



Utility of preoperative colour flow Doppler assessment of perforator anatomy in medial sural artery perforator (MSAP) free flaps

Ben J. Steel¹ · Darpan Mehta¹ · Michael Nugent¹ · Ajay Wilson¹ · Andrew Burns¹

Received: 6 December 2021 / Accepted: 2 August 2022 / Published online: 18 August 2022
© The Author(s), under exclusive licence to Springer-Verlag GmbH Germany, part of Springer Nature 2022

Abstract

Purpose It is known that the vascular perforators upon which the medial sural artery perforator (MSAP) flap is based are subject to considerable variation. This study seeks to evaluate the use of colour flow Doppler (CFD) as an imaging technique to establish the presence of suitable vessels, the discriminatory findings from that imaging, the rate of flap abandonment and flap complications.

Methods All patients undergoing MSAP in our institution since 2015 had a pre-operative CFD using a standardised technique. A prior group of 22 patients not having CFD acted as a control group. Data were collected prospectively.

Results Fourteen patients had CFD. In one patient, no suitable vessels were found. In 13 patients, vessels of suitable size and position were identified, which then correlated precisely with operative findings. Three had suitable vessels in one leg only. No flaps in the CFD group were abandoned. One flap in the CFD group was partially lost. One flap in the prior control group was abandoned.

Conclusions CFD provided reliable discriminatory information to decide on flap suitability/which leg and correlated precisely with operative findings, with no flap abandonment. Flap survival rate was very high.

Keywords Imaging · Reconstruction · Perforator flap

The medial sural artery perforator (MSAP) free flap has become an option for head and neck soft tissue reconstruction since its first description in 2001 [1]. The medial sural artery originates from the popliteal artery and passes distally within the muscle of the upper medial gastrocnemius. Musculocutaneous perforator vessels pass to the skin along its course. It is these perforator vessels upon which the flap is based. However, multiple dissection and imaging studies have found the number, position and size of these vessels to be somewhat variable [1–3]. This variation is both between individuals and between legs in the same individual. There can be one, two, three or four main arterial branches. Dusseldorp et al. (2014) found one branch in 31% of cases, two in 59% and three in 10% [3]. Dominant perforators in that skin region have been found to originate from the medial sural artery in 92% [3]–94% [2] of cases and the lateral sural in 31% [2] of cases. A direct fasciocutaneous perforator

originating from the popliteal artery has also been reported [4]. Position can vary between 9 and 18 cm distal to the popliteal crease [1] and 1.5 to 3.5 cm medial to the posterior midline [3]. Arterial diameters range from 1 to 2 mm and venous diameters 2–6 mm [5].

Vascular mapping before perforator flaps in general can aid surgical efficiency and reduce flap abandonment by identifying the best perforator [6]. Such imaging is well established and standard practice in many centres. Options include handheld Doppler (HHD), colour flow Doppler (CFD), computed tomography (CTA), magnetic resonance angiography (MRA) and indocyanine green immunofluorescence.

Vascular imaging before MSAP has received little study. He et al. (2015) discussed CTA in a single case report [7]. A study of 32 legs in healthy volunteers found duplex ultrasound reliable in identifying dominant perforators [2]. Correlation between MSAP imaging and operative findings in small studies has been reported as 93% for HHD [8] and 100% for CFD [9]. To the best of our knowledge, the discriminatory findings on CFD that indicate MSAP flap suitability have not been studied.

✉ Ben J. Steel
ben.steel2@nhs.net

¹ Oral & Maxillofacial Surgery Department, Sunderland Royal Hospital, Kayll Road, Sunderland SR4 7TP, UK

When evaluated pre-operatively with HHD, the rate of MSAP flap abandonment has been reported at 5–10% [10, 11]. As well as congenital variation in vascular architecture, atherosclerotic and occlusive vascular disease can all affect the presence, size and suitability of perforator vessels. Whether pre-operative imaging with CFD can reduce the rate of MSAP flap abandonment has not been proven.

In our unit, CFD has been used routinely before MSAPs since 2015. It is an easy, cheap, very sensitive technique yielding information superior to HHD by showing vessel flow velocity, resistance, calibre and course [12].

The study aims to compare utility of CFD in aiding pre-operative selection of donor site laterality, perforator anatomy, rate of flap abandonment and rate of flap complication compared to control subjects where preoperative CFD was not utilised.

Methods

The cohort study involved all patients planned for MSAP free flap in a single head and neck unit during the period of September 2013 to September 2020. This study was approved by the clinical effectiveness department at Sunderland Royal Hospital as an audit-based study.

