ORIGINAL ARTICLE

LOWER EXTREMITY RECONSTRUCTION: UTILITY OF SMARTPHONE THERMAL IMAGING CAMERA IN PLANNING PERFORATOR BASED PEDICLED FLAPS

Muhammad Omar Afzal, Ata ul Haq, Muhammad Ahsan Riaz, Moazzam Nazeer Tarar, Hamid Fazeel Alvi

Allama Iqbal Medical College/ Jinnah Burn and Reconstructive Surgery Centre Lahore

Background: Presence of good size perforators are mandatory to design perforator based pedicelled flaps specially in lower limb as flap failure rate is relatively high. We have explored the use of smartphone based dynamic thermal imaging and compared it with doppler to devise a protocol for planning and execution of pedicled perforator flaps and described its use in deciding delay of flap. We have also compared the time required for detecting dominant perforators. **Methods:** This prospective case series was done at Jinnah burn and reconstructive surgery center Lahore from July to September 2018 and included patients requiring pedicled fasciocutaneous or musculocutaneous flap for lower extremity reconstruction. Smartphone based dynamic thermal imaging and doppler were used to map out suitable perforators and confirmed intraoperatively. Comparison was made regarding their ability to locate dominant perforators and total time required. Utility of thermal imaging to ascertain flap perfusion postoperatively was also assessed. Flaps were designed according to thermal mapping. Clinical judgement supplemented with thermal imaging was used to ascertain flap survival. **Results:** The study included 15 patients in which 22 out 23 dominant perforators as located with thermal imaging were confirmed intra-operatively (positive predictive value = 95.7%) as compared to 22 out of 32 with doppler (positive predictive value=68.8%). Mean time required with doppler was 591.27±252.48, compared to 598.47±192.94 seconds with thermal imaging. In two cases flap was delayed. Partial flap necrosis occurred in one case. **Conclusion:** Dynamic thermal imaging can be reliably used in planning of pedicled perforator flaps for lower limb reconstruction. We have found it more reliable than handheld doppler in locating dominant perforators.

KeyWords: Dynamic Thermal Imaging; Perforator Based Flaps; Lower Extremity Reconstruction

Citation: Afzal MO, Haq A, Riaz MA, Tarar MN, Alvi HF. Lower extremity reconstruction: utility of smartphone thermal imaging camera in planning perforator based pedicled flaps. J Ayubmed Coll Abbottabad 2020;32(Suppl. 1):612–7

INTRODUCTION

Lower extremity reconstruction poses a challenge to every reconstructive surgeon. Not only are there limited locoregional flap options but both local and free tissue transfer have a higher complication rate in lower limb reconstruction when compared to other regions, i.e., 21.4% as compared to 6.5% in upper limb.[1–3] Bearing in mind the importance of eventless recovery needed for early ambulation, transfer of a robust flap ensures quick healing. Handheld doppler device is used extensively in detecting perforators which can be included at the base of pedicled fascio-cutaneous flaps to enhance their vascularity.[3]

But variable pressure, direction of probe and human error results in high rate of false positive detection of perforators.[4] Thermal imaging, which maps the location of perforators that supply the skin, has recently seen revival due to smaller and handier devices being available.[5] Earlier studies utilizing digital thermographic camera with a photovoltaic liquid nitrogen cooled detector highlighted high sensitivity of this method with dominant perforators found at all sites as confirmed with dissection.[6] But the technique and technology were cumbersome as described by Theuvenet *et al*. [6]

Smartphone based thermal imaging camera is widely and easily available. It carries no additional risk of ionizing radiation as compared to computed tomography angiography (CT-angiography) and is less operator dependant when compared to doppler.[7] Additional uses of this modality have also been explored e.g. perforator mapping in planning of free flaps, their monitoring, assessment of burn depth, response of haemangioma to various treatment modalities, even claiming to take less time when compared to doppler.[8,9] CT-angiography has been regarded as gold standard for evaluation of perforators.[10] When smartphone thermal imaging was compared with CT-angiography, it was found to be highly sensitive and specific in locating perforators.[11] A high concordance between CT-angiography and smartphone thermography was found (p<0.001).

