fortune Journals

Research Article

JOURNAL OF SURGERY AND RESEARCH

ISSN: 2640-1002

Single Centre Experience of Flap Reconstruction in Patients with Lower Limb Vascular Anatomical Variants: Case Series, Review of the Literature and Algorithm for Management

Frances Bowerman[1,2], James Warbrick-Smith[1], Ahmed Emam[1,2], Nicholas Marsden[1,2*]

Abstract

Introduction: Soft tissue reconstruction in the form of local and free tissue transfer provides the mainstay of treatment in open lower-limb fractures. Developments in pre-operative imaging have led to improved surgical planning, reduced operative times, and aid in identifying abnormal vascular anatomy. There is a paucity of literature regarding soft tissue reconstruction in patients with aberrant vascular anatomy, with no general consensus on management. We describe our experience managing a series of seven patients within the last two-years with anatomical vascular variations requiring soft tissue reconstruction for open lower limb fractures, review the current literature and propose a surgical algorithm to aid in managing these complex cases.

Materials and Method: Retrospective analysis of a departmental lower limb-flap database performed to identify all traumatic defects requiring flap reconstruction over a 24-month period (September 2020-Aug 2022) following the establishment of a Major Trauma Network. Patient demographics, injury details, surgical procedures and post-operative complications were recorded. All patients had a computed tomography angiography (CTA) prior to definitive surgery. Inclusion criteria included all patients identified to have a vascular anatomical variant following pre-operative CTA.

Results: 7/188 patients undergoing flap reconstruction for lower-limb trauma were identified as meeting the inclusion criteria. Mean age 40 (28-81 years), female to male ratio of 4:3. There were four gracilis, two anterolateral thigh and one medial plantar artery flap performed, with two flaps requiring AV loops. There was one flap failure. There were five previous cases identified in the literature for review. Based on our experience and on reviewing the literature we propose a management algorithm for these complex cases.

Conclusion: This series demonstrates that free and pedicled flaps based on anatomical vascular variants can be successfully performed in limb salvage surgery. Pre-operative planning, informed by a surgeon-reviewed CTA, minimises the risk of distal ischaemia and allows thorough surgical planning to reduce technical difficulties that would otherwise be encountered intra-operatively.

Keywords: Vascular variations; Peronea arteria magna; Open lower limb fracture; Free flap; Microsurgery

Affiliation:

[1]Welsh Centre for Burns & Plastic Surgery, Morriston Hospital, Swansea, UK

[2]Major Trauma Centre, University Hospital of Wales, Cardiff, UK

***Corresponding author:**
Nicholas Marsden, Welsh Centre for Burns & Plastic Surgery, Morriston Hospital, Swansea, UK

Citation: Frances Bowerman, James Warbrick-Smith, Ahmed Emam, Nicholas Marsden. Single Centre Experience of Flap Reconstruction in Patients with Lower Limb Vascular Anatomical Variants: Case Series, Review of the Literature and Algorithm for Management. Journal of Surgery and Research. 7 (2024): 76-80.

Received: January 09, 2024
Accepted: January 18, 2024
Published: February 26, 2024

Bowerman F, et al., J Surg Res 2024
DOI:10.26502/jsr.10020344

Introduction

Soft tissue reconstruction in the form of local and free tissue transfer provides the mainstay for managing open fractures of the lower limb. Imaging and cadaveric studies have well described the anatomical variations in the vascular branching pattern distal to the popliteal vessels, originally classified by Lippert and Pabst [1] and subsequently modified over recent years (Table 1) [2,3]. A meta-analysis found that almost 93% of all limbs have a normal popliteal branching pattern (Type IA - division of the popliteal artery below the knee into the anterior tibial (AT) artery and a common trunk for the posterior tibial (PT) and peroneal (PR) arteries), meaning around 7% of people have anatomical variants of the vascular anatomy [4]. As reconstructive microsurgeons, the main focus on lower limb arterial variations, in particular with peronea arteria magna (PAM) has been concern when planning free fibula harvest and the risk of devascularising the limb [5]. However, although there have been several algorithms describing the selection of recipient vessels for lower limb reconstruction [6,7] in patients with normal anatomy, patients found to have abnormal anatomical variants pose a difficult challenge and there is no published algorithm for managing these patients. We describe our experience of managing a series of patients with anatomical vascular variations requiring soft tissue reconstruction for open lower limb fractures, review the literature and propose an algorithm to aid in managing these complex cases.

