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Efficiency Assessment of Multidetector-Row Computed Tomographic Angiography Using Reconstruction With Locoregional Perforator Flaps

Évaluation de l'efficacité de la tomoangiographie numérisée à multidétecteurs utilisant la reconstruction avec des lambeaux perforants locorégionaux

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Abstract

Background: Reconstruction with the use of perforator flaps makes it possible to make the skin surface resistant to the influence of mechanical factors and as similar to the lost skin cover as possible. However, while planning any flap, along with the design of the required shape and size, its blood supply should be taken into account to ensure optimal viability. Therefore, the task to precisely determine the topographic–anatomical relationships suitable for the formation of a pedicle of perforators is still relevant. The aim of this study was to increase the efficiency of surgical reconstruction of wound defects by transposition of locoregional perforator flaps. **Methods:** The authors conducted a retrospective analysis of 72 cases of reconstruction by means of locoregional perforator flaps with vascular pedicle detachment to determine the efficiency of preoperative diagnostic preparation with the help of multidetector-row computed tomographic angiography (MDCT) in the process of reconstruction. Thirty-seven individual cases of surgical interventions were chosen using a case-controlled study from the study group when MDCT with angiography was used for preoperative planning of perforator flaps, as well as 35 control cases similar in terms of important predictive peculiarities with the reconstruction at the same level of difficulty. The patient groups were precisely matched by gender ($P = .950$), age ($P = .804$), flap area ($P = .192$), and type of reconstruction that was performed. **Results:** In all cases, the location of the perforator with a diameter greater than 1.0 mm was marked. All perforators determined during MDCT scanning were faultlessly localized intraoperatively. The distance between the intraoperative position of the perforator and the position obtained in the result of the examination did not exceed 1 cm. There was no need to change the planned design of the flap intraoperatively. In all cases where MDCT was performed, the duration of the surgical procedure varied from 60 to 150 minutes (average: 120.77 [18.90] minutes) and was reduced by 49.40 minutes (95% CI: 39.17-59.63) compared with the patients who did not undergo preoperative visualization of perforators where the average duration of the operation was 170.17 (19.19) minutes (from 140 to 220 minutes). Among the patients examined by MDCT, surgical complications were noted in 5 cases (13.51%) compared to 14 cases (40.00%) in the control group. **Conclusions:** The preoperative MDCT for the locoregional perforator flap reconstruction makes it possible to increase the efficiency of patient treatment given the reduction in surgery duration by

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49.40 minutes (95% CI: 39.17-59.63) on average and the reduction in the level of postsurgery complications from 40% to 13.5% compared with the group of patients in whom presurgical visualization was not performed ($P = .031$).

