Journal of Plastic, Reconstructive & Aesthetic Surgery (2019) 72, 759–762

JPRAS
An International Journal of Surgical Reconstruction
www.JPRASurg.com

Augmented Reality Microsurgical Planning with a Smartphone (ARM-PS): A dissection route map in your pocket

Nicolás Pereira, MD, MSc[a,b,*], Matías Kufeke, MD[a,b], Leonardo Parada, MD[a], Ekaterina Troncoso, MD[a], Jorge Bahamondes, MT[c], Luis Sanchez, MT[c], Ricardo Roa, MD[a]

[a] *Department of Plastic Surgery and Burns, Hospital del Trabajador; Santiago, Chile*
[b] *Department of Plastic Surgery, Clínica Las Condes; Santiago, Chile*
[c] *Department of Radiology, Hospital del Trabajador; Santiago, Chile*

Received 8 July 2018; accepted 2 December 2018

KEYWORDS
Augmented reality;
Smartphone;
Preoperative planning;
Microsurgical planning;
Perforator flap;
SCIP flap;
New technologies

Summary *Introduction:* Perioperative microsurgical planning increases the likelihood of successful results. Augmented reality (AR) is the addition of artificial information to allow the user to perform tasks more efficiently. The aim of our study is to report the use of AR for microsurgical planning with a smartphone (ARM-PS) as a dissection route map.
Patients and methods: AR was used for superficial circumflex iliac artery perforator (SCIP) flap planning. Three-dimensional (3D) reconstruction images of the inguinal and lower abdomen vascular anatomy were obtained by computed tomography angiography. These 3D images were imported to a smartphone and an AR app was used to superimpose them with the camera. The drawings performed with ARM-PS were correlated with handheld Doppler and intraoperative findings.
Results: The correlation of ARM-PS drawings with handheld Doppler results was 100% for superficial inferior epigastric artery (SIEA) and superficial and deep branches of SCIP in 60 inguinal areas studied. Intraoperative findings matched perfectly in all 30 cases with ARM-PS drawings for the location of the mentioned vessels and lymph nodes. Flap harvest time decreased in 20% compared with our traditional timing.
Conclusions: ARM-PS is an easy, noninvasive, and accurate method that provides a dissection route map, thereby standardizing flap harvesting, and shows a perfect correlation with

* Corresponding Author: Nicolás Pereira, MD, MSc, Department of Plastic Surgery and Burns, Hospital del Trabajador, 185 Ramon Carnicer, 5th floor. Providencia #7501239. Santiago, Chile
E-mail address: npereira@hts.cl (N. Pereira).

https://doi.org/10.1016/j.bjps.2018.12.023

intraoperative findings. It reduces operating time and may improve operative results, thus decreasing donor site morbidity.

Introduction

From the first description of the deep inferior epigastric artery perforator flap by Koshima and Soeda[1] in 1989, perforator flaps have been widely used and have had an exponential evolution, as has also evolved the technology implemented for their study. Currently, we have accurate methods to determine the location of perforators and defining their course through the skin.

Handheld Doppler, color Doppler, computed tomography angiography (CTA), and magnetic resonance angiography are methods for perioperative planning[2-4]. These methods have shown to decrease operative time, decrease the donor site morbidity, and increase the likelihood of successful results[5]. Technological advances have allowed the application of new technologies, safer and with greater portability. A survey found that 87% of physicians use a smartphone or tablet device in their workplace, including 80% above the age of 55 years[6]. Recently, we have described the use of a smartphone thermal camera for detecting perforators with a high correlation with CTA[7].

Augmented reality (AR) is the addition of artificial information to one or more of the senses that allows the user to perform tasks more efficiently. This can be achieved using superimposed images, videos, or computer-generated models. Augmentation of reality has been used in surgery for many years particularly in neurosurgery, where stereotactic surgery has used the combination of radiographic scan data in stored or real-time acquisition to allow accurate and safer "neuronavigation."[8]

The use of AR for microsurgical planning with a smartphone (ARM-PS) is revolutionary and until now has not been described. The aim of our study is to report the use of ARM-PS as a dissection route map in the surgeon's pocket.

