tibial origin, splitting the muscle longitudinally, partially along a distinct anatomical plane, and preservation of anatomical continuity of the muscle. We suggest that improved blood supply to this flap derives from the intact major lateral proximal pedicles via the intact lateral portion into the flap. We also think that minimal damage to intramuscular vasculature integrity contributes to the improved circulation. The flap has been designed and studied using ten fresh cadaver leg dissections, Angiographic studies proved adequate blood supply to the flap. The flap has been tested eight times on seven patients with favourable results.

A soft tissue defect of the lower third of the leg presents a challenging problem because of the proximity of skin to bone, shortage of local soft tissues and poor local circulation. These difficulties are reflected by the numerous techniques that have been proposed to reconstruct the distal leg.

Local tissues and split skin graft should be considered first. The multi-staged jump flap has been abandoned because of the high risk of flap loss and prolonged hospitalisation (Serafin *et al.*, 1977). The time-honoured cross leg flap is still widely accepted as a method of choice in covering distal leg defects in children. In older patients the incidence of complication, deep vein thrombosis in particular, cannot be ignored (Morris and Buchan, 1978).

The recently described fasciocutaneous flaps are reliable axial flaps that are reported to have a high success rate (Pontén, 1981; Barclay *et al.*, 1982; Cormack, 1985; McGregor and Palmer, 1985).

The rapid development of microsurgery during the past decade introduces the free composite tissue flap as another option for reconstruction of the lower leg, the groin free flap (Baudet *et al.*, 1976), latissimus dorsi and tensor fasciae latae musculocutaneous flaps being the most commonly used. Although these flaps are reliable (Harii and Ohmori, 1976; O'Brien, 1977; Serafin *et al.*, 1977), we believe that they should be kept as a last resort in the management of a wound.

The reasons are long anaesthetic time, which is associated with its own risks, donor site morbidity, and the too bulky coverage which is often achieved.

The use of the soleus muscle is associated with the least donor site morbidity when compared with other locally available muscles. The distal leg, however, is outside the arc of rotation of the proximally based flap. The use of the muscle on the distal pedicles has been described by Townsend in 1978. When the entire muscle is mobilised, based on the distal pedicles, the flap is risky and associated with a high failure rate.

The soleus is a type II muscle in Mathes-Nahai classification, receiving muscular branches from the popliteal, posterior tibial and peroneal arteries along its proximal third, and three muscular branches from the posterior tibial vessels along the medial border of the distal two-thirds (Mathes and Nahai, 1982). Innervation is from the tibial nerve close to the origin of the muscle which arises from the soleal line of the tibia and the proximal third of the fibula and inserts into the tendo calcaneus. It is the major flexor of the ankle joint as well as the major venous pump of the leg.

The aim of this study was to refine the surgical technique in order to construct a reliable distally based soleus muscle flap.

Method

Anatomical studies

The soleus muscle blood supply was studied in 10 fresh cadaver legs. Both anatomical dissection and barium suspension angiography were used (Fig. 1). Based on information collected at this stage, the proposed flap was designed. In 5 of the 10 legs the flap was mobilised *in situ*. Following this, barium

suspension was injected into the popliteal artery. The muscle was harvested and X-rayed ex situ. The filling of the flap arterial tree was studied (Fig. 2).

Clinical study

Eight flaps were performed on seven patients (Table 1), four males and three females aged 22 to 57 years, with a mean of 32 years. Six of them were road accident victims and the seventh one was a burn victim. In 6 of the 8 legs compound fractures of the tibia and fibula were present, all of them type III in the modified Coustille classification (Byrd *et al.*, 1981). The delay between the accident and definitive coverage ranged between 2 and 30 days, mean 13 days, and the follow-up period ranged between 4 and 20 months, with a mean of 10 months. In 5 of the 8 legs pre-operative osteitis was noted by clinical observation and confirmed by pus swab cultures. All the wounds had been excised down to bleeding bone and viable tissue prior to coverage.