Résumé

Contexte : La reconstruction faisant appel à des lambeaux perforants permet de rendre la surface de la peau résistante à l'influence de facteurs mécaniques et de la rendre aussi semblable que possible à la couverture cutanée perdue. Cependant, tout en planifiant un lambeau, son approvisionnement en sang doit être pris en compte au même titre que sa forme et sa taille pour assurer une viabilité optimale. Par conséquent, la tâche visant à déterminer avec précision les rapports topographiques-anatomiques convenables pour la formation d'un pédicule perforateur reste pertinente. L'objectif de cette étude était d'augmenter l'efficacité de la reconstruction chirurgicale des lacunes post-blessures par transposition de volets perforateurs locorégionaux. **Méthodes :** Les auteurs ont réalisé une analyse rétrospective de 72 cas de reconstruction utilisant le détachement d'un pédicule vasculaire de volets perforateurs locorégionaux pour déterminer l'efficacité de la préparation diagnostique préopératoire aidée par la tomoangiographie numérisée à multidétecteurs (MDCT) dans le processus de reconstruction. 37 cas individuels d'interventions chirurgicales ont été choisis dans une étude cas-contrôles à partir du groupe d'étude quand la tomoangiographie numérisée à multidétecteurs a été utilisée pour la planification préopératoire des lambeaux perforants. 35 cas-contrôles similaires en termes de particularismes prédictifs importants pour la reconstruction avec le même niveau de difficulté. Les groupes de patients ont été appariés avec précision pour le genre ($P = 0{,}950$), l'âge ($P = 0{,}804$), la surface du lambeau ($P = 0{,}192$) et le type de reconstruction qui était exécuté. **Résultats :** Dans tous les cas, l'emplacement du perforateur avec un diamètre supérieur à 1 mm a été marqué. Tous les perforateurs déterminés au cours de la MDCT ont été localisés sans erreur en peropératoire. La distance entre la position peropératoire du perforateur et la position obtenue dans le résultat de l'examen n'a pas dépassé 1 cm. Il n'a pas été nécessaire de modifier le plan prévu du lambeau en peropératoire. Dans tous les cas où la MDCT a été réalisée, la durée de la procédure chirurgicale a été de 60 à 150 minutes (moyenne, 120,77 [18,90] minutes) et a été réduite de 49,40 minutes (IC à 95%: 39,17 à 59,63) comparativement aux patients qui n'ont pas eu de visualisation préopératoire des perforateurs; pour ces derniers, la durée de l'intervention a été de 170,17 (19,19) minutes (de 140 à 220 minutes). Parmi les patients examinés par MDCT, des complications chirurgicales ont été observées dans 5 cas (13,51%) comparativement à 14 cas (40,00%) dans le groupe témoin. **Conclusions :** La MDCT préopératoire pour la reconstruction avec lambeau perforateur locorégional permet d'améliorer l'efficacité du traitement des patients compte tenu de la réduction des temps opératoires de 49,40 minutes (IC à 95%, 39,17 à 59,63) en moyenne et de la réduction de 40% à 13,5% des complications postopératoires comparativement au groupe de patients n'ayant pas bénéficié de visualisation avant l'intervention ($P = 0{,}031$).

Keywords

CT angiography, perforator flaps, perforator vessels, reconstructive surgery

Background

Reconstruction with the use of perforator flaps makes it possible to make the skin surface resistant to the influence of mechanical factors and as similar to the lost skin cover as possible.[1-4] The priority for surgical closure of the defect is to achieve like-with-like reconstruction with excellent contours and minimal donor site morbidity.[4] This type of plastic is the preferred choice since it allows effective restoration of the skin covering in a single step.[2,5,6] However, while planning any flap, along with the design of the required shape and size, its blood supply should be taken into account to ensure optimal viability.[2,6,7]

In order to reduce problems, some surgeons suggest limiting the angle of rotation of the propeller flap[8] or use the design of the flap without turning,[9] but this is not acceptable for a number of clinical cases. Brunetti and colleagues argued that handheld Doppler device is enough for preoperatively visualizing the perforator vessels directly through the wound edge.[10] Although variable instrumental techniques[11-14] are being actively developed to solve this problem, different clinics currently apply different diagnostic models with different clinical efficiencies. If we take into account that Doppler device can show a false-positive result,[10] the task to precisely determine the topographic–anatomical relationships suitable for the formation of a pedicle of perforators is still relevant. The aim of this study was to increase the efficiency of surgical reconstruction of wound defects by transposition of locoregional perforator flaps.

Patients and Methods

We conducted a retrospective analysis of 72 cases of reconstruction by means of locoregional perforator flaps with vascular pedicle detachment to determine the efficiency of preoperative diagnostic preparation with the help of multidetector-row computed tomographic angiography (MDCT) in the process of reconstruction. In all cases, an audio Doppler with an 8-MHz sensor was used to determine the location of the perforators.

Multidetector-row computed tomographic angiography has not been used in all cases. The use of MDCT angiography was

Table 1. Parameters of Multiple Detector Computer Tomography and Scanning.

Parameters	Description
Scanner	128-slice MDCT scanner (Aquilion CXL; Toshiba Medical Systems)
Detector configuration	64-row, 0.5-mm slice thickness
Detector coverage	64 mm
Pitch	Standard
Gantry rotation speed	0.5 second/rotation
Tube voltage	120 kV
Contrast	350 mg/mL Tomohexol (iohexol 350; Farmak)
Contrast volume	(Scan time + 10) × 5 mL/s + 0.9% NaCl 61 mL
Infusion rate	5 mL/s
Bolus tracking method	SureStart
Start time	Aortic enhancement up to 180 HU
Image reconstruction	0.5 mm with overlap

complicated by the fact that the computed tomography (CT) machine was in another hospital. Thus, the study required organizational efforts and was complicated by the need to transport patients to another clinic, which was not always possible.