Patients planned for MSAP since September 2015 have had pre-operative CFD using a Philips Healthcare EPIQ Elite machine and eL18-4 PureWave transducer (Koninklijke Philips, Netherlands) jointly by a vascular technologist and one of the surgical team, at a dedicated pre-operative appointment. The mark-up followed the standard technique described by Nugent et al. [5]. With the patient standing, a horizontal line was drawn on the skin across the popliteal fossa and another vertically downwards from the midpoint of this line to the Achilles tendon. A third line was then drawn parallel to this but 5 cm medial, between 8 and 12 cm down from the popliteal crease. The perforator vessels were sought in the area between the two vertical lines and marked on the skin surface.

A group of 22 patients planned for MSAP flap during the study period but not imaged with CFD were used as a comparison or control group. This includes all patients treated from September 2013 to September 2015 before CFD was introduced locally, and the minority of patients treated between September 2015 and September 2020 for whom the vascular technology team were not available to perform the CFD pre-operatively. In all of these cases, the vascular anatomy was assessed pre-operatively with HHD, MRA or CTA either alone or in combination.

Variables of interest comprised patient age and gender, imaging and operation date, vascular imaging technique(s) used, number and diameter of perforator arteries and veins on imaging and at operation, concordance between marked

perforator position location at operation, pedicle length and flap survival. Flap outcomes were categorised according to the classification from Ho et al. [13] (see Fig. 1). The data used in this study were collected prospectively when being entered into the UK national head and neck flap database, and then retrospectively abstracted for use in this study. Abstracted data were stored and manipulated within Microsoft Excel (Microsoft Corp, Washington, USA).

Results

Basic descriptive statistics for the CFD and non-CFD (control) groups are given in Table 1. In terms of gender distribution, age range, average age, tumour histology and site of tumours, there was no apparent difference between the two groups. There was also no discernible difference in terms of comorbidity profile. Numbers were insufficient to interrogate for differences with formal statistical tests.

Between September 2013 and September 2020, 36 patients were planned for MSAP flap in our department. Fourteen patients planned for MSAP flaps had CFD, all between September 2015 and September 2020. In one, no suitable perforator vessels were identified in either leg, and a radial forearm flap (RFFF) went on to be used instead. Among the other 13 patients, three had visible perforators in one leg only. Ten patients had visible perforators bilaterally. In such cases, the side with the largest vessel was later used.

At surgery, for the 13 patients who received MSAP flap, seven had one identified perforator, five had two, and one had four. Mean perforator diameter was 1.4 mm with range 1.0–2.0 mm. In all cases, the operative position of perforators correlated accurately with the CFD mark-up. Comparison of imaging and operative vessel diameter was possible in 5 cases where this had been recorded during imaging — in all cases, it was equal.

No flaps were abandoned intra-operatively. Post-operatively, in one case, arterial thrombosis occurred on day 5, leading to 30% flap loss but not requiring further surgery. In the other 12 cases, the MSAP flaps survived completely. Flap outcomes are shown in Table 2.

Among patients in the control/comparison group, 22 patients were planned for MSAP flap. Pre-operative imaging comprised CTA in six, MRA in two and HHD in the remaining cases. One flap was abandoned intra-operatively in a patient evaluated with HHD only. The only perforator found was too small. None of the flaps in patients evaluated with CTA or MRA were abandoned. Two flaps in the control group partially failed. One patient assessed with HHD developed arterial failure at 21 days. No surgery was required as there was adequate residual healthy tissue. Another flap imaged with MRA partially failed on day 9 with complete

Outcome categories for reconstruction with free tissue transfer	Subcategory	Description
1 – Reconstruction successful	1a	Complete success
	1b	Partial success with loss of some components of the flap, but secondary reconstruction or prosthesis not required
2 – Partial failure: some component of flap lost, and secondary reconstruction or prosthesis required to rehabilitate defect (based on intention to treat)	2a	Second flap (free or pedicled) required to rehabilitate residual defect
	2b	Prosthesis used to address residual defect
3 – Complete flap failure	3a	Second flap (free or pedicled) required to rehabilitate residual defect
	3b	Prosthesis used to address residual defect
	3c	Residual defect did not require further reconstructive procedure or prosthetic rehabilitation
<i>Option for addition of further subcategories for outcome 3a/b/c (eg, 3a.i)</i>	<i>i</i>	<i>Arterial failure</i>
	<i>ii</i>	<i>Venous failure</i>
	<i>iii</i>	<i>Uncertain/other causes- eg, microcirculatory</i>
4 – Failure to establish reconstruction	4a	Flap harvest attempted but abandoned because of unfavourable anatomy – eg, inadequacy of perforators in MSAP* or ALT**
	4b	Flap harvested but abandoned because of failure to perfuse before release from donor site, or inadequacy of the recipient vessels available – eg, more extensive ablation required
	4c	Flap harvested and transferred to recipient site but abandoned/discarded because of failure to perfuse after attempted anastomosis to recipient vessels

* medial sural artery perforator.
 ** anterolateral thigh.