Patients and methods

AR was used for superficial circumflex iliac artery perforator (SCIP) flap planning in the Department of Plastic Surgery and Burns, Hospital del Trabajador, and the Department of Plastic Surgery, Clínica Las Condes, during January to June 2018. Patients who underwent upper or lower extremity microsurgical reconstruction with SCIP free flap were included. This research was conducted by following the principles of the Helsinki Declaration[9] and obtaining approval from the Scientific Ethics Committee. The authors adhered to STARD guidelines for diagnostic measure research (http://www.stard-statement.org). All patients signed a written consent authorizing their inclusion in the study.

Lower extremity CTA images were obtained using a 64-detector row helical CT system (Brilliance 64; Philips, Amsterdam, The Netherlands) with perforator protocol, maximum intensity projection, and 1-mm slice width. A 3-dimensional (3D) reconstruction image of inguinal and lower abdomen vascular anatomy was obtained using multimodality advanced vessel analysis software (AVA) (Philips, Amsterdam, The Netherlands) to identify referential landmarks, i.e., umbilicus, both anterior superior iliac spines (ASIS) and superior border of pubic symphysis (PS) (**Figure 1**).

The 3D image obtained by CTA was reviewed online in a smartphone (Samsung Galaxy S7, Seoul, South Korea) and downloaded directly to the picture's gallery. Sensitive information was not included to maintain privacy for patients. The 3D image was imported from the smartphone's gallery to an AR app (Augmented Drawing, New Taipei City, Taiwan) to superimpose the image with the camera. Freehand drawings were performed guided through the smartphone screen by fixing the image to the landmarks (umbilicus, both ASIS and PS) and identifying arteries and veins derived from the femoral vessels (superficial inferior epigastric (SIE), superficial branch of SCIP (s-SCIP), deep branch of SCIP (d-SICP)), and groin lymph nodes. Drawings performed with ARM-PS were correlated with handheld Doppler and intraoperative findings. Flap harvest time was recorded and compared to a series of 15 consecutive cases performed without ARM-PS, operated by the same team.

Results

CTA and 3D reconstruction images were obtained in 30 patients. ARM-PS was performed in 60 inguinal areas **(Video 1)** and was correlated with handheld Doppler findings (SIEA, s-SCIP, and d-SCIP). Intraoperative findings were correlated with ARM-PS drawings in 30 SCIP flap cases.

Correlation of ARM-PS drawings with handheld Doppler results was 100% for SIEA, s-SCIP, and d-SCIP arteries of the 60 inguinal areas studied **(Video 2)**. Intraoperative findings correlated in all 30 cases with the ARM-PS drawings for the location of the mentioned vessels and lymph nodes (**Figure 2 and Video 3**).

The perfect correlation of ARM-PS with handheld Doppler and intraoperative findings allowed us to decide which side to use for the SCIP flap based on vascular characteristics and its relations with lymph nodes. It also aided to optimize flap design including the largest amount of the vascularized tissue and tailor it to the defect (**Figure 3**). Using ARM-PS, the average time for our flap harvest was 72 minutes, while the time of the series that did not use this technology was 90 minutes, with a decrease in the average harvest time by 20%.

Discussion

Presently, efforts are directed toward finding complementary, portable, accurate, and bedside studies that might

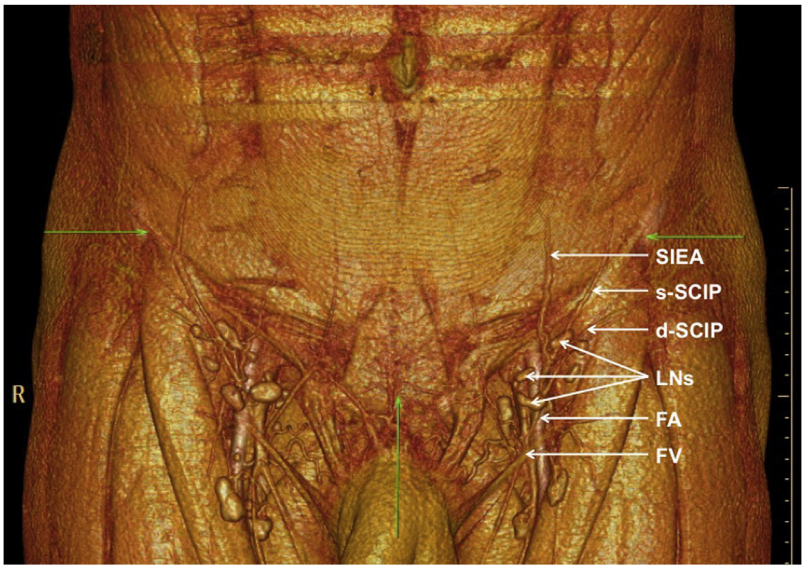

Figure 1 3D reconstruction image of inguinal and lower abdomen vascular anatomy. Landmarks used are umbilicus and green arrows (both anterior superior iliac spines and superior border of pubic symphysis). (**SIEA:** superficial inferior epigastric artery; **s-SCIP:** superficial branch of superficial circumflex iliac artery perforator; **d-SCIP:** deep branch of superficial circumflex iliac artery perforator; **LNs:** lymph nodes; **FA:** femoral artery; **FV:** femoral vein).