Finally, the decision to use MDCT angiography was based on the patient consent to bear the additional financial costs of the study. The study involved patients who underwent reconstruction on the trunk or upper or lower extremities. Inclusion criteria were as follows: adult men and women aged 22 to 72 years with deep wound defects and exposure of deep anatomical structures that require closure with flaps. The etiologies of defects that needed reconstruction were as follows: deep burns, cicatricial deformities, oncology, and traumatic wounds. Exclusion criteria for study groups included medical comorbidities such as diabetes mellitus, human immunodeficiency virus/acquired immunodeficiency syndrome, systemic connective tissue diseases, cardiovascular diseases, and patients having undergone previous radiation therapy to the reconstructive area.

Thirty-seven individual cases of surgical interventions were chosen using a case-controlled study from the study group when MDCT with angiography was used for preoperative planning of perforator flaps (Table 1). Then 35 control cases similar in terms of important predictive peculiarities (age and gender of patients, the coverage area of the defect, and perforator used) with the reconstruction at the same level of difficulty according to Hirase classification[15] were chosen. These cases were treated during the same period of time and by the same surgical team but without the use of MDCT for presurgery planning and visualization.

Aspects of the Surgical Technique

In all cases, pedicle perforator flaps or propeller perforator flaps were used. Blood-free, clean dissection was achieved by separating the tissue with low-current electrocautery and a wide spatula tip. Flap dissection begins after the location of the necessary skin perforator with the help of a Doppler study. Initially, only one skin edge is incised so that the skin paddle can be altered according to the feeding vessel selected. The dissection proceeds at the suprafascial level. Once the perforator has been identified and approached in the prefascial plane, it is necessary to open the deep fascia and follow the vessel through its intramuscular course. The collagenous cuff around the perforator is cut.

For propeller flap cases, the dominant perforator acts as a pivot point. The longest part of the flap can turn approximately 180° into the defect. The perforator should be dissected to a level below the fascia and to a sufficient distance to ensure flap turning will not cause torsion of the vessel to the extent that it compromises perfusion.

Computed Tomography Scanning Technique

All CT angiography examinations of perforators were conducted using 128 MDCT Aquilion CXL (Toshiba Medical Systems) jointly by a radiologist, an X-ray technician, and a plastic surgeon. Scanning parameters are presented in Table 1.

The scanning was performed with the patient in a position corresponding to the positioning on the surgery table, and the patient held his/her breath during visualization of the main trunk. Scanning was restricted by the segment of the body on which surgical intervention was planned.

All MDCT scans were performed with the gantry rotation speed of 0.5 seconds per rotation, detector coverage of 40 mm, and detector configuration of 0.5 mm and 64 rows. Scan time depended on the range of the investigated segment. For CT angiography, axial images with a thickness of 0.5 mm were reconstructed with an interval of 0.5 mm of overlap and were transferred to the workstation.

In all cases, the location of the perforator with a diameter greater than 1.0 mm was marked. Additionally, the spots of penetration by perforator vessels of deep fascia as well as the direction of the perforator branches over the fascia were determined on PC. Thus, all the flaps were formed considering the exact data on the exit point of the perforator and the directions of its branches on the suprafascial level.

Statistics

The difference between the 2 averages was estimated by the unpaired t test, between proportions by the χ^2 test. For all tests, P values $<.05$ were considered significant.