Materials and Methods

Retrospective analysis of our departmental lower limb flap database was carried out to identify all traumatic limb defects requiring flap reconstruction over a 24-month period following the establishment of a Major Trauma Network (September 2020-August 2022). All patients underwent Computed Tomographic Angiography (CTA) prior to their surgery. Inclusion criteria included all patients identified to have a vascular anatomical variant following CTA. Patient demographics, injury details, surgical procedures and post-operative complications were recorded. All patients were managed by a combined specialist orthoplastic team, according to the British Orthopedic Association (BOA) – British Association of Plastic Reconstructive and Aesthetic Surgery (BAPRAS) standards for management of open fractures [9]. A combined orthoplastic approach was utilised in all high energy cases, firstly with initial wound excision, skeletal stabilisation and wound temporisation with negative pressure wound therapy (NPWT), followed by second stage definitive skeletal fixation and soft tissue coverage. In cases of low energy fragility open fractures in the elderly, we aim for a single stage fix and flap approach whenever possible. All patients received prophylactic dose low molecular weight heparin thromboprohylaxis pre- and post-operatively, continued for a maximum of six-weeks until fully weight bearing. A literature search was performed on Medline, Embase and Scopus using the terms peronea arteria magna, open lower limb fractures and free flaps. This yielded 17 results, of which five case reports were relevant.

Results

Between September 2020 and August 2022, 188 patients had flap reconstruction for open lower limb traumatic injuries. Seven patients were identified for inclusion for analysis, with a mean age of 40 (28-81 years) and a female to male ratio of 4:3. Patients demographics, injury details, anatomical variant and surgical management are presented in table 2.

Six of the patients had grade IIIB open fractures of the distal tibia, with the one patient having a closed ankle fracture, with subsequent skin necrosis requiring delayed exchange of metalwork and soft tissue coverage. Four patients underwent

Classification	Vascular Pattern
IA	Normal pattern
IB	Trifurcation: AT, PT and PER arise below knee within 0.5cm of each other
IC	Anterior tibioperoneal trunk: PT is first branch, then TPT bifurcates into PER and AT
IIA1	AT arises at or above the knee joint, with normal course in its proximal segment
IIA2	AT arises at or above the knee joint, with medial curve in its proximal segment
IIB	PT arises at or above the knee joint common trunk or AT and PER
IIC	PER arises at or above the knee joint, common trunk Of AT and PER
IIIA	**Hypoplastic or aplastic PT, distally replaced by PER**
IIIB	**Hypoplastic or aplastic AT, DP replaced by PER**
IIIC	**Hypoplastic or aplastic AT and PT, DP and PT replaced by PER (Peronea Ateria Magna)**

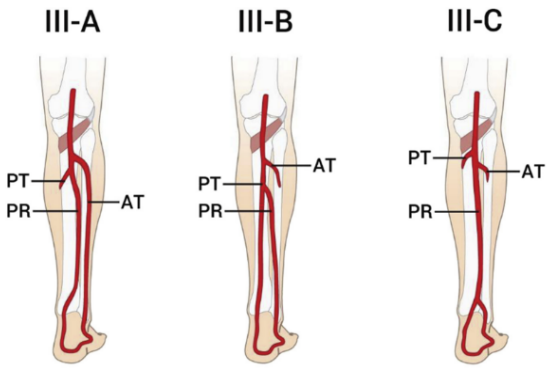

Table 1: Classification of the vascular anatomical variants distal to the popliteal artery, highlighting type IIIA-C as those posing difficulties to the lower limb reconstructive surgeon. AT = Anterior tibial artery, PER = Peroneal artery, PT = Posterior tibial artery, TPT = Tibioperoneal trunk, DP = Dorsalis pedis. Image adapted from Abou-Foul et al. 2015 [8].

Citation: Frances Bowerman, James Warbrick-Smith, Ahmed Emam, Nicholas Marsden. Single Centre Experience of Flap Reconstruction in Patients with Lower Limb Vascular Anatomical Variants: Case Series, Review of the Literature and Algorithm for Management. Journal of Surgery and Research. 7 (2024): 76-80.