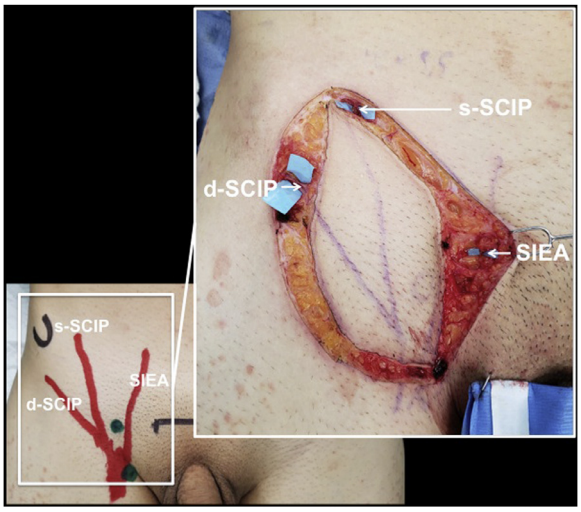

Figure 2 Correlation of ARM-PS drawings with intraoperative findings of a right SCIP flap. (**SIEA:** superficial inferior epigastric artery; **s-SCIP:** superficial branch of superficial circumflex iliac artery perforator; **d-SCIP:** deep branch of superficial circumflex iliac artery perforator).

contribute in both preoperative and intraoperative periods. The use of AR with a smartphone is an easy, noninvasive, and accurate method for microsurgical planning. It also provides relevant information regarding vascular anatomy and its relations, contributing to flap design and harvest.

There are several methods for microsurgical planning. Handheld Doppler is an inexpensive and portable device for the evaluation of perforators but provides limited information regarding three-dimensionality, venous anatomy, vessel origin, and vessel course[10,11]. Color Doppler ultrasound not only provides more information about the course, origin, and structures surrounding the perforator but also gives a hemodynamic evaluation[12]. It has high sensitivity and 100% concordance with intraoperative findings in expert hands, even in previous surgical sites[13]. Despite the above, it is a time consuming and operator-dependent method, with no 3D reconstruction.

CTA is currently considered the gold standard with excellent performance. The use of CTA in preoperative planning has been shown to decrease operative time, decrease donor site complications, and decrease the learning curve of the technique[3,14]. It allows identification of the vessels origin, intramuscular pathway, fascial perforation site and its ramification in the subcutaneous tissue. It has the option of 3D reconstructions to determine more accurately the path of the vessels and its relations with adjacent soft tissue structures.

Bosc et al.[15] performed AR for perforator identification in deep inferior epigastric perforator flap by using smart glasses, thus providing binocular visualization in the operative field of the vessels identified with CTA. We demonstrated a perfect correlation of ARM-PS with intraoperative findings, without using any other device but the smartphone. This allows to optimize the size of the flap by adjusting the design to the axiality of the pedicle and the anatomy of arteries and veins, being able to make freestyle designs tailored to the defect. It delineates venous anatomy, given that handheld Doppler is not suitable for that, being of particular interest to avoid flap congestion. Preoperative identification of lymph nodes and their relations may decrease donor site morbidity and harvesting time, thus anticipating complex dissections.