Results

The patient groups were precisely matched by gender ($P = .950$), age ($P = .804$), flap area ($P = .192$), and type of reconstruction that was performed (Table 2). Among the 37 patients, 11 women and 26 men underwent MDCT. The average age of the patients was 42.11 (15.37) years (range: 22-72 years). In total, 12 women

Table 2. Patient Demographic Data.[a]

Index		Patients with MDCT (n = 37)	Patients without MDCT (n = 35)	*P*
Gender, n (%)	Men	26 (70.27%)	23 (65.71%)	.950
	Female	11 (29.73%)	12 (34.29%)	
Age, years, M (SD)		42.11 (15.37)	43.10 (18.33)	.804
Length of flap, cm, M (SD)		11.21 (4.65)	13.38 (5.78)	.053
Width of flap, cm, M (SD)		7.12 (3.51)	6.31 (2.78)	.283
Flap area, cm^2, M (SD)		72.62 (48.11)	88.90 (56.53)	.192
Surgical complications, n (%)		5 (13.51%)	14 (40.00%)	.031
Etiology of defects	Deep burns	5 (13.51)	6 (17.14)	.638
	Oncology	6 (16.22)	8 (22.86)	
	Cicatricial deformities	10 (27.03)	10 (28.57)	
	Traumatic wounds	16 (43.24)	11 (31.43)	
Donor site coverage, n (%)	Primary closure	19 (51.35%)	25 (71.43%)	.197
	Skin grafting	11 (29.73%)	7 (29.00%)	
	Primary closure + skin grafting	7 (18.92%)	3 (8.57%)	

Abbreviations: M, mean; MDCT, multidetector-row computed tomographic angiography.
[a]*P* is the discrepancies between the groups by criterion χ^2 for relative indexes and by Student *t* test for the average ones.

Table 3. Analysis of the Use of MDCT With Angiography in Patients Chosen on "Case–Control" Basis.

Index	Patients with MDCT (n = 37)	Patients without MDCT (n = 35)	*P*
Timing of surgery, minutes, M (SD)	120.77 (18.90)	170.17 (19.19)	<.001
Timing of surgery on upper extremities, minutes, M (SD)	112.50 (27.16)	168.33 (27.87)	.006
Timing of surgery on lower extremities, minutes, M (SD)	120.00 (15.05)	170.23 (16.14)	<.001
Timing of surgery on trunk, minutes, M (SD)	136.25 (12.50)	200.0 (10.50)	.020
Complications, n (%)	5 (13.51%)	14 (40.00%)	.031

Abbreviations: M, mean; MDCT, multidetector-row computed tomographic angiography.

and 23 men were included as patients who did not undergo MDCT. The average age of patients was 43.10 (18, 33) years (from 22 to 71 years). On average, the size of the flap in patients who underwent MDCT was 11.21 (4.65) cm along the horizontal length and 7.12 (3.51) cm along the vertical length. In patients who did not undergo MDCT, these values were 13.38 (5.78) and 6.31 (2.78) cm, respectively ($P = .141$ and $P = .189$, respectively).

All perforators identified by the MDCT examinations were located during surgery without any errors. The distance between the intraoperative position of the perforator and the position obtained in the result of the examination did not exceed 1 cm. There was no need to change the planned design of the flap intraoperatively.

In all cases where MDCT was performed, the duration of the surgical procedure varied from 60 to 150 minutes (average: 120.77 [18.90] minutes) and was reduced by 49.40 minutes (95% CI: 39.17-59.63; Figure 1) compared with patients who did not undergo preoperative visualization of perforators where the average duration of the operation was 170.17 (19.19) minutes (from 140 to 220 minutes). Reconstruction in the patients who did not undergo MDCT lasted on average 168.33 (27.87) minutes for the upper extremities, 170.23 (16.14) minutes for the upper extremities, and 200.0 (10.50) minutes for the trunk (Table 3). The corresponding indexes in case where patients underwent MDCT were significantly lower ($P < .05$).

Among the patients examined by MDCT, surgical complications were noted in 5 cases (13.51%), including 1 case of epidermolysis, 1 case of marginal necrosis after infection contamination that needed additional wound care, and 3 cases of marginal necrosis after venous congestion that required additional skin grafting. In all these cases, the complications were eliminated and did not significantly affect the treatment. Postsurgical complications with flaps were observed in the patients not examined with MDCT in 14 cases (40.00%), including 5 cases of partial necrosis after venous congestion that required additional wound care, 6 cases of partial necrosis that required additional skin grafting, and 3 cases (8.57%) of complete loss of the flap and that required alternative reconstructions. Statistically significant differences were found in terms of frequency of complications in different groups ($P = .031$; Table 3).