Bowerman F, et al., J Surg Res 2024
DOI:10.26502/jsr.10020344

a free gracilis flap, two of which required a single stage AV loop onto the superficial femoral artery at the time of definitive surgery (Figure 1), two had an ALT flap and one patient had a pedicled medial plantar artery flap.

There was one flap failure and one patient that required a return to theatre after 12 hours for venous congestion, which was successfully salvaged. The patient who had a flap failure had a IIIA variant with a hypoplastic PT, which was anastomosed end-to-end to the gracilis flap. This failed and a second ALT was performed, using an AV loop to the popliteal artery. Despite being discharged on day 6 with a healthy flap, unfortunately the patient, who was of no-fixed abode and an intra-venous drug user, returned at two-weeks with a necrotic ALT flap and underwent a below knee amputation. Only one patient had a free flap anastomosed end-to-side onto the true PER vessel and this was for a medial defect. The PER vessel was approached medially, which was technically challenging and only possible because the patient was very slim (Figure 2).A literature search was conducted, the results of which can be found in table 3.

Discussion

Anatomical variation in the branching pattern of the popliteal vessels is well established. Although rare, PAM variations have a significant impact on the management and reconstruction of open lower limb fractures. Knowledge of these variations is essential in the planning and execution of pedicled and free flaps to the lower limb and needs to be considered in the pre-operative planning stage, as it impacts the choice of reconstruction, recipient vessel selection, choice of anastomosis, and can pose a threat to the blood supply of the foot if not properly managed. A literature search demonstrated a wealth of information outlining the significance of PAM in the planning and execution of free fibula harvest for reconstruction of maxillo-facial defects, and the resultant risk of devascularising the limb [3]. However there is little published with regards to PAM in the context of lower limb trauma and reconstruction, with only five case reports in the literature.

Peterson et al reported a patient with a bimalleolar ankle fracture with a medial wound, who underwent a free ALT with end-to-side anastomosis to the PER via a lateral approach [10]. This is the only case whereby the lateral approach and

Patient	Age	Sex	Injury	Location	GA Grade	Mechanism	Anatomical variant	Flap	Recipient vessels	Flap survival
1	31	M	Distal 1/3 open tib #	Medial	IIIB	RTC	IIIC	ALT	PER E-S	100%
2	81	F	Open ankle # dislocation	Medial	IIIB	Mechanical fall	IIIA	MPA	Based on PER contribtion to MPA	100%
3	48	F	Distal 1/3 open tib #	Medial	IIIB	Struck by metal object	IIIA	Gracilis	Hypoplastic PT E-E	0%
4	49	F	Distal 1/3 open tib #	Medial	IIIB	RTC	IIIA	Gracilis	PER as coursed medial to form MPA E-S	100%
5	40	M	Distal 1/3 closed tib #	Anterior	N/A	Fall from height	IIIA	ALT	AT E-S	100%
6	32	F	Mid-distal 1/3 open tib #	Medial	IIIB	RTC	IIIA	Gracilis	AV loop (LSV) to SFA	100%
7	28	M	Distal 1/3 open tib #	Medial	IIIB	RTC	IIIA	Gracilis	AV loop (LSV) to SFA	100%

Table 2: Demonstrating patient demographics, injury details, anatomical variations, andsurgical management and outcomes. GA = Gustilo-Anderson, Tib = tibia, # = fracture, RTC = road traffic collision, ALT = anterolateral thigh flap, E-S = end-to-side anastomosis, E-E = end-to-end anastomosis, AV = arterio-venous, LSV= long saphenous vein, Alt= anterolateral thigh flap, MPA = medial plantar artery flap, PER = perineal artery, PT = posterior tibial artery Of note, case 5 was a closed fracture with subsequent delayed skin necrosis over the fracture site.

