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ORIGINAL ARTICLE

Application of Multidetector Computed Tomography Angiography in Preoperative Planning of Freestyle Leg Perforator Flap

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Abstract

Background: ***Preoperative assessment of available options for reconstruction of leg defects is one of the most challenging problems to tackle. Many techniques for mapping the perforators have been reported to guarantee the flap's success. However, primarily concentrate on the site of the perforator. With the size and site direction calibre of the perforator near the defect, we still have deficient knowledge of the best. Increased spatial resolution is provided in the final product image by a more significant amount of thin-sliced computed tomographic images generated by multidetector-row computed tomography (MD-CTA).***

Objective: ***To evaluate the usefulness and efficacy of MD-CTA in preoperative planning of leg perforator freestyle flap.***

Materials and Methods: ***Thirty patients all had post-traumatic minor to moderate-size leg defects between August 2018 and February 2023; after a complete medical history examination, they underwent an MD-CTA scan to map the available leg perforators around the defect. Clinical correlation to radiological findings was evaluated regarding size, site, MD-CTA accuracy, and its role in the preoperative assessment of leg defects.***

Results: ***Every perforator that the MD-CTA had detected was found during surgery. The perforators' intraoperative placements and the positions determined by the MDCT analysis were separated by no more than 1 cm.***

Conclusion: ***MD-CTA can be a useful imaging tool when preoperatively constructing a free-floating pedicled perforator flap to treat minor to average-size defects in the legs.***

Keywords: Multidetector-row computed tomography; leg defect; freestyle flaps; perforator flaps

1. Introduction

Leg soft tissue repair continues to pose a significant challenge. Flap coverage is typically required for even modest soft tissue abnormalities of the leg due to restricted movement and a lack of sufficient skin covering.[1] The advancement of reconstructive techniques led to a reevaluation of the contributions made by Manchot and Salmon, which in turn ushered in the period of perforator flaps, as studied by Taylor and Palmer. The inception of this era dates back to 1989, when Koshima and Soeda documented the initial implementations of these flaps.[2,3] To guarantee a successful outcome of perforator flap dissection, it is imperative to conduct a meticulous preoperative assessment utilizing a range of techniques to identify and map the perforators accurately. Handheld Doppler imaging, colour Duplex imaging, and computed tomography angiography are commonly employed in clinical settings to assist reconstructive surgeons in achieving more accuracy before surgery for a perforator flap.[4,5] The MDCTA scanner array consists of numerous detector rows aligned in the scanning direction. This enables capturing many images with each rotation of the X-ray detection tube around the patient. Therefore, multidetector-row computed tomography yields a substantial quantity of finely sliced computed tomographic images acquired relatively briefly. The use of multidetector-row computed tomography results in a higher number of thin-sliced computed tomographic pictures compared to typical single detector–row computed tomography. This leads to an enhanced spatial resolution in the resulting product image. This enables a comprehensive assessment of the perforators from multiple angles and provides three-dimensional visualizations of the perforating vessels.[6,7]

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This study aimed to assess the utility and effectiveness of multidetector C.T. angiography in the preoperative planning of leg perforator freestyle flap.

2. Patients and methods

Thirty patients with post-traumatic small to moderate-size leg soft-tissue lesions had freestyle pedicled perforator flap covering at Al-Azhar University Hospital between August 2018 and February 2023. Patient ages ranged from 10 to 70, with an average age of 32. Sizes of the flap ranged from 3 by 4 cm to 10 by 18 cm. A team comprising a radiologist, radio technician, and plastic surgeon performed an MD-CTA scan (Figure 1) in each case to map the damaged leg perforators using a 128-slice MDCT scanner (G.E. Optima 128 slices C.T. scanners, General Electric Healthcare, Waukesha, WI, U.S.A.).

