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Case Series

Surgery Section

Role of Colour Doppler Ultrasound in Planning Pedicled Perforator Flaps for Lower Limb Reconstruction: A Case Series

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ABSTRACT

Coverage of lower limb defects is a common challenge in reconstructive surgery. Flaps are often required, and perforator flaps are widely used. Preoperative mapping of perforators and donor site morbidity are key concerns. Traditional modalities used to locate perforators include computed tomographic angiography, magnetic resonance imaging and angiography, and handheld Doppler devices. With advancements in duplex ultrasound, minute details of the arterial system and its perforators can now be assessed preoperatively and utilised in surgical planning for lower limb reconstruction. A total of 17 patients with lower limb defects were reconstructed using pedicled perforator flaps guided by Colour Doppler Ultrasound (CDU). Fourteen patients were male and three were female. The mean age was 36±12.4 years (range: 13-57 years), and the mean follow-up period was six months. All defects were due to trauma. The average defect size was 33.6 cm² (range: 12-200 cm²). The choice of perforator flap was based on the best adjacent perforator identified using colour Doppler ultrasound. The mean perforator diameter was 1.4±0.2 mm (range: 1.1-1.8 mm), and the mean peak systolic blood flow velocity was 24.8±8.08 cm/s (range: 12-37 cm/s). The procedure was successful in 16 patients (94%). Colour Doppler ultrasound is a useful tool for identifying perforators for pedicled perforator flaps in lower limb reconstruction. Further studies with larger sample sizes are needed to establish linear correlations.

Keywords: Donor site, Flaps, Perforators, Reconstructive surgery, Trauma

INTRODUCTION

Coverage of lower limb defects remain a common challenge in reconstructive surgery. Flaps are frequently required, and perforator flaps have become widely used. The high variability of perforator systems compared with their parent axial vessels necessitates accurate perforator mapping to facilitate surgical planning. When such variations are detected during surgery, surgeons may be compelled to modify the operative plan, potentially prolonging operative time, anaesthesia exposure, and increasing fatigue, which may contribute to poorer outcomes [1]. Preoperative perforator mapping and donor site morbidity are therefore major concerns. Traditional imaging modalities include conventional angiography, computed tomographic angiography [2], magnetic resonance imaging and angiography [2], and handheld Doppler devices [3]. Some centres have also utilised indocyanine green fluorescence angiography for intraoperative assessment of blood flow in pedicled perforator flaps [4]. With advancements in duplex ultrasound technology, detailed assessment of arterial anatomy and perforator characteristics is now possible preoperatively, aiding surgical planning for lower limb reconstruction [5].

CASE SERIES

In the present case series, 17 patients with lower limb defects were reconstructed using pedicled perforator flaps. A handheld acoustic Doppler (Mini Doppler, 10 MHz) was initially used to detect suitable perforators, which were subsequently evaluated using CDU. The optimal perforator, characterised by larger diameter and higher blood flow velocity, was selected for surgical planning and correlated intraoperatively. Patients who were smokers, had peripheral vascular disease or varicose veins, were lost to follow-up, or had incomplete data were excluded.