Results

Anatomical studies

The blood supply of the proximal portion of the muscle is segmental, arising from the popliteal, peroneal and posterior tibial arteries. This is consistent

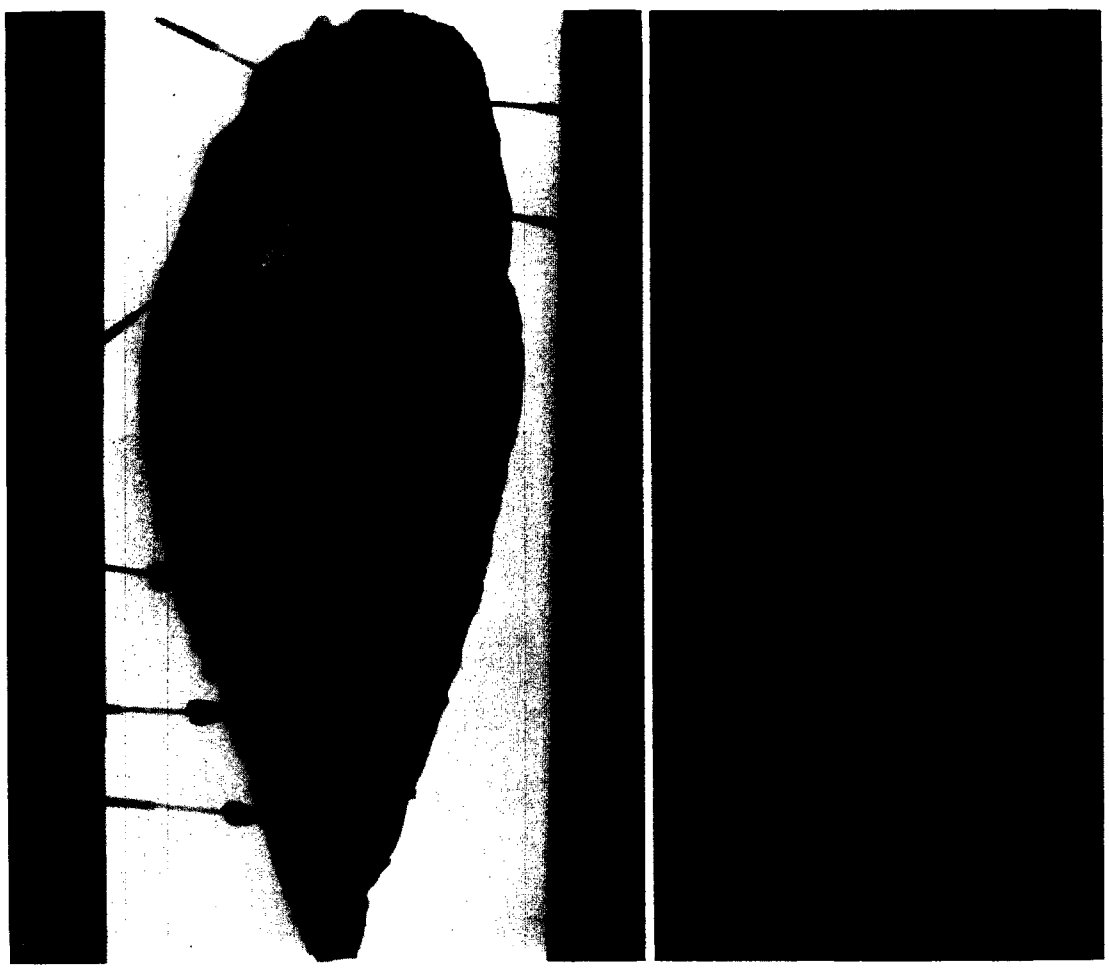

Fig. 1

Figure 1—(A) Anatomical and (B) radiological appearance of the vascular anatomy of the soleus muscle. M = medial, L = lateral, O = origin, A = insertion at tendo Achilles, PA = popliteal artery (retracted, not in its natural anatomical relationship). PT = posterior tibial artery, PR = peroneal artery. In (A) the microvascular swabs point to the muscular pedicles. Note in (B) the axial pattern of the muscular vessels on the distal portion of the muscle (arrow).