Ethical Approval

The Al-Azhar University faculty of medicine's institutional review board and ethical committee approved this work. This investigation was carried out at Cairo's Al-Azhar University Hospital's plastic and reconstructive surgery department. Every study participant signed an informed written consent form.

scanning technique

All patients received an administration of a nonionic water-soluble contrast agent called Ultravist 300. This was done by inserting a wide-bore cannula (18-20G) into a large vein. The administered dose was determined to be 1-3 ml of contrast material per kilogram at a rate of 3-3.5cc per second. Serial low-dose monitor C.T. images are taken at 2-second intervals, starting 10 seconds after the introduction of IV contrast. Once the region of interest identifies a certain level of contrast enhancement (often a value between 100-150 Hounsfield Units), the scanner is automatically activated to capture images within the required scan range, beginning at the level closest to the celiac axis and extending down to the feet. This procedure saves time and ensures the best possible improvement of the arteries in the area being studied. In this investigation, all patients underwent a second run or "late phase" acquisition as part of the scanning protocol. A computer workstation was utilized for image reconstruction and manipulation. Nevertheless, examining the axial source imagery continues to be a crucial component of the evaluation.

During the scanning process, individuals were positioned precisely as they would be on the operating table. This is important because the body's posture can significantly impact the blood flow to the perforators while performing MD-CT angiography. Before the operation, the position and trajectory of the primary blood vessel were identified in the area where the tissue would be taken from. The location of the blood vessel, as determined by M.D. C.T.A. was confirmed using an 8 MHz handheld Doppler device and indicated using a permanent marker on the skin.

A *B*

Figure 1. (A) Defective pretibial top third of leg (B) Multidetector-row computed tomography was used to locate and map the subcutaneous path of the pedicle perforators prior to surgery. The locations of the perforators are shown by the red arrows.

Flap design and dissection (Figure 2, 3 & 4): Once the position, caliber, and direction of the ideal perforators have been determined, a dependable flap design is created to patch a nearby soft-tissue defect. Many potentially helpful perforators are typically exposed after the first incision, and the best one is selected based on a number of criteria (location, size, and pulsation), but the most crucial sign of reliability is a strong pulse. A draft flap design is created, using the selected perforator as the flap's pivot point. After the flap design was finished in the shape of the defect, the underlying muscle fascia was separated, and the flap was then released circumferentially as an island until it reached the required range of motion.

Figure 2. Medial sural artery perforator flap design in a freestyle manner.

Figure 3. The perforators of the medial sural artery shown intraoperatively.

Figure 4. Complete flap harvesting and intramuscular dissection of medial sural art to gain the length that allows tension-free flap in the setting.

Flap in setting (Figure 5): With extreme caution, the flap is removed from the wound bed and rotated around its pedicle. The angle formed by the defect and the flap's proximal long axis determines which way the rotation will go. The maximum angle of this angle is 180°. The donor location was either mostly closed or required a skin transplant.

a) b)

Figure 5. a) Flap rotation and in-setting b) 1 month postoperative.

Postoperative follow up: A suitable antibiotic cover was provided. For the first 48 hours, flap monitoring (temperature, color, and capillary refilling) was done every two hours; after that, it was done twice a day. The sutures are removed by the 12th or 15th POD, with the dressings being replaced every two days.

Table 1. Patient data and flap details.