Case Report 1

A man (26 years old) was admitted to the hospital with a mine shrapnel injury of the back with an 8 cm × 6 cm tissue defect in the left of the spinal column (Figure 2). To eliminate the tissue defect, after the wound was debrided and treated with negative pressure for 3 days, the surgeons scheduled the reconstruction with the use of a propeller flap 10 × 5 cm in size using a perforator pedicle from the space of paravertebral

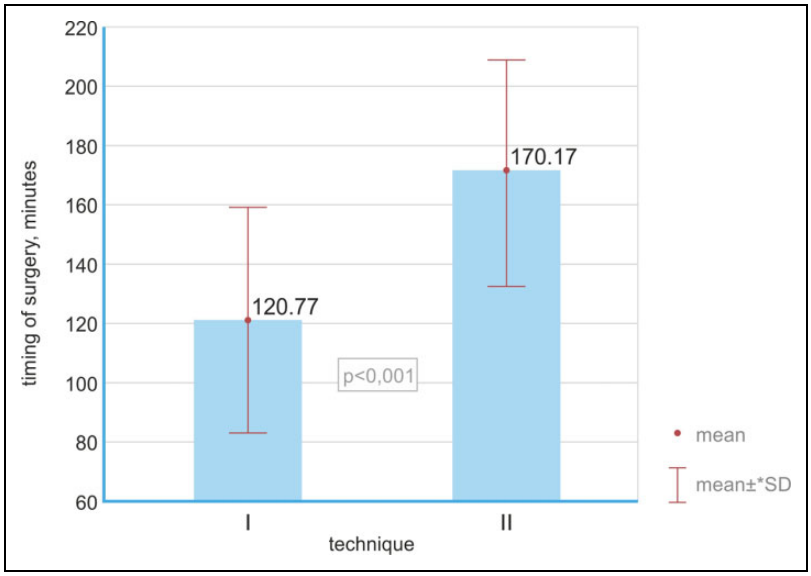

Figure 1. The average duration of surgery in minutes in patients with preliminary multidetector-row computed tomographic angiography (MDCT) examination (I) and patients in whom MDCT examination was not performed (II) (arithmetic mean and SD).

Figure 2. A photo of a mine shrapnel injury of the back with 8 cm × 6 cm tissue defect in the left of the spinal column.

artery in the right of the spinal column. With the help of Doppler and MDCT angiography, 2 perforators were identified, and the exact location of the exit and its direction were determined to precisely plan the flap design (Figure 3). The location of the perforator defined with the help of MDCT angiography was completely confirmed intraoperatively (Figure 4).

After debriding, the wound defect was closed with an adipocutaneous perforator propeller flap that was 10 cm × 5 cm on the perforator of paravertebral artery (Figure 5) via 85° rotation. No complications were noted during the postoperative period, and microcirculatory disorders in the flap were not detected. During medical examination at 4 weeks, the cutaneous flap has similar properties compared with the lost tissue. The new scars after surgery appear pink, and silicone-based products in conjunction with compression were recommended for treatment (Figure 6).

Case Report 2

Patient D (71 years old, female) was admitted to the clinic due to deep third-degree electric burns in the popliteal fossa (Figure 5). For the closure of the wound defect in the popliteal fossa, a posterior thigh flap based on the third perforator of the profunda femoris artery perforator flap (PFAP-3) was planned. Perforator diagnostics were performed by CT angiograms and Doppler.

After the preliminary location of the dominant perforator in the lower one-third of the thigh was determined (Figure 7), a skin fascial flap measuring 15 cm × 6 cm was raised along the posterior surface. The flap was rotated 180° to the area of the wound defect, where radical debridement and hemostasis were previously performed. As a result of the surgery, a complete cover was created in the popliteal fossa, which allowed functional restoration of the joint and limb as a whole (Figure 8).