with the findings of a previous study (Magee *et al.*, 1980). In the distal half of the muscle the vessels gain a longitudinal axial orientation (Fig. 1B). This directionality is parallel to an intramuscular septum which arises from the anterior surface of the tendo calcaneus in a "T" form and splits the distal portion of the muscle into two sub-units. Small vessels connect the two systems. The bipennate muscle inserts into this septum as well as into the anterior surface of tendo achilles. The size of this septum is inconsistent and sometimes it is identified just by the confluence of the bipennate muscle fibres. The medial system anastomoses with the distal pedicles arising from the posterior tibial artery as low as the junction of the two distal quarters of the leg. The lateral most distal pedicle arises from the peroneal artery and enters the soleus muscle via the flexor hallucis longus at about the mid-calf level (Fig. 1A). This pedicle prevents further distal mobilisation of the lateral portion of the muscle without risking the flap so the arc of rotation of the lateral portion flap is smaller than that of the medial portion. The medial flap can easily reach the ankle level. Barium suspension angiography demonstrated adequate blood supply to the tip of the flap (Fig. 2).

Surgical technique

A medial approach is used (Fig. 3) and an incision made through the deep fascia. The planes deep and superficial to the muscle are identified. The tibial origin of the muscle is sharply dissected. Careful muscle splitting rather than muscle cutting dissection is used to divide the muscle longitudinally (Fig. 4). We have found blunt dissection safer in the proximal portion of the muscle where a distinct anatomical plane cannot be identified. The splitting technique allows easy identification and preservation of the intramuscular vessels. Three to four pedicles have to be sacrificed in the area of the tibial origin of the muscle to allow adequate mobilisation. Sharp dissection is used to mobilise the muscle off the anterior aspect of the tendo calcaneus or to incise the tendon at the proximal portion of the musculo-tendinous junction. A split skin graft is applied to the exposed muscle after transfer to the recipient area.

Fig. 2

Figure 2—Barium angiography showing perfusion right to the tip of the flap.

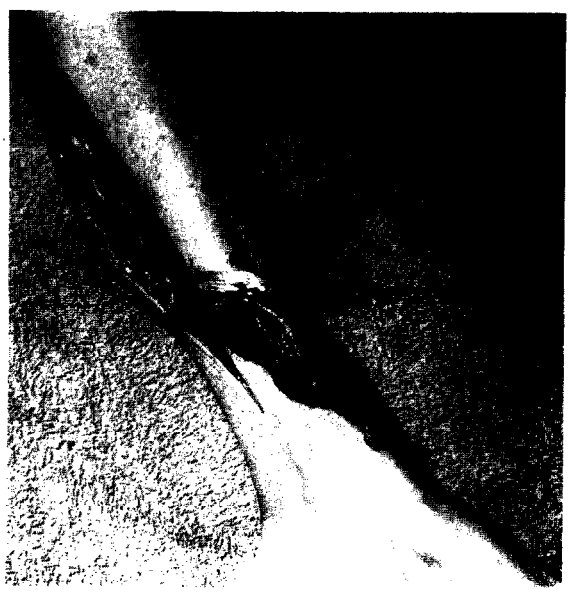

Fig. 3

Figure 3 Cadaver study demonstrating the surgical approach and the arc of rotation of the flap.

Clinical experience

We experienced no flap loss and obtained stable wound cover in all cases. Four of the six fractures have united and the other two are still uniting, one of them after a secondary bone graft. In two legs post-operative infection occurred and required elevation of the flaps and secondary debridement. Complete healing resulted. One patient, a burn victim with an exposed 21 cm segment of tibia, required two flaps— medial head of gastrocnemius and distally based split soleus—to cover the defect. Two illustrative cases are shown in Figs 5 and 6.