Dynamic thermography with mobile device has been recently introduced, which involves cooling the skin where a fascio-cutaneous free flap is planned and then observing hot spots as skin is re-perfused. This results in better localisation of the perforators.[11] Thermography maps not only the arteriosome but also the venosome.[12] A venous perforator is visualised as a bright yellow or white spot which is warmer than an arterial perforator which is visualised as red.[12] Hence this modality can be used to safely locate reliable perforators when fascio-cutaneous free flaps are planned. The surface temperature of flap varies with systemic temperature, as well as of the surroundings.[13] But, the patency of the perforator can be monitored with thermography which provides indirect insight about the flap perfusion.[7] Although recent literature points out to its use in planning free fascio-cutaneous flaps, its use in planning pedicled flaps is almost not described.

Perforator based pedicled flaps in lower limb requires careful planning as there are not only paucity of locoregional flaps, but they also inherit the common drawbacks of the pedicled flaps. Selection of perforator can influence the reach of flap and flap based on minor perforators which are less than 0.2 mm can result in flap necrosis.[14,15] Based on angisome concept, anatomical landmarks have been described to determine safe dimensions of a flap.[12] For islanded flaps, the length of the flap can also be roughly determined by keeping it as 1/3 of the total length of leg.[16] Yet partial loss can also occur if the flap has already compromised blood supply or an extended flap is designed. This can be often prevented by delaying the flap transfer, but mostly compromised supply is evident once flap in setting is done and delay in detection results in flap necrosis.[17] When free style perforator flaps are raised, doppler is an indispensable tool to locate perforators preoperatively. It can greatly decrease the overall operative time but can occasionally become time consuming due to variable anatomy and body habitus.[18] Another technique for free style flaps is to give an exploratory incision and rely on intra-operative findings.[19] This may result in total wastage of site for future reconstruction, wastage of time and an additional scar if suitable perforator is not found. Keeping these three pitfalls of pedicled perforator flaps, we have further explored the use of smartphone based dynamic thermal imaging and devised a protocol for planning and execution of pedicled perforator flaps in lower extremity. The study also describes the use of thermal imaging in deciding delay of flap which hadn’t been done before. We have compared it with doppler in detecting dominant perforator and the total time required in it to quantify its utility.

MATERIAL AND METHODS

This prospective case series was done in Jinnah burn and reconstructive surgery center Lahore from July to December 2018. After approval from ethical review board, we included both male and female patients of age 12 years or older, who needed pedicled fascio-cutaneous or musculocutaneous flap for lower limb reconstruction. We excluded patients who required free tissue transfer for larger soft tissue defect as well as those where pedicled muscle flaps were planned. After determining suitability of the patient, informed consent was taken and then enrolled for the study. Pre-operative assessment, thermal camera and doppler aided marking and photography was done a day before surgery. Protocol for planning and execution, described later, was followed. Intra-operatively flap was raised, and perforators were identified. Dominant perforators were identified as being pulsatile or relatively larger than the smaller ones. Intra operative and post-operative photographs, and findings were recorded. At complete flap elevation and after conclusion of the procedure, flap perfusion was observed clinically and with thermal imaging for three days to ascertain its survival.

Extremity and wound were exposed, and ambient temperature was kept at 22℃. The first author used FLIR ONE® mobile phone based thermal imaging camera. Timer was started and first image was taken after 1 minute, the time needed to bring surface temperature in equilibrium with surrounding. It was made sure that the skin surface was dry, and image was taken at a distance of 60 cm. Then an ice pack was applied until the thermal image showed uniform cold surface. Next thermal image was taken once hot spots appeared after removal of ice pack, to mark site/sites of dominant perforators. The timer was stopped as soon as locations of perforators were marked. Dominant were identified as brighter spots that appeared before than the smaller less bright spots. Photographs were taken and marking was erased. The second author used 8 MHz handheld doppler to locate perforators and marked them. Timer was started, any surface marking to guide perforator was made, gel was applied, and perforators were located using the probe. Timer was stopped as soon as one or more dominant perforators were marked. Locations where doppler signal was loudest were assumed to be dominant perforators. Photographs were taken and using previously taken thermal image and plain image as reference, the locations of perforators were superimposed. Flap was designed by planning in reverse and marked. One or more dominant perforators were taken subjected to flap design and thermal mapping only. Intra-operatively, incision was given; relative size and plasticity of perforators were noted with reference to thermal camera and doppler. Dominance of a perforator was determined if it was either pulsatile or bigger than the rest of perforators. If more than one dominant perforator was located, the one which allowed maximum length of flap to be used was selected, and the microvascular clamp was applied on the other to see that flap is adequately perfused. Perfusion was adequate if fresh blood was coming at the distal flap edges. Flap was then raised over perforator once perforator was selected. Bleeding from the flap edge, its colour, as well as thermal image was taken to see adequacy of perfusion. If there was inadequacy in distal part, flap was delayed and stitched back. Otherwise flap was transferred and again vascularity was assessed clinically and with thermography. All the findings were recorded on a pro forma.