Discussion

The priority for surgical closure of the defect is achieve like-with-like reconstruction with excellent contours and minimal donor site morbidity.[4] This type of plastic is the preferred choice since it allows effective restoration of the skin covering

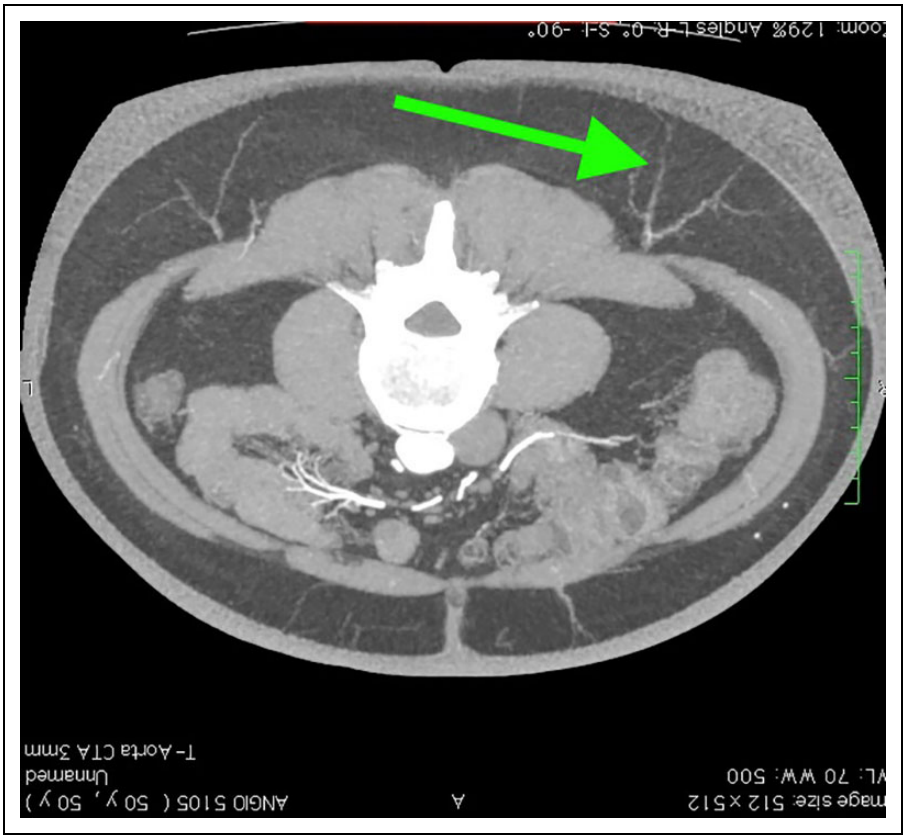

Figure 3. Multidetector-row computed tomographic angiography (MDCT) angiography. Green arrow shows the perforator of the paravertebral artery on the right to be used as feeding vascular pedicle of the flap.

Figure 4. Photo of the stage of dissection of the vascular pedicle at the moment of flap elevation; positioning of the perforator determined during multidetector-row computed tomographic angiography (MDCT) angiography scanning was completely confirmed intraoperatively.

Figure 5. Photo on the fourth week after reconstruction: the wound defect was restored with a cutaneous flap that was adjusted to maximally match the properties of the lost tissue; new postsurgical scars requiring rehabilitation are noted.

in a single step.[2,5,6] However, while planning any flap, along with the design of the required shape and size, its blood supply should be taken into account to ensure optimal viability.[2,6,7]

The design of the perforator flap is different in each new clinical case. This is due to the pronounced individual variability of perforating vessels, in their quantity, localization of the axis, and the point of exit into the covering tissues. This variability exists even when comparing the contralateral segments in one person, and even more so in different

Figure 6. Deep burn in the popliteal fossa of the left lower extremity and the design of a posterior thigh flap based on the profunda femoris artery perforator flap (PFAP-3).