Fig. 1 Classification of complications of free flaps, taken from Ho MW, Nugent M, Puglia F et al. (2019) Results of flap reconstruction: categorisation to reflect outcomes and process in the management of head and neck defects. British Journal of Oral and Maxillofacial

Surgery 57(9):935–937. Published with kind permission of Elsevier under STM Permissions Guidelines 2022 without requirement for further specific permission to reproduce here

Table 1 Comparison of basic variables between CFD and non-CFD (control) groups

Variable	CFD group	Non-CFD (control) group
Age range	45–76 years	42–77 years
Average age	58.2 years	58.4 years
Gender distribution	11 male, 3 female	19 male, 3 female
Tumour histology	Squamous cell carcinoma — 14	Squamous cell carcinoma — 22
Site of tumour	Tongue — 9 Floor of mouth — 2 Pharynx — 3	Tongue — 11 Floor of mouth — 5 Pharynx — 4 Retromolar — 1 Larynx — 1

Table 2 Flap outcomes by groups imaged and not imaged by CFD, defined by the classification by Ho et al. [13]

	CFD	No CFD
Outcome 1a (complete success)	13	19
Outcome 1b (partial flap loss, no further reconstruction)	1	1
Outcome 2a (partial flap loss, second free flap needed)	0	1
Outcome 4a (flap harvest abandoned)	0	1

skin and partial muscle necrosis necessitating a second flap (RFFF) to restore oral seal.

Discussion

In this study, a cohort of MSAP flap patients has been reported with very low rate of flap abandonment. Pre-operative CFD for vascular mark-up was associated with an ability to establish suitability for MSAP, produce a vascular mark-up very reliable

to surgical anatomical findings and with no flaps being abandoned when CFD was used. MSAP abandonment has been reported at one in 21 cases [10] and one in ten cases [11] (all using HHD), reportedly due to no or inadequately sized perforators being found. Since introducing routine CFD to our service, no MSAPs have been abandoned. Overall, when combining the 13 patients evaluated with CFD and 22 patients before CFD commenced, completing 34 out of 35 planned MSAPs compares favourably with other studies. In this study, CFD proved reliable in demonstrating the presence of suitable perforators, with mark-up positions accurate to surgical findings, which avoided this commonest scenario of flap abandonment due to lack of perforators either at all or of suitable calibre.

A meta-analysis of 526 MSAPs from 35 studies reported partial flap loss of 3.1% and complete failure also 3.1% [14] — in our series, 8.9% and 0.0% respectively. There are very many factors that can potentially influence flap outcomes, which could include pre-operative imaging; however, identifying any association between imaging and outcomes is not possible from the data in this study.

Comparison of CFD with HHD in this study showed a lower rate of flap abandonment with CFD. Other studies have shown HHD when used alone in planning perforator flaps to have a disappointing level of accuracy [15]. Comparison of the utility and reliability of CFD vs CTA or MRA is an area that warrants further study. Low numbers with cross-sectional imaging limit this comparison here. There is some evidence of superior sensitivity, specificity and accuracy of CFD over CTA before perforator flaps [16]. CFD as an imaging modality avoids some of the disadvantages and practical difficulties of cross-sectional imaging with CTA or MRA. Specifically, no ionising radiation is involved and long scan times lying flat within the confines of a scanner are not required. MRA in particular can be challenging for patients with claustrophobia or medical conditions that create difficulties in lying flat for prolonged periods.

This study corroborates earlier work by Mehta et al. [9] that CFD is accurate in identifying suitable vessels for MSAPs. Our data showed CFD to be reliable in locating suitable perforators and provided discriminatory information on suitability, donor side and position for MSAP. Presence of an adequately sized vessel (≥ 1.0 mm) within the standardized markup area was deemed sufficient. Our study also demonstrates the value of the surgeon and vascular technologist performing and interpreting the scan together, as decisions could be made there and then and plans for surgery made as required.

Conclusions

This study provides further confirmation of the variation in calf vasculature and the minority of patients lacking suitable perforators for MSAP in at least one leg. CFD as an

imaging technique before MSAP flap has several advantages and identifies the presence of perforators of a suitable size and position very accurately. CFD provided reliable discriminatory information for selection of donor site laterality and pre-operative knowledge of perforator anatomy that correlated well with intraoperative findings. Use of CFD is a potentially useful diagnostic tool to prevent intraoperative flap abandonment due to lack of presurgical knowledge of unfavourable perforator anatomy in MSAP flaps.

Declarations

Ethics approval This study was performed in line with the principles of the Declaration of Helsinki. The clinical effectiveness Department at Sunderland Royal Hospital granted permission for this audit-based study.