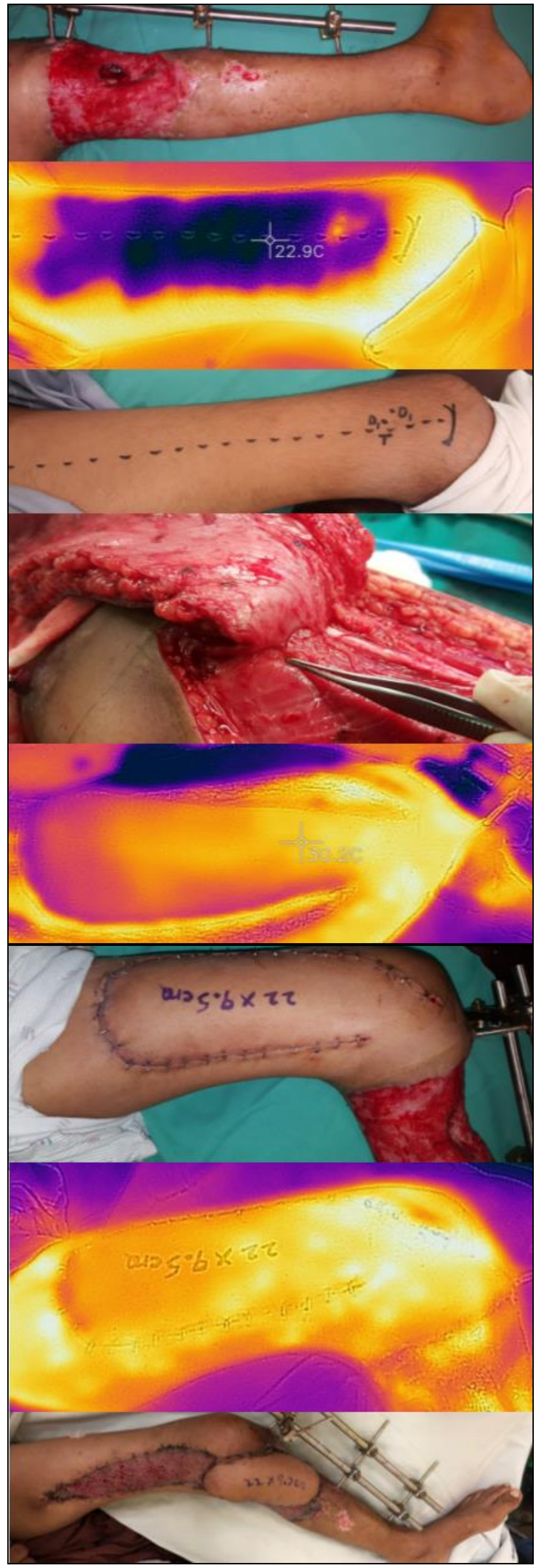
RESULTS

Among the 15 patients enrolled in the study, 11 (73.3%) were male and 4 (26.7%) were female. Mean age was 35.9±16.3 years, with a minimum of 13 years and maximum 62 years. Table-1 summarises flaps used and the comparison between locations of perforators identified by doppler, thermal imaging and intra-operatively, whether flap was delayed, survival and time required for localisation of perforators of different flaps. Pre-operatively, 23 dominant perforators were found with the help of thermal imaging camera as compared to 32 found through doppler. Total dominant perforators confirmed intra-operatively were 22. The positive predictive value of thermal mapping was 95.7% and doppler 68.8%. In 5 out of 15 cases, dominant perforators were found intra operatively at all the sites marked with doppler. In comparison, in 14 out of 15 cases dominant perforators were found at all the marked sites localised with thermal imaging. However, the location of perforators as detected by the two modalities coincided. In 2 of the cases, flaps were delayed on the bases of thermal imaging and clinical observation. Flaps were recorded to be completely perfused after 72 hours and were then inset after seven days on next available list. Partial flap necrosis was observed in 1 case due to venous congestion. It was picked by clinical observation and a brighter thermal image of the flap 12 hours after the surgery as compared to previous images. Tight sutures were removed, and ultimately 80% flap survived. Mean time required with doppler imaging was 591.27±252.48 seconds as compared to 598.47±192.94 seconds with thermal imaging (*p*=0.61).