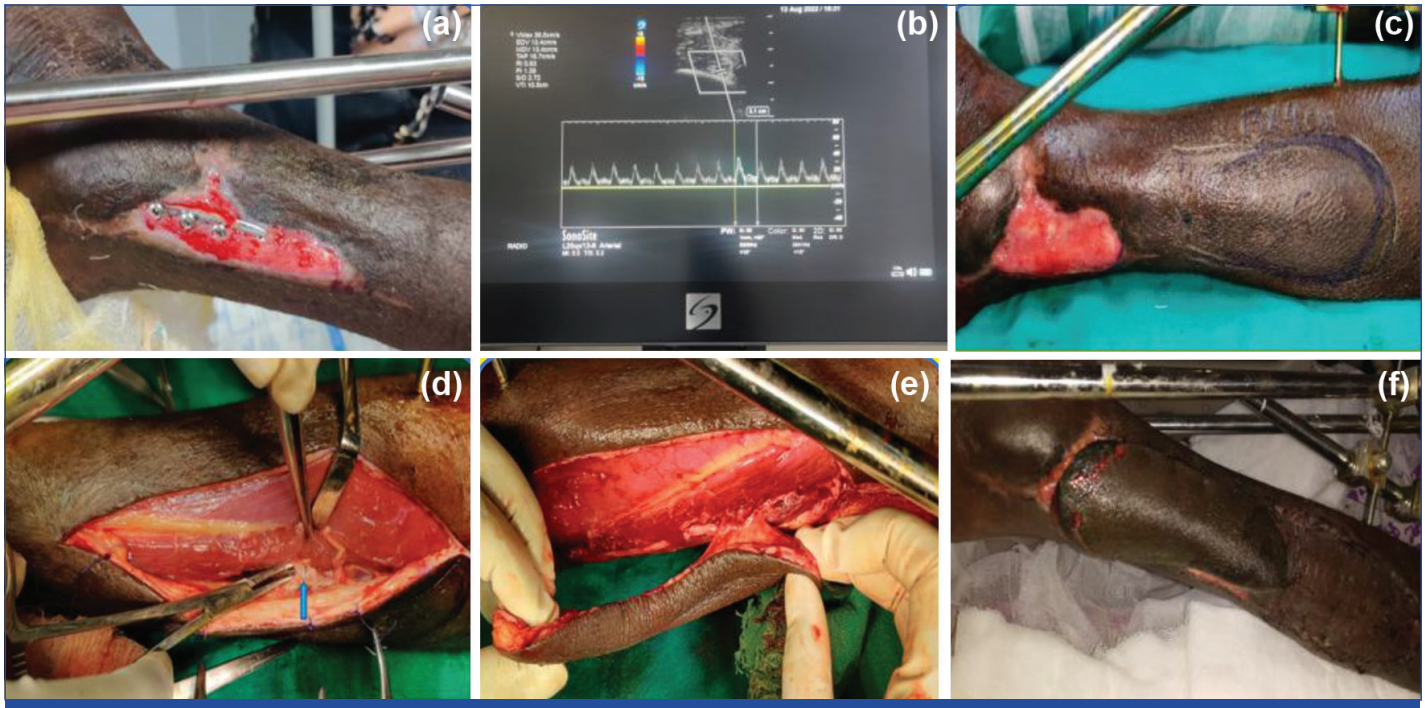
A total of 17 patients met the inclusion criteria [Table/Fig-1], including 14 males (82.4%) and three females (17.6%). The mean age was 36±12.4 years (range: 13-57 years). The mean follow-up duration was six months. Most defects resulted from road traffic accidents (n=16; 94%), with one case due to a fall from height.

The average defect size was 33.6 cm² (range: 12-200 cm²). The mean perforator diameter was 1.4±0.2 mm (range: 1.1-1.8 mm), and the mean peak systolic blood flow velocity was 24.8±8.08 cm/s (range: 12-37 cm/s). The average flap size was 156.7±40.8 cm² (range: 36-200 cm²). The procedure was successful in 16 patients (94%). Representative cases are shown in [Table/Fig-2,3].

S. No.	Sex	Age	Mechanism of injury	Site	Defect size (Sqcm)	Flap size	Source artery	Perforator diameter (mm)	Peak systolic velocity (cm/sec.)	Complication	Follow-up (months)
1.	M	39	Fall from height	Distal third	6×3	13×4	Peroneal artery	1.5	36.5	Superficial Necrosis Treated with a dressing until healing with secondary intention	8
2.	M	38	Road Traffic Accident	Middle third	6×4	12×5	Anterior tibial artery	1.8	31.2	Nil	8
3.	F	57	Road Traffic Accident	Distal third	18×8	20×10	Posterior tibial artery	1.5	33.4	Nil	7
4.	M	39	Road Traffic Accident	Distal third	4×3	8×5	Posterior tibial artery	1.4	28.4	Nil	6

5.	M	18	Road Traffic Accident	Knee Proximal third	12×8	14×10	Superomedial genicular artery	1.4	28	Nil	4
6.	M	45	Road Traffic Accident	Distal third	5×4	8×5	Posterior tibial artery	1.5	20	Nil	4
7.	M	20	Road Traffic Accident	Middle third	5×4	10×6	Posterior tibial artery	1.4	12	Nil	8
8.	M	13	Road Traffic Accident	Proximal third	10×6	10×8	Peroneal artery.	1.7	17.9	Nil	5
9.	F	43	Road Traffic Accident	Distal third	7×4	10×6	Peroneal artery	1.7	26.8	Nil	4
10.	F	47	Road Traffic Accident	Distal third	8×6	10×8	Posterior tibial artery	1.4	32	Nil	8
11.	M	33	Road Traffic Accident	Proximal third	6×6	8×6	Medial sural artery	1.7	37	Nil	7
12.	M	48	Road Traffic Accident	Distal third	5×4	8×6	Peroneal artery	1.8	37	Nil	6
13.	M	22	Road Traffic Accident	Distal third	6×7	8×10	Peroneal artery	1.2	28	Nil	5
14.	M	24	Road Traffic Accident	Distal third	4×5	6×6	Posterior tibial artery	1.4	16.6	Nil	6
15.	M	22	Road Traffic Accident	Middle third	6×7	8×10	Posterior tibial artery	1.4	35.3	Nil	4
16.	M	34	Road Traffic Accident	Proximal third	10×6	8×10	Medial sural artery	1.1	16.4	Nil	7
17.	M	38	Road Traffic Accident + Diabetes Mellitus)	Distal third	8×6	8×10	Peroneal artery	1.5	32.2	Complete flap loss treated with another local flap	5