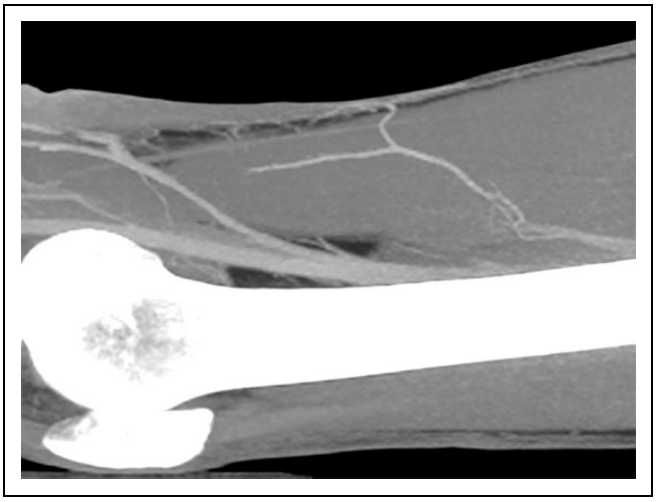

Figure 7. Computed tomography (CT) angiograms for the Third perforator of the profunda femoris artery to form the profunda femoris artery perforator flap (PFAP-3).

patients.[16-18] This necessitates the diagnosis in the preparation of operations.

The most common planning procedure (determining the anatomical and topographic features) of perforators is a Doppler study using an audio Doppler.[11,19] The advantage of this method is its convenience, less expensive, and the possibility of widespread use. However, this method does not provide visual data, and the data obtained depend on the user and require the experience of the researcher.

Ultrasound scanning with color Doppler sonography provides more information than audio Doppler. Such visualization has high sensitivity and 100% predictive value; it allows to determine the vessel diameter and its rheological properties, such as blood flow velocity, resistance, and resistance in perforating and mainly vessels.[20,21] However, this method is still inferior to CT scan with angiography for informativeness and visualization of the topographic–anatomical relationship of perforating vessels with other anatomical structures.[2,21] Computed tomography scan with angiography finds positive feedback from specialists performing these operations.[16,12,22,23]

Figure 8. State of the lower limbs after 2 months of plastic reconstruction.

Although the MDCT technique had been developed more than 15 years ago, the scope of its applications has been expanding over the years and has recently emerged to encompass its use as a noninvasive and a reliable tool in preoperative perforator flap analysis. The first report of the application of the MDCT technique to the preoperative planning of the perforator propeller flaps for closing of the defects in the various body parts was published in 2011.[22] The recent improvements in the areas of data analysis and visualization via MDCT have, nevertheless, resulted in a few reports on the 3D analysis of the perforator vessels for the construction of the perforator flaps.[12,24] These works have demonstrated that the 3D images of the perforator vessels generated via MDCT are excellent tools in the identification of the sites where the perforators emerge, as well as their locations in the soft tissues. As such, this technique allows for an accurate investigation of the options for the flap harvesting.

The possibility of using MDCT with angiography or its informational content has a number of limitations. This may be due to the general condition of patients (eg, an increased level of creatinine), the presence of orthopedic metal structures, organizational issues of patient transportation, and so on.

In our opinion, further development of methods for imaging of perforating vessels will most likely be aimed at the possibility of using the simplest, minimally invasive, and cheap methods, but with great information content. Even today, thermography and Indocyanine green (ICG) are being actively introduced into practice, and perhaps very soon these methods will be quite competitive with MDCT. And the combined application of several techniques can provide the most complete information.

Conclusion

The preoperative MDCT for the locoregional perforator flap reconstruction makes it possible to increase the efficiency of patient treatment given the reduction in surgery duration by 49.40 minutes (95% CI: 39.17-59.63) on average and the reduction in the level of postsurgery complications from 40% to 13.5% compared with the group of patients in whom presurgical visualization was not performed ($P = .031$).

Authors' Note

Treatment of the patient was conducted fully in accordance with the Helsinki Declaration. Informed consent was obtained from all individual participants included in the study. Treatment of the patient was not related to any of the clinical trial. Pavlo Badiul contributed to surgery, patient care, writing the manuscript, and research the scientific literature. Sergii Sliesarenko contributed to the idea of the research, writing the manuscript, and administrative and material support. Nataliia Cherednychenko contributed to CT angiography examinations, work with CT angiography images by OsiriX program, and research the scientific literature. Olga Morgun contributed to CT angiography examinations.

Declaration of Conflicting Interests

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Supplemental Material

Supplemental material for this article is available online.

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