Table-1: Flaps used and the comparison between locations of perforators identified by doppler, thermal imaging with the intra-operative findings, flap delay, survival and time required for localisation of perforators of different flaps.

Flap	Number of Dominant perforators detected with Doppler	Number of Dominant perforators detected with dynamic thermal imaging	Location of perforators localised with doppler and thermal imaging coincided	Number of Dominant perforators as located intra operatively on exploration	Number of perforators on which flap was based	Flap Delay	Flap survival %	Time required with thermal (sec)	Time required with doppler (sec)
Medial Genicular artery perforator flap	2	1	yes	1	1	Yes	100	458	740
Distally based Sural Flap	3	2	yes	2	2	No	100	470	410
Profunda femoral artery artery perforator flap	3	2	yes	2	1	No	100	704	779
Distally based Sural Flap	3	1	yes	2	1	No	100	483	386
Medial Sural artery perforator flap	2	1	yes	1	1	No	100	690	905
Medial Sural artery perforator flap	1	1	yes	1	1	No	80	714	1054
Posterior tibial artery perforator flap	2	1	yes	1	1	No	100	540	484
Distally based Sural Flap	3	2	yes	2	1	Yes	100	449	354
Posterior Tibial Artery perforator flap	2	1	yes	1	1	No	100	463	369
Distally based sural flap	3	2	yes	2	2	No	100	417	341
Peroneal artery perforator	2	2	yes	2	1	No	100	769	497
Posterior thigh flap	3	2	yes	2	1	No	100	1143	1335
Posterior Tibial Artery perforator flap	2	1	yes	1	1	No	100	547	485
Peroneal artery perforator flap	2	2	yes	2	1	No	100	690	523
Medial genicular artery perforator flap	1	1	yes	1	1	No	100	440	685

Case-1: 24-year-old male patient presented with open fracture of right tibia and fibula. Dynamic thermal imaging localised single dominant perforator in medial sural artery perforator flap territory, visible as bright yellow spot, and marked as "T". 2 equally audible perforators were identified with doppler and both marked as D1. Intra-operatively bigger perforator was located at the site found with thermal imaging. Flap was islanded over this perforator and MSAP was raised with gastrocnemeus with muscle used to fill the dead space and MSAP to cover the skin defect. Flap was adequately perfused clinically and confirmed with thermal imaging.



Case-2: 18 years old presented with open fracture of left proximal 1/3 tibia and fibula. Medial genicular artery perforator flap was planned. Dynamic thermal imaging located single dominant perforator, with a minor perforator seen as less bright and smaller bright spot. Doppler located both perforators but with equal intensities, marked as D1. Intraoperatively dominant perforator was located at site identified with thermal imaging. Flap was delayed as the distal part of the flap was cold on thermal imaging and subdermal bleeding was less as compared to rest of the flap. After 72 hours thermal imaging showing adequate perfusion of the flap which was transferred based on single dominant perforator. Complete flap survival was noted at 5th post op day

DISCUSSION

Designing and execution of pedicled flaps in lower limb require meticulous planning as failure rate is higher as compared to other regions.[1,2] Axial pattern flaps can be designed which are more robust and larger in dimension as compared to random pattern flaps. Anatomic locations of perforators have been described in literature, but exact location of dominant perforators allow precise planning and improve probability of their survival. Thermal imaging devices which analyze surface temperature to locate hot spots have recently seen a revival in locating dominant perforators.[5] It is due to handier devices that have made it possible to use this technology in the theatre without hassle. Previously hot spots as seen in single thermal image were taken as the location perforators, with larger ones coinciding with dominant perforators.[5,6] But the advent of dynamic thermal imaging has improved the sensitivity and specificity which involves cooling the area and observing the intensity and pattern of re-appearance of hot spots.[11] This technology has been used primarily in planning free flaps where one or more dominant perforators can be included within the anatomically defined area of flap regardless of their location.[8,9] We have used this technique to plan pedicled flaps where selection of perforators effects the design and reach of flap. We have also described use of delay procedure based on the perfusion assessment with thermal imaging and both have not been described before.