CASE	AGE/SEX	DEFECT SITE	DEFECT SIZE	PERFORATOR NUMBER	P.D. (MM)	SOURCE ARTERY	FLAP SIZE	ROTATION	OPERATIVE TIME (MINUTES)	COMPLICATIONS	TIME OF COVERAGE
1	14/M	Pretibial upper 1/3	5 x 7	4	1.1,1.4,0.9,1.5	Medial sural	6 x 8	90	150	No	3 weeks
2	33/M	Lower 1/3	6 x 4	2	1.7, 2	Post. tibial	7 x 5	90	180	Partial necrosis	2 days
3	48/M	Lower 1/3	4 x 7	2	1.5, 1.8	Post. tibial	5 x 8	120	150	Venous congestion	4 weeks
4	40/M	Lower 1/3	3 x 8	2	1.6, 1.9	Post. tibial	4 x 9	90	150	No	1 week
5	40/F	Lower 1/3	3 x 6	2	1.1, 1.4	Ant. tibial	4 x 7	120	180	No	3 days
6	30/M	Middle 1/3	4 x 6	3	1.5, 1.6, 2	Post. tibial	5 x 7	90	200	Partial necrosis	6 months
7	17/M	Upper 1/3	6 x 10	3	0.8, 0.9, 1.1	Medial sural	7 x 11	90	200	No	10 days
8	20/M	Middle 1/3	5 x 7	2	0.8, 1.1	Post. tibial	6 x 8	90	150	S. epidermolysis	4 days
9	18/M	Achilles T.	6 x 4	3	0.8-1	Peroneal	7 x 5	150	150	Venous congestion	2 days
10	23/F	Lower 1/3	5 x 7	2	0.9, 1.2	Peroneal	6 x 8	120	180	Partial necrosis	25 days
11	17/M	Upper 1/3	8 x 10	4	0.8, 1, 1.4, 1.2	Medial sural	9 x 11	90	200	No	3 days
12	55/M	Upper 1/3	6 x 10	3	0.8, 1.2, 1.4	Ant. tibial	7 x 10	90	200	Partial necrosis	2 months
13	37/M	Upper 1/3	6 x 8	3	0.8, 0.9, 1.1	Medial sural	7 x 9	90	180	No	4 days
14	55/M	Middle 1/3	4 x 6	3	0.8, 1.7, 2	Post. tibial	5 x 7	90	200	Venous congestion	6 weeks
15	33/M	Lower 1/3	7 x 11	2	1.5, 1.8	Post. tibial	8 x 12	180	180	S. epidermolysis	7 days
16	38/M	Lower 1/3	8 x 11	2	1.2, 1.5	Peroneal	9 x 12	120	180	No	10 days
17	48/F	Lower 1/3	4 x 7	2	1.1, 1.8	Post. tibial	5 x 8	120	200	Venous congestion – total loss	8 months
18	27/M	Lower 1/3	3 x 6	2	1.3, 1.5	Post. tibial	4 x 7	180	180	Partial necrosis	3 months
19	25/M	Upper 1/3	4 x 8	4	0.9, 1, 1.1, 1.4	Medial sural	5 x 8	180	180	No	1 week
20	10/M	Achilles T.	3 x 5	3	0.8, 1.2, 1.6	Post. tibial	4 x 6	150	120	No	1 day
21	20/M	Lower 1/3	5 x 6	2	1.1, 1.4	Post. tibial	6 x 7	180	200	Venous congestion	7 days
22	70/M	Middle 1/3	4 x 7	3	0.9, 1.2, 1.4	Post. tibial	5 x 8	120	150	No	5 days
23	35/F	Middle 1/3	4 x 6	3	0.8, 1.1, 1.3	Ant. tibial	5 x 7	90	180	No	3 weeks
24	10/M	Lower 1/3	3 x 6	2	0.9, 1.2	Peroneal	4 x 7	120	200	Partial necrosis	2 months
25	30/F	Achilles T.	4 x 6	3	0.9, 1.2, 1.4	Peroneal	5 x 6	180	180	Partial necrosis	3 days
26	45/M	Middle 1/3	5 x 7	4	0.8, 1, 1.2, 1.6	Post. tibial	6 x 8	90	200	No	7 days
27	34/F	Lower 1/3	4 x 6	2	0.9, 1.4	Post. tibial	5 x 7	120	180	Venous congestion	2 months
28	28/M	Achilles T.	3 x 5	3	1.1, 1.3, 1.4	Peroneal	4 x 6	120	180	No	4 days
29	29/M	Middle 1/3	5 x 7	4	0.8, 0.9, 1.2, 1.5	Ant. tibial	6 x 8	90	200	Partial necrosis	3 months
30	25/M	Middle 1/3	6 x 8	3	0.9, 1.1, 1.3	Post. tibial	7 x 9	90	150	No	14 days

M: Male, F: Female, P.D.: perforator diameter, Post. tibial: posterior tibial, Ant. tibial: Anterior tibial, Achilles T.: Tendon Achilles, S. epidermolysis: Superficial epidermolysis.

3. Results

A spontaneous Thirty patients underwent perforator flap repair for soft tissue abnormalities over the leg (Table 1). Intraoperatively, all perforators found during the MDCT exams were discovered. The perforators' intraoperative placements and the positions determined by the MDCT analysis were separated by no more than 1 cm. Thirty patients had a total of eighty-two perforators (two to four perforators per flap) discovered by MD-CT angiography, all of which were verified intraoperatively throughout the flap dissection. Preoperative MD-CT angiography had an overall sensitivity of almost 97% in identifying perforators. In one instance, we discovered a single perforator that MDCTA missed (perhaps as

a result of hardware artifact). Perforators ranged in size from 1.5 mm to 3 cm, with an average gap of 3 cm between them and the wound edge.