[Table/Fig-1]: Summary of characteristics of study subjects.



[Table/Fig-2]: A 39-year-old male presented with a history of a fall from height, Gustilo 3b trauma of the right lower limb, (a) Preoperative image; (b) USG Doppler (SonoSite) PSV 36.5cm/sec, perforator diameter 1.5 mm; (c) Flap size (13×4=52 sqcm; (d) Identifiction of perforator; (e) Eccentric perforator for propeller flap; (f) Post operative distal tip necrosis.
PSV: Peak systolic velocity

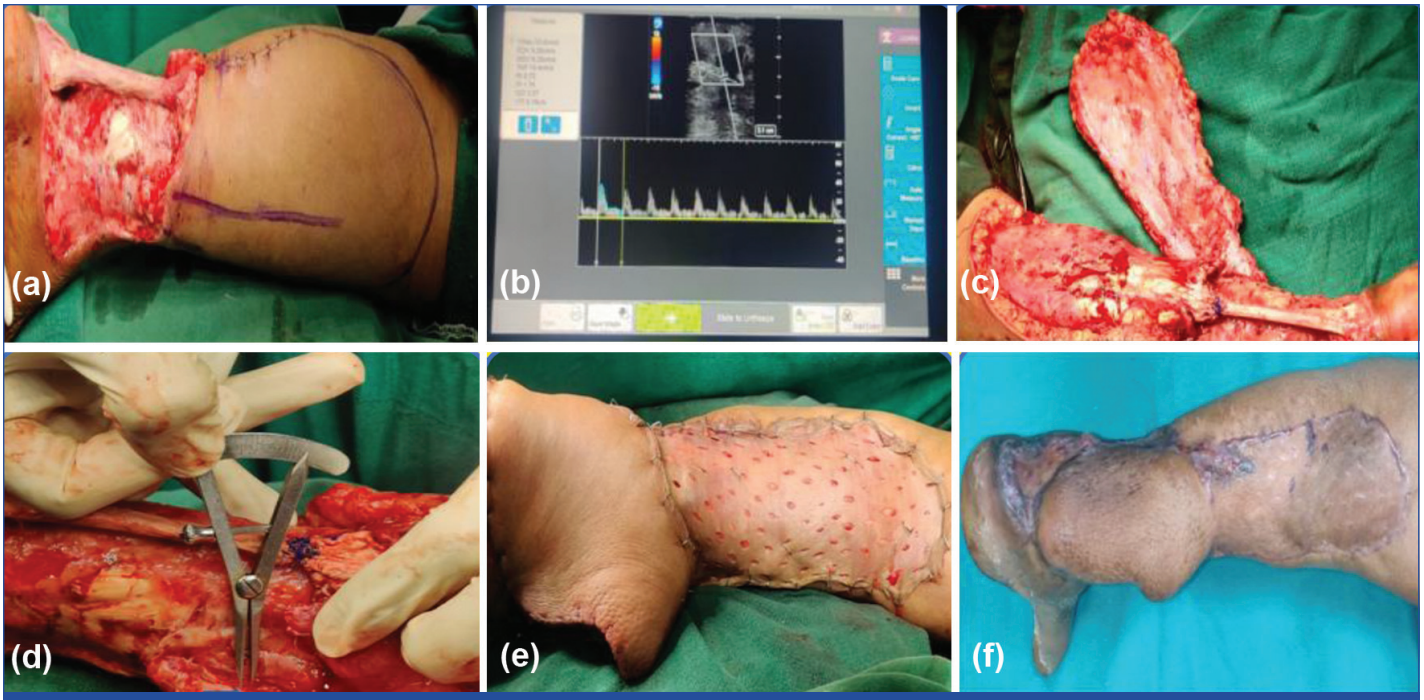
DISCUSSION

The CDU can be effectively used as a preoperative tool for perforator mapping and flap planning, resulting in higher success rates and fewer complications in lower limb reconstruction. Several comparative studies are summarised in [Table/Fig-4] [6-8]. In the present case series, all defects were post-traumatic (100%), whereas Eldahshoury T et al., [8] reported 65.21% and Yadav P et al., [9] reported 77.35% post-traumatic cases. Reconstructive options for lower limb defects include local flaps, regional flaps such as cross-leg flaps, and free flaps [9]. Pedicled local flaps are the simplest to perform, although their arc of rotation is a limiting factor [9]. Ibrahim RM et al., (2018) demonstrated that CDU facilitates precise flap design based on optimal perforator selection and its subcutaneous course [10], a principle also applied in our study. Debelmas A et al., introduced a CDU protocol for prefabricated flap planning, achieving 5 mm accuracy at the fascial penetration point with a sensitivity of 90% [6].

In the current case series, most defects were associated with fractures. Computed tomographic angiography was limited by artefacts, and magnetic resonance angiography was relatively contraindicated, prompting reliance on CDU for perforator identification and measurement of velocity, calibre, and course.

Rammos, CK et al., (2020) noted that CDU is particularly accurate for determining vascular calibre, although CT angiography remains the gold standard for perforator mapping [11]. The average flap size in our study (156.7 cm^2) was comparable to that reported by Ozdemir R et al., (161.6 cm^2) [12]. In the present case series, a fallacy was found in one out of 17 cases, with 94% agreement between the preoperative CDU results and the intraoperative findings. These results were in coherence with other studies conducted by Martínez JG, which quote positive and negative predictive values for Colour Doppler ultrasound as 100 percent [13].