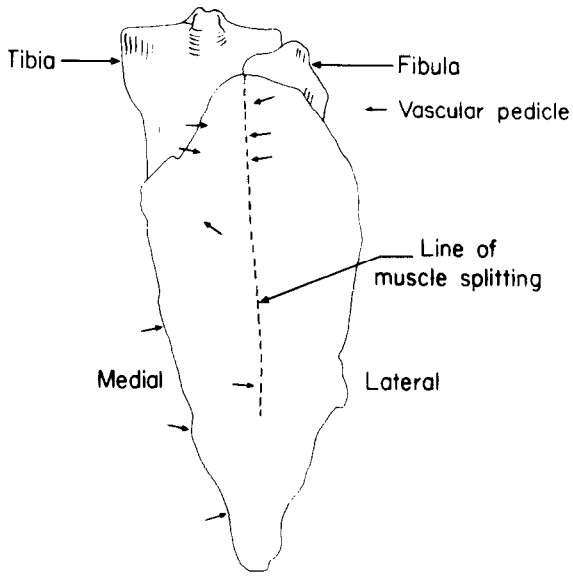

Fig. 4

Figure 4 The line of muscle splitting. The arrows point to the vascular pedicles.

Discussion

The improved blood supply of the split distally based soleus flap when compared with the whole muscle distally based is a result of the following:

(i) Minimal injury to the intramuscular vasculature is achieved by splitting the proximal portion of the muscle rather than cutting it. In the distal half a distinct anatomical plane—an intramuscular septum—can be identified and followed.

Table 1 Case summaries

Case No.	*Age Sex*	*Cause*	*Size and age of defect*	*Wound condition*	*Follow-up period*	*Complications*	*Soft tissue result*	*Bony result*
1.	45 F	Motor vehicle accident	10 × 7 cm 14 days	Compound tibia fibula fracture	20 months	Osteitis	Complete healing	Union at 18 months
2.	22 M	Motor vehicle accident	9 × 6 cm 3 days	Compound tibia fibula fracture	17 months	None	Complete healing	Union
3.	20 F	Pedestrian knocked down by car	Rt 10 × 15 cm Lt 12 × 17 cm 21 days	Bilateral compound tibia fibula fracture	13 months	None	Partial cover with flap, rest with skin graft. Complete healing	Union
4.	52 M	Full thickness burn	21 × 8 cm 30 days	Exposed tibia with osteitis	20 months	Osteitis	Cover with combined medial head of gastrocnemius musculocutaneous flap and distally based soleus with skin graft	Second debridement at three months
5.	17 M	Motorbike accident	9 × 6 cm 10 days	Compound tibia fibula fracture with osteomyelitis	8 months	None	Complete healing	Secondary bone graft uniting
6.	12 M	Pedal bike accident	8 × 6 cm 2 days	Compound tibia fibula fracture	4 months	None	Complete healing	Uniting
7.	57 F	Motor vehicle accident	4 × 2 cm 3 days	Exposed tibialis anterior tendon and periosteum	3 months	None	Complete healing	N/A

(ii) The anatomical continuity of the lateral portion of the muscle is preserved. This allows additional blood supply from the major proximal pedicles via the intact lateral portion into the distally based flap. This anatomical continuity also allows the post-operative morbidity to be kept to a minimum.

The principle of this modification has been independently studied by Tobin and was published recently (Tobin, 1985). We disagree with his conclusion that the intramuscular septum is a distinct watershed of blood supply. In all five of our cadaver dissections studied with barium angiography, a significant vascular communication between the medial and lateral systems was shown, and we believe that the proposed flap is enhanced through these channels (Fig. 2). The other major advantage of the flap is its arc of rotation which allows it easily to cover defects as low as the ankle joint. The laterally based split soleus muscle flap does not reach as far because the distal pedicles from the peroneal artery, which are probably important to the survival of the flap (we have had no clinical experience to confirm this conclusion), enter the muscle at about mid-leg level and prevent further mobilisation of the axis of the flap. We believe that our method is safer than an alternative advocating ligation of the proximal posterior tibial artery and using the back flow through the distal portion of this artery as the blood supply to the distally based soleus flap (Guyuron *et al.*, 1982).

The principle of using a muscle flap to treat infection in a bone is now accepted world-wide (Mathes, 1984). The infection rate in our series—2 out of 8 legs—is comparable with series describing equivalent injuries (Morain, 1980). We believe that this relatively high complication rate can be dramatically improved when adequate debridement and coverage are carried out as a primary or delayed primary rather than a secondary procedure (Brown, 1965; Byrd *et al.*, 1981).