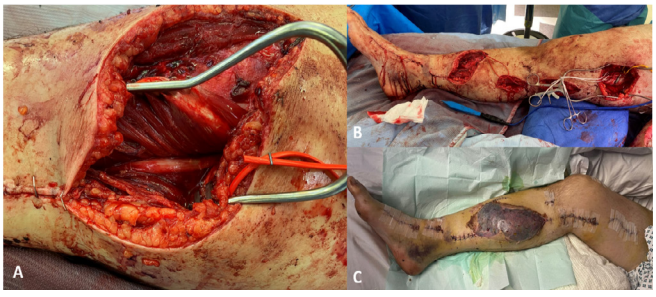

Figure 1: Clinical images demonstrating case 7 in our series, a young man with an open mid-shaft tibial fracture and type IIIA anatomical variant with absent posterior tibial artery. A) medial defect of the lower limb with absence of vascular structures in the posterior tibial region, with an isolated tibial nerve, B) demonstrating the intra-operative steps of the AV loop up to the superficial femoral artery, C) five-days post-op demonstrating a healthy free gracilis flap with adherent skin graft and D) six-weeks post op with fully healed wounds prior to commencing scar therapy.

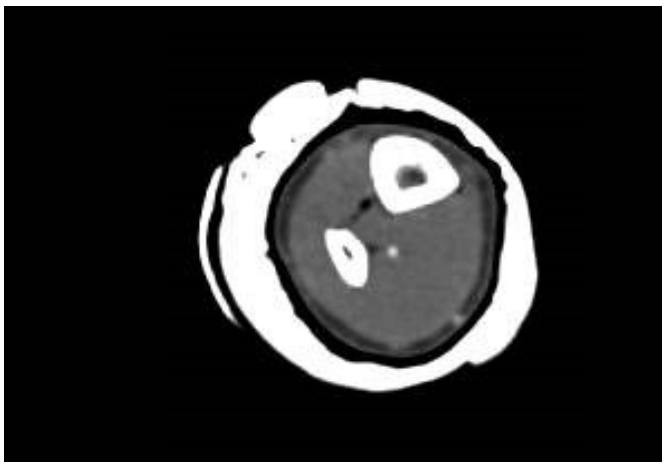

Figure 2: CTA axial slice of the lower limb just proximal to the distal 1/3 tibial fracture in Case 1, demonstrating a hyperplastic PER with absent AT and PT vessels – type IIIC.

Citation: Frances Bowerman, James Warbrick-Smith, Ahmed Emam, Nicholas Marsden. Single Centre Experience of Flap Reconstruction in Patients with Lower Limb Vascular Anatomical Variants: Case Series, Review of the Literature and Algorithm for Management. Journal of Surgery and Research. 7 (2024): 76-80.

Bowerman F, et al., J Surg Res 2024
DOI:10.26502/jsr.10020344

	Age	Sex	Injury	Location	GA Grade	Mechanism	Anatomical variant	Flap	Recipient vessels	Flap survival
Peterson 2016	63	M	Open ankle #	Medial	Unknown	Unknown	IIIA	ALT	PER E-S	100%
Dargan 2021	55	M	Open ankle #	Anteromedial	IIIB	Cyclist vs HGV	IIIC	Gracilis	E-S medial branch of PER	100%
Troisi 2018	68	F	Open ankle #	Medial	IIIB	Unknown	IIIA	MSAP	E-S medial branch of PER	100%
Lutz 2000	36	F	Open # dislocation foot + ankle	Medial	N/A	Pedestrian vs truck	IIIC	LD	E-E medial branch of PER	100%
Elswick 2019	57	M	Distal 1/3 closed tib #	Anterior	N/A	RTC	IIIA	Parascapular	PER E-S	100%

Table 3: Summary of the five cases previously published of flap reconstruction in lower limb trauma with anatomical variants. LD = Latissimus dorsi, MSAP = Medial sural artery perforator PER= perineal artery HGV= heavy goods vehicle RTC = road traffic collision ALT= anterolateral thigh

fibula osteotomy was used to gain access to the PER. Dargan et al report a free gracilis flap for an open tibial fracture in a patient with IIIC PAM abnormality, anastomosed end-to-side to the PER distally where it coursed medially to form the medial plantar artery [11]. This medial course of the PER where it forms the MPA was also used by Troisi et al for a free medial sural artery perforator (MSAP) flap anastomosed end-to-side [12] and by Lutz et al, for a free latissimus dorsi flap for an open ankle fracture-dislocation, however this was performed via an end-to-end anastomosis [13]. The final case by Elswick et al is a PAM IIIA which underwent free parascapular flap with an end-to-side anastomosis onto the PER via a medial approach [14]. They note the benefits of this medial approach to the PER being that the fibula does not obscure the view, and that the long saphenous vein is in vicinity should it become necessary to utilise this [14].