Handheld Doppler is an indispensable tool to locate perforators so that flap can be designed over them. By judging the intensity of sound, one can differentiate between dominant and minor perforators. But there are chances of error as applied pressure on skin and direction of probe can easily affect the judgment.[18] We think it as the primary reason that in only 22 out of 32 sites marked with doppler, dominant perforators were conformed. In contrast, in 22 out of 23 sites localized with thermal imaging dominant perforators were confirmed. Thus, thermal imaging was found to be better at detecting dominant perforators as compared to handheld doppler in this study. We found it easier with dynamic thermal imaging to locate dominant perforators, as error due to variable pressure and angle is eliminated. Although when there was a single dominant perforator, both modalities were equally good at detection.

In two cases, flaps were delayed based on thermal imaging findings. After 72 hours thermal imaging showed adequate perfusion till the distal end of the flaps. In both cases, safe anatomic limits of flaps as described in literature, were kept in mind during designing and planning. Delayed flaps were then transferred to the defects after seven days on next available list, without any flap necrosis post operatively. Although clinical findings, like subdermal bleeding, colour and refill of distant edge of flap can reliably tell us about flap perfusion but it is difficult to ascertain how much length of flap is poorly perfused. Also, colour and refill are difficult to judge in patients with darker complexion. Laser doppler and fluorescent sensor foils have been used to assess flap perfusion in delayed and transplanted flaps, but the equipment needed is expensive and time consuming as compared to mobile based thermal imaging.[20,21] Thermal imaging offers easy and inexpensive way to counter these pitfalls with little training and also post operatively flap perfusion can be monitored. [20] Some authors have argued that there was a delay in detectable change of surface temperature of free flaps after pedicle thrombosis.[22] But we have found that for at least pedicled flaps, comparison of thermal images serially taken can reliably show flap perfusion on which decision to delay can be made.[23,24]

We found that mean time to detect perforators with doppler required less time as compared to thermal imaging, although the difference wasn’t significant. This was contrary to previous claims that thermal imaging required less time.[8,9] In some anatomic areas, the perforators emerge along a linear longitudinal axis. Doppler took less time in detecting those perforators when flaps over those anatomic areas were planned. But for the flaps in which perforators did not emerge along a single longitudinal axis, thermal mapping took less time in locating dominant perforators. Although we have tried to compare the modalities to determine which takes less time, but there were chances of error in the technique of exactly measuring the time. Hence there is room for better comparative study design to accurately measure the timing of each technique.

CONCLUSION

On the bases of our study, we recommend that dynamic thermal imaging can be reliably used alone in planning of pedicled perforator flaps for lower limb reconstruction, as it is more reliable than handheld doppler in locating dominant perforator on which flap can be based. It is also a reliable method to assess flap perfusion and is easy to perform with little practice. By following the protocol designed for safe planning, high flap survival rate can be achieved too.

AUTHORS' CONTRIBUTION

MOA: Study design, chief operator, case contribution, conceptualization, write-up, data collection. AUH: Case contribution, conceptualization, data collection. MAR: Case contribution, data collection. MNT: Conceptualization, proof reading. HFA: Data collection, data analysis, literature search.