Consent to participate Not required.

Consent for publication Not required.

Competing interests The authors declare no competing interests.

References

1. Cavadas PC, Sanz-Giménez-Rico JR, Gutierrez-De la Cámara A et al (2001) The medial sural artery perforator free flap. *Plast Reconstr Surg* 108(6):1609–1615. <https://doi.org/10.1097/00006534-200111000-00027>
2. Kosutic D, Pejkoivic B, Anderhuber F et al (2012) Complete mapping of lateral and medial sural artery perforators: anatomical study with Duplex-Doppler ultrasound correlation. *J Plast Reconstr Aesthet Surg* 65(11):1530–1536. <https://doi.org/10.1016/j.bjps.2014.05.016>
3. Dusseldorp JR, Pham QJ, Ngo Q et al (2014) Vascular anatomy of the medial sural artery perforator flap: a new classification system of intra-muscular branching patterns. *J Plast Reconstr Aesthet Surg* 67(9):1267–1275. <https://doi.org/10.1016/j.bjps.2012.04.045>
4. Tuncer FB, Sacak B, Cavus Ozkan M, Celebiler OB (2017) An anatomical variation of the MSAP flap: single direct cutaneous perforator in the posterior calf region. *Microsurgery* 37(5):465–466. <https://doi.org/10.1002/micr.30090>
5. Nugent M, Endersby S, Kennedy M, Burns A (2015) Early experience with the medial sural artery perforator flap as an alternative to the radial forearm flap for reconstruction in the head and neck. *Br J Oral Maxillofac Surg* 53(5):461–463. <https://doi.org/10.1016/j.bjoms.2015.02.023>
6. Blondeel PN, Beyens G, Verhaeghe R et al (1998) Doppler flowmetry in the planning of perforator flaps. *Br J Plast Surg* 51(3):202–209. [https://doi.org/10.1016/S0007-1226\(98\)80010-6](https://doi.org/10.1016/S0007-1226(98)80010-6)
7. He Y, Jin SF, Zhang ZY et al (2014) A prospective study of medial sural artery perforator flap with computed tomographic angiography-aided design in tongue reconstruction. *J Oral Maxillofac Surg* 72(11):2351–2365. <https://doi.org/10.1016/j.joms.2014.05.019>
8. Zhao W, Li Z, Wu L et al (2016) Medial sural artery perforator flap aided by ultrasonic perforator localization for reconstruction after oral carcinoma resection. *J Oral Maxillofac Surg* 74(5):1063–1071. <https://doi.org/10.1016/j.joms.2015.11.011>

9. Mehta D, Nugent M, Endersby S (2017) Use of colour flow Doppler in locating the optimum donor site for perforator free flap reconstruction. *Br J Oral Maxillofac Surg* e125. <https://doi.org/10.1016/j.bjoms.2017.08.117>
10. Taufique ZM, Daar DA, Cohen LE et al (2019) The medial sural artery perforator flap: a better option in complex head and neck reconstruction? *Laryngoscope* 129(6):1330–1336. <https://doi.org/10.1002/lary.27652>
11. Toyserkani NM, Sørensen JA (2015) Medial sural artery perforator flap: a challenging free flap. *Eur J Plast Surg* 38(5):391–396. <https://doi.org/10.1007/s00238-015-1110-5>
12. Hallock GG (2003) Doppler sonography and color duplex imaging for planning a perforator flap. *Clin Plast Surg* 30(3):347–357. [https://doi.org/10.1016/s0094-1298\(03\)00036-1](https://doi.org/10.1016/s0094-1298(03)00036-1)
13. Ho MW, Nugent M, Puglia F et al (2019) Results of flap reconstruction: categorisation to reflect outcomes and process in the management of head and neck defects. *Br J Oral Maxillofac Surg* 57(9):935–937. <https://doi.org/10.1016/j.bjoms.2019.08.005>
14. Daar DA, Abdou SA, Cohen JM et al (2019) Is the medial sural artery perforator flap a new workhorse flap? A systematic review and meta-analysis. *Plast Reconstr Surg* 143(2):393e–403e. <https://doi.org/10.1097/PRS.0000000000005204>
15. Shaw RJ, Batstone MD, Blackburn TK et al (2010) Preoperative doppler assessment of perforator anatomy in the anterolateral thigh flap. *Br J Oral Maxillofac Surg* 48(6):419–22. <https://doi.org/10.1016/j.bjoms.2009.08.016>
16. Martinez JG, Perez AT, Vega MG et al (2020) Preoperative vascular planning of free flaps: comparative study of computed tomographic angiography, color Doppler ultrasonography and hand-held Doppler. *Plast Reconstr Surg* 146(2):227–237. <https://doi.org/10.1097/PRS.0000000000006966>

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.