There is increasing consensus on the recommendation for pre-operative CTA in cases with open lower limb fractures. Not only is there evidence to suggest a reduction in operative times [15], but one study demonstrated that 26.5% of patients with open fractures of the lower limb were noted to have a vascular injury that wasn't clinically apparent[16]. Our experience as outlined in this case series, highlights the importance of pre-operative CT angiogram of the lower limbs in surgical planning, which is a common theme across the other case reports in the literature [10-14]. We have found that it is imperative that the surgeon personally reviews the images during the preoperative planning stage, rather than relying on the radiologist report. Interestingly five out of seven of the CTA's in our series were reported as normal three vessel run off into the foot, with no mention of vascular anatomical variation. In addition to discrepancies in reporting, there are additional limitations of CTA to remain aware of, such as antero/retrograde flow, and adequate perfusion pressure required to produce sufficient contrast appearance. However despite this, surgeon reviewed CTA delineated the anatomy adequately for surgical planning in this cohort of patients. In our unit, formal angiography with real-time imaging has not been used, although this is another imaging option used in other centres. Based on our own experience and on reviewing the current literature we propose an algorithm for managing lower limb trauma requiring soft tissue reconstruction in patients with anatomical vascular variations, based on the vascular classification and defect location (**Figure 3**).

We have found that in the context of treating fragility open ankle fractures in type IIIA variants, if the peroneal artery courses medially in the distal leg to reconstitute the MPA then the pedicled MPA flap is a safe option and should be considered as first choice for reconstruction in this context.

This case series also demonstrates that E-S onto the PER is a safe option. It should be noted that even in thin patients, it is technically more challenging to perform the anastomosis from the medial side. Both medial and lateral approaches have been described, and depending on the location of the defect, resection of the fibula may be necessary to access if a lateral approach to the vessels is used [9].

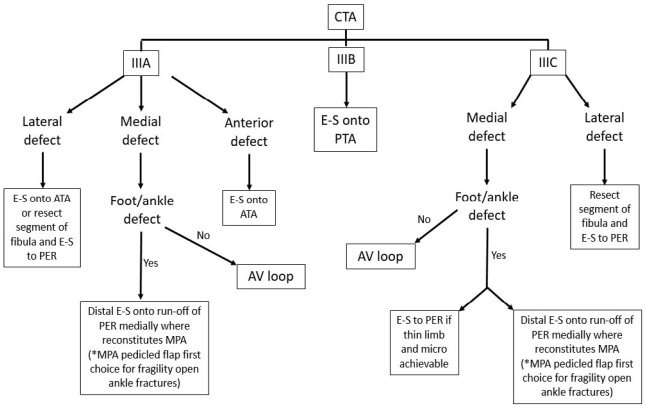

Figure 3: Algorithm demonstrating the options for recipient vessels for flap reconstruction of lower limb defects, based on the type of anatomical variant identified on pre-operative CTA and the location of the defect.

Interestingly we didn't identify any cases of IIIB variants in our series, although in our practise, E-S anastomosis onto the PT is the favoured recipient vessel for most lower limb flaps, and so in IIIB variants, this would be amenable to our standard approach.

Finally, we feel that an AV loop using the LSV is an invaluable option in all types of PAM, but particularly in IIIC types. This is because it is relatively quick to perform, allows flexibility in where to perform the anastomosis and does not require an end to side anastomosis in the only vessel supplying the limb, therefore minimising the risk of devascularizing the limb. An AV loop should be in the armamentarium of all lower limb reconstructive surgeons. AV loops were performed in a single stage, although two stage procedures are an option, with comparable complications rates[17]. In our centre we would prefer to use a single stage AV loop rather than performing bypass procedures assuming the ipsilateral LSV is intact, as this is quick to perform and only requires one extra anastomosis.

The limitations of this study include it was a small cohort of patients. Furthermore, it was a single centre study and so our experience with radiology reporting aberrant anatomy as normal may not be universal.