REFERENCES

1. Khan UD, Miller JG. Reliability of handheld Doppler in planning local perforator-based flaps for extremities. Aesthetic Plast Surg 2007;31(5):521–5.
2. Gunnarsson GL, Jackson IT, Westvik TS, Thomson JB. The freestyle pedicle perforator flap: a new favorite for the reconstruction of moderate-sized defects of the torso and extremities. Eur J Plast Surg 2015;38:31–6.
3. Bekara F, Herlin C, Somda S, De Runz A, Grolleau JL, Chaput B. Free versus perforator – pedicled propeller flaps in lower extremity reconstruction: what is the safest coverage? A meta – analysis. Microsurgery 2018;38(1):109–19.
4. Winkler P, Helmke K. Major pitfalls in Doppler investigations with particular reference to the cerebral vascular system. Pediatr Radiol 1990;20(4):219–28.
5. Suphachokauychai S, Kiranantawat K, Sananpanich K. Detection of perforators using smartphone thermal imaging. Plast Reconstr Surg Glob Open 2016;4(5):e722.
6. Theuvenet WJ, Koeyers GF, Borghouts MH. Thermographic assessment of perforating arteries. A preoperative screening method for fasciocutaneous and musculocutaneous flaps. Scand J Plast Reconstr Surg 1986;20(1):25–9.
7. Hardwicke JT, Osmani O, Skillman JM. Detection of perforators using smartphone thermal imaging. Plast Reconstr Surg 2016;137(1):39–41.
8. John HE, Niumsawatt V, Rozen WM, Whitaker IS. Clinical applications of dynamic infrared thermography in plastic surgery: a systematic review. Gland Surg 2016;5(2):122–32.
9. Konczalik W, Nikkhah D, Mosahebi A. Applications of Smartphone thermal camera imaging system in monitoring of the deep inferior epigastric perforator flap for breast reconstruction. Microsurgery 2017;37(5):457–8.
10. Pereira N, Valenzuela D, Mangelsdorff G, Kufeke M, Roa R. Detection of perforators for free flap planning using smartphone thermal imaging: A concordance study with computed tomographic angiography in 120 perforators. Plast Reconstr Surg 2018;141(3):787–92.
11. de Weerd L, Mercer JB, Weum S. Dynamic infrared thermography. Clin Plast Surg 2011;38(2):277–92.
12. Paul SP. Using a thermal imaging camera to locate perforators on the lower limb. Arch Plast Surg 2017;44(3):243–7.
13. Perng CK, Ma H, Chiu YJ, Lin PH, Tsai CH. Detection of free flap pedicle thrombosis by infrared surface temperature imaging. J Surg Res 2018;229:169–76.
14. Georgescu AV. Propeller perforator flaps in distal lower leg: Evolution and clinical applications. Arch Plast Surg 2012;39(2):94–105.
15. Stadler F, Brenner E, Todoroff B, Papp C. Anatomical study of the perforating vessels of the lower leg. Anat Rec 1999;255(4):374–9.
16. Panse NS, Bhatt YC, Tandale MS. What is safe limit of the perforator flap in lower extremity reconstruction? Do we have answers yet? Plast Surg Int 2011;2011:349357.
17. Hamilton K, Wolfswinkel EW, Weathers WM, Xue AS, Hatef DA, Izaddoost S, *et al*. The delay phenomenon: A compilation of knowledge across specialties. Craniomaxillofac Trauma Reconstr 2014;7(2):112–8.
18. Hennessy O, Potter SM. Use of infrared thermography for the assessment of free flap perforators in autologous breast reconstruction: A systematic review. JPRAS Open 2019;23:60–70.
19. Teo TC. Perforator local flaps in lower limb reconstruction. Cirugia Plast Iberolatinoamer 2006;32:15–6.
20. Gersch RP, Fourman MS, Dracea C, Bui DT, Dagum AB. The delay phenomenon: Is one surgical delay technique superior? Plast Reconstr Surg Glob Open 2017;5(10):e1519.
21. Meier JK, Prantl L, Müller S, Moralis A, Liebsch G, Gosau M. Simple, fast and reliable perfusion monitoring of microvascular flaps. Clin Hemorheol Microcirc 2012;50(1-2):13–24.
22. Yamamoto T, Todokoro T, Koshima I. Handheld thermography for flap monitoring. J Plast Reconstr Aesthet Surg 2012;65(12):1747–8.
23. Perng CK. Recent advances in postoperative free microvascular flap monitoring. Formos J Surg 2013;46(5):145–8.
24. Busic V, Das-Gupta R. Temperature monitoring in free flap surgery. Br J Plast Surg 2004;57(6):588.

Submitted: February 11, 2020	Revised: June 17, 2020	Accepted: August 4, 2020

Address for Correspondence:

Muhammad Omar Afzal, Senior Registrar, Department of Plastic Surgery, Allama Iqbal Medical College/ Jinnah Burn and Reconstructive Surgery Centre Lahore-Pakistan

Cell: +92 300 411 1418

Email: dromarplasticsurgeon@gmail.com