In conclusion, refinement of the surgical technique of the distally based soleus muscle flap is pro-

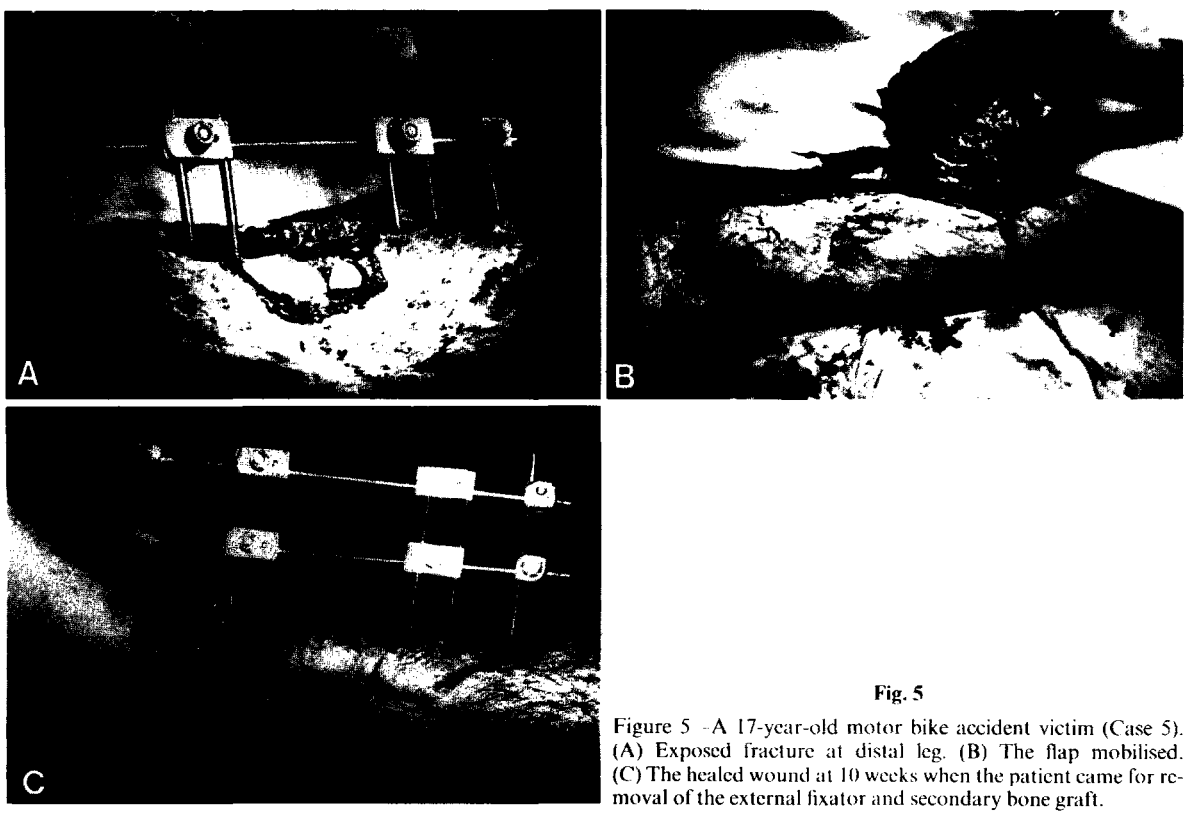

Fig. 5

Figure 5 -A 17-year-old motor bike accident victim (Case 5). (A) Exposed fracture at distal leg. (B) The flap mobilised. (C) The healed wound at 10 weeks when the patient came for removal of the external fixator and secondary bone graft.

Fig. 6

Figure 6— A 57-year-old female who was involved in a car accident (Case 7). (A) Exposed tibialis anterior tendon (arrow). (B) The flap mobilised. (C) The healed wound 3 months after surgery.

posed. We suggest the use of muscle splitting rather than the cutting technique and we propose the preservation of muscle continuity of the lateral portion of the muscle. Our early clinical experience provides favourable results.

Acknowledgements

We wish to thank Mr R. Stott for his contribution to this paper. We also wish to express our appreciation to Mrs D Hamilton for her editorial assistance and to Mrs L. Jossel for her photographic assistance.

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