In half of the cases, the posterior tibial artery was the source of the artery. Of the patients, 14 (46.7%) had complete survival, whereas the remaining 53.3% had problems. Eight patients had partial flap necrosis of the distal 1-2 cm of flap; two cases had superficial epidermolysis; five cases had venous congestion; and one case had total flap loss.

Case reports:

Figure 6. Middle 1/3 pretibial leg defect reconstructed by freestyle perforator flap based on a posterior tibial artery perforator whech is mapped using MDCTA, about 19 mm proximal to medial malleolus.

Figure 7. (A) post traumatic middle 1/3 leg defect with exposed fracture mid-shaft tibia, reconstructed by free style perforator flap based on posterior tibial artery perforator.

4. Discussion

Leg deformities often arise from physical injuries and remain a prevalent and complex area of reconstructive surgery. Minor deformities might provide problems, particularly in the lower leg, due to the thin and non-expandable nature of the soft tissue.[8]

Perforator flaps in the lower leg are a beneficial choice in reconstructive surgery because they can replace tissue similar in texture, thickness, pliability, and colour. This method also avoids the need for multiple surgical sites, reduces the adverse effects on the donor site, and limits scarring to only one area. The number is [9], and the freestyle approach is a specific method for harvesting perforator flaps.

Asko Seljavaara In 1983, the phrase "freestyle free flaps" was coined to describe a technique for harvesting flaps. This technique involves identifying a perforator/cutaneous vessel and designing a skin island over it. The number is. [10] Prior to performing a freestyle perforator flap, it is crucial to conduct a thorough preoperative evaluation utilizing several techniques to identify and map the perforators. This is essential to guarantee the successful dissection of the flap.

Multidetector row CT (MD-CT) angiography is a medical imaging technique that captures detailed 3- and 4-dimensional pictures of large and small blood vessels in a perforator flap. MDCTA can offer precise data regarding the position, nature, dimensions, and trajectory of the perforators within the body.[11]

Rozen et al. Examined individuals who received breast reconstruction using a deep inferior epigastric artery perforator flap and demonstrated that CT angiography was highly accurate in identifying perforators, with a positive predictive value of 99.6%.[12]

This study aimed to assess the utility and effectiveness of multidetector CT angiography in the preliminary preparation of leg perforator freestyle flap. The 3D pictures of the perforator vessels produced by MDCTA are highly effective tools for identifying the quantity and places where the perforators arise and their positions in the subfascial region and the soft tissues. This technique allows for a precise examination of the possibilities for flap harvesting. All perforators discovered using preoperative MD-CTA were successfully located during the flap elevation procedure. Furthermore, the dimensions of a perforator were precisely evaluated, and a prominent perforator may be found for utilization in the freestyle perforator flap design. These findings align with the obtained results by Yang

et al. study.[13]

Based on the results above and our expertise, MD-CTA offers numerous advantages compared to other methods for detecting perforators, such as Doppler, duplex scan, and magnetic resonance imaging. Initially, this method was characterized by its minimal invasiveness while maintaining high reliability and accuracy in depicting a variety of blood arteries using a three-dimensional reconstruction model. Furthermore, the data has the potential to be transformed into a 4-dimensional film designed explicitly for the perforators. Furthermore, by employing a contrast agent, MD-CTA can effectively assess the blood supply and its distribution to the tissue, enabling its in vivo application for analyzing the blood supply of the entire flap. Furthermore, MD-CT angiography does not incur higher expenses than conventional computed tomography angiography.[14]

Hence, we suggest utilizing MD-CTA as a standard preoperative examination for all freestyle pedicled perforator flaps. This approach facilitates the identification of a substantial perforator with the least intramuscular and suprafascial pathways, simplifying and enhancing the safety of flap dissection. Additionally, additional research is necessary to accurately evaluate the function of MDCT in terms of costs and its impact on patient outcomes.

4. Conclusion

MD-CT angiography is a highly successful kind of imaging that can be used to design the surgery for a freestyle pedicled perforator flap, which is used to fill minor to moderate-size defects on the leg. This technique enables the preoperative identification and selection of the most suitable and significant blood vessels with the shortest path within the muscle or near the surface. This results in a safer and more straightforward dissection of the tissue flap, leading to an optimal outcome. This contemporary imaging technique is helpful in the preoperative planning of diverse perforator flaps, particularly for freestyle flaps.

Disclosure

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