Conclusion

Anatomical variants impact both the use of the lower limb as a donor and recipient site during free flap surgery. This series demonstrates that free tissue transfer and pedicled flaps based on anatomical vascular variants can be successfully performed in limb salvage surgery. With adequate forehand knowledge and planning, abnormal recipient vessels can be used as a to salvage limbs in the context of lower limb trauma, although it may reduce the free tissue reconstructive options considerably. Pre-operative planning, informed by a surgeon-reviewed CTA, minimises the risk of distal ischaemia and allows thorough surgical planning to reduce technical difficulties that would otherwise be encountered intra-operatively. It also allows a more thorough consent process and patient counselling to enable informed consent with risks most pertinent to their anatomy.

References

1. Lippert H, Pabst R. Arterial variations in man: Classification and frequency. München, Germany: JF. Bergmann (1985).
2. Kim D, Orron DE, Skillman JJ. Surgical significance of popliteal arterial variants. A unified angiographic classification. Annals of Surgery 210 (1989): 776-781.
3. Longo B, Sorotos M, Nicolotti M, et al. Retrospective analysis of incidence of peroneal artery hypoplasia in 101 free fibula transfers and new classification of popliteal branch anomalies. Injury 45 (2014): 394-398.
4. Tomaszewski KA, Popieluszko P, Graves MJ, et al. The evidence-based surgical anatomy of the popliteal artery and the variations in its branching patterns. Journal of Vascular Surgery 65 (2017): 521-529.
5. Holzle F, Ristow O, Rau A, et al. Evaluation of the vessels of the lower leg before microsurgical fibular transfer. Part I: anatomical variations in the arteries of the lower leg. Br J Oral Maxillofac Surg 49 (2011): 270-274.
6. Park S, Han SH, Lee TJ. Algorithm for recipient vessel selection in free tissue transfer to the lower extremity. Plastic and Reconstructive Surgery 103 (1999): 1937-1948.
7. Chen HC, Chuang CC, Chen S, et al. Selection of recipient vessels for free flaps to the distal leg and foot following trauma. Microsurgery 15 (1994): 358-363.
8. Abou-Foul AK, Borumandi F. Anatomical variants of lower limb vasculature and implications for free fibula flap: systematic review and critical analysis. Microsurgery 36 (2016): 165-172.
9. Eccles S, Handley B, Khan U, et al. Standards for the management of open fractures. Oxford University Press (2020).
10. Peterson L, Nguyen T. Free Flap coverage of a medial ankle wound in a patient with arteria peronea magna. Trauma Cases and Review 2 (2016): 71.
11. Dargan D, Lakshminarayan R, Chuo CB. Free Gracillis end-to-side microanastamosis to a peronea arteria magna: a case report. Journal of Medical Case Reports 15 (2021).
12. Troisi L, Berner JE, Gujral S, et al. Importance of Computed Tomography Angiography for Planning Free Tissue Reconstruction in the Presence of Aberrant Vessel Anatomy. International Journal of Orthoplastic Surgery 1 (2018): 10-12.
13. Lutz B, Siemers F, Zun LS, et al. Free Flap to the Arteria Peronea Magna for Lower Limb Salvage. Plastic and Reconstructive Surgery. 105 (2000): 31.
14. Elswick S, Miglani A, Letteri S. Medial approach to the peroneal vessels as recepients for free flap reconstruction of the leg. Microsurgery. Case Report 4 (2019).
15. Schneider CM, Palines PA, Womac DJ, et al. Preoperative Computed Tomography Angiography for ALT Flaps Optimizes Design and Reduces Operative Time. J Reconstr Microsurg 38 (2022):491-498.
16. Chummun S, Wigglesworth T, Young K, et al. Does Vascular Injury Affect the Outcome of Open Tibial Fractures? Plast Reconstr Surg 131 (2013): 303.
17. Henn D, Wahmann M, Horsch M, et al. One-Stage versus Two- Stage Arteriovenous Loop Reconstructions: An Experience on 103 Cases from a Single Centre. Plast Reconstr Surg 143 (2019): 912-924.

Citation: Frances Bowerman, James Warbrick-Smith, Ahmed Emam, Nicholas Marsden. Single Centre Experience of Flap Reconstruction in Patients with Lower Limb Vascular Anatomical Variants: Case Series, Review of the Literature and Algorithm for Management. Journal of Surgery and Research. 7 (2024): 76-80.