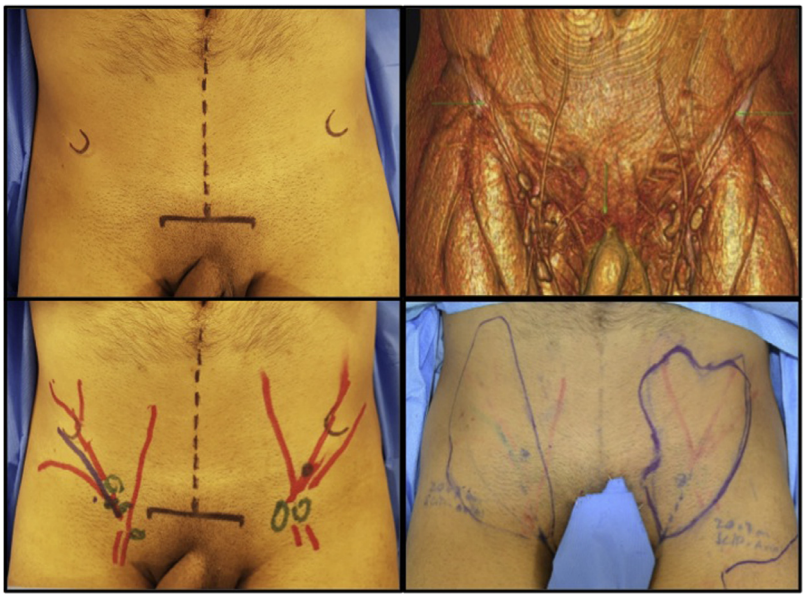

Figure 3 Optimizing the design of the flap and tailoring it to the defect using ARM-PS.

Conclusions

ARM-PS is an easy, noninvasive, and accurate method that provides a dissection route map, thereby standardizing flap harvesting, and shows a perfect correlation with intraoperative findings. It reduces operating time and may improve operative results, thereby decreasing donor site morbidity.

Acknowledgments

The authors thank "La Copia Feliz productions" for their help in editing the videos.

Financial Disclosure Statement

The authors have no financial interest to declare in relation to the content of this article.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.bjps.2018.12.023.

References

1. Koshima I, Soeda S. Inferior epigastric artery skin flaps without rectus abdominis muscle. *Br J Plast Surg* 1989;**42**:645–8.
2. Rozen WM, Stella DL, Phillips TJ, Ashton MW, Corlett RJ, Taylor GI. Magnetic resonance angiography in the preoperative planning of DIEA perforator flaps. *Plast reconstr Surg* 2008;**122**:222e–223e.
3. Rozen WM, Ashton MW, Stella DL, et al. Developments in perforator imaging for the anterolateral thigh flap: CT angiography and CT-guided stereotaxy. *Microsurgery* 2008;**28**:227–32.
4. Stekelenburg CM, Sonneveld PM, Bouman MB, et al. The hand held Doppler device for the detection of perforators in reconstructive surgery: What you hear is not always what you get. *Burns* 2014;**40**:1702–6.
5. Rozen WM, Ashton MW, Pan WR, et al. Anatomical variations in the harvest of anterolateral thigh flap perforators: a cadaveric and clinical study. *Microsurgery* 2009;**29**:16–23.
6. Chase J. IPads and other drugs. Medical Marketing & Media: The Interactive Guide 2013:10-11.
7. 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**:787–92.
8. Alberti O, Dorward NL, Kitchen ND, Thomas DG. Neuronavigation–impact on operating time. *Stereotact Funct Neurosurg* 1997;**68**:44–8.
9. General Assembly of the World Medical Association World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. *J Am Coll Dent* 2014;**81**(3):14–18.
10. Giunta RE, Geisweid A, Feller AM. The value of preoperative Doppler sonography for planning free perforator flaps. *Plast Reconstr Surg* 2000;**105**:2381–6.
11. Ensat F, Babl M, Conz C, Fichtl B, Herzog G, Spies M. Doppler sonography and colour Doppler sonography in the preoperative assessment of anterolateral thigh flap perforators. *Handchir Mikrochir Plast Chir* 2011;**43**:71–5.
12. Ogawa R, Hyakusoku H, Murakami M. Color Doppler ultrasonography in the planning of microvascular augmented "superthin" flaps. *Plast Reconstr Surg* 2003;**112**:822–8.
13. De Frene B, Van Landuyt K, Hamdi M, et al. Free DIEAP and SGAP flap breast reconstruction after abdominal/gluteal liposuction. *J Plast Reconstr Aesthet Surg* 2006;**59**:1031–6.
14. Smit JM, Dimopoulou A, Liss AG, et al. Preoperative CT angiography reduces surgery time in perforator flap reconstruction. *J Plast Reconstr Aesthet Surg* 2009;**62**:1112–17.
15. Bosc R, Fitoussi A, Pigneur F, Tacher V, Hersant B, Meningaud JP. Repérage des vaisseaux perforants par réalité augmentée: application au lambeau perforant d'arteère épigastrique inférieure profonde. *Annales de chirurgie plastique esthétique* 2017;**62**:336–9.