In our series, one flap out of seventeen had complete necrosis; the reason was that more than two perforators were present in different axes, which could not be detected preoperatively by CDU.



[Table/Fig-3]: A 57-year-old female presented with a post-RTA Defect in the lower third of the left leg with exposed tendoachilles, (a) Defect in the lower third of left leg with exposed tendoachilles; (b) Perforator diameter(1.5 mm) and flow velocity (33.4 cm/sec); (c) Pedicled perforator flap raised on posterior tibial artery ,size 20×10=200 sqcm; (d) Intra-operative location of perforator with Vernier's caliper used to measure perforator diameter which is between 1-2 mm; (e) Immediate post-op picture; (f) Follw up picture.

Study	Information regarding CDU	Number of cases	Peak systolic velocity (cm/sec)	Perforator diameter (Millimeter)	Result	Conclusion
Debelmas A et al., (2018) [6]	Voluson LOGIC e portable ultrasound machine, 12MHz linear probe	22	No information	No information	CDU-sensitivity of 84% and specificity of 100%	Preoperative CDU seems to be reliable, accurate and compatible for exploration of perforator vessels in the anterolateral thigh thin flap
Lovětínská V et al., (2024) [7]	B-mode US, Colour coded duplex sonography, pulse wave, and Power Doppler (PD)	10	21.9 -27.2	1.14-1.16	colour-coded sonography detected 35 out of 40 perforators (87.5%)	In most patients with chronic lower leg wounds and other comorbidities, adequate perforators for reconstruction can be identified by using conventional methods
Eldahshoury T et al., (2021) [8]	US arterial duplex Peak artenial velocity targeted the vessels which the flap was based upon recorded in distal lower limb pre and postoperatively.	23	49.2	No information	21 out of 23 flaps succeded to reconstruct the patient defect safely.	Perforator propeller flaps are a safe cost-effective reconstruction modality for distal lower limb defects.
Present study	CDU with linear transducer ultrasonic frequency of 9 to 15MHz;	17	12 - 37	1.1 - 1.8	94% agreement between the preoperative CDU results and the intraoperative finding.	16 out of 17 flaps were survived.

[Table/Fig-4]: Studies using CDU in perforator flap planning for lower limb reconstruction [6-8].

CONCLUSION(S)

The CDU is a valuable tool for identifying perforators for pedicled perforator flaps in lower limb reconstruction. Preoperative identification of perforator vessels using CDU and intraoperative confirmation facilitates the elevation of larger flaps and may reduce the need for free flap reconstruction in small to medium-sized leg defects.

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