

Evaluation of the Intraoperative Blood Flow of Pedicled Perforator Flaps Using Indocyanine Green-fluorescence Angiography

Rafael G. Jakubietz, MD
 Karsten Schmidt, MD
 Silvia Bernuth, MD
 Rainer H. Meffert, MD
 Michael G. Jakubietz, MD

Background: Although indocyanine-green fluorescence angiography (ICG-FA) has been established as a useful tool to assess perfusion in free tissue transfer, only few studies have applied this modality to pedicled perforator flaps. As both volume and reach of pedicled perforator flaps are limited and tip necrosis often equals complete flap failure, ICG-FA may help to detect hypoperfusion in pedicled flaps.

Methods: In 5 patients, soft tissue reconstruction was achieved with pedicled perforator flaps. ICG-FA was utilized intraoperatively to visualize flap perfusion.

Results: Three pedicled anterolateral thigh flap flaps and 2 propeller flaps were transferred. ICG-FA detected hypoperfusion in 2 flaps. No flap loss occurred; in 2 cases, prolonged wound healing was encountered.

Conclusions: ICG-FA confirmed clinical findings and reliably detected tissue areas with hypoperfusion. A clear cut-off point between nonvital tissue and such that stabilized in the following clinical course could not be found. ICG-FA is a promising technology which could also be used in pedicled perforator flaps. (*Plast Reconstr Surg Glob Open* 2019;7:e2462; doi: [10.1097/GOX.0000000000002462](https://doi.org/10.1097/GOX.0000000000002462); Published online 30 September 2019.)

INTRODUCTION

The intraoperative evaluation of flap perfusion is essential to the success of tissue transfer.^{1,2} Despite flap survival, hypoperfusion at the tip or along the wound edges predisposes patients for delayed wound healing, tissue necrosis and sometimes requires a second flap.^{3,4} As this represents a major complication, considerable efforts have been undertaken to improve intraoperative assessment of peripheral flap perfusion, which often remains a highly subjective evaluation based on the surgeon's individual experience taking into account parameters such as capillary refill, turgor, flap temperature, and bleeding from the wound edges to variable degrees.² Objective methods like thermography, laser-assisted Doppler flow measurement, or tissue oxygenation have been proposed but have not become widely accepted in the clinical setting for numerous reasons.² In recent years, indocyanine-green fluorescence angiography (ICG-FA) has evolved considerably making it cost-effective and simple to use in

the clinical setting.^{2,5-7} In autologous breast reconstruction with microvascular-free flaps, ICG-FA has helped to reduce postoperative fat necrosis by allowing visualizing the extent of critically perfused areas intraoperatively which need to be resected.⁸⁻¹⁰ Only few reports utilizing ICG-FA in pedicled flaps exist.¹¹⁻¹³ In a pedicled flap, both the amount of tissue available for transfer and inset of the flap are limited. Contrary to a microvascular deep inferior epigastric artery perforator flap, the potential for intraoperative tissue resection at the margins is significantly limited as it reduces flap reach without any means of lengthening the vascular pedicle. Adequate perfusion of the tip of the flap is crucial as it often covers the most critical aspect of the defect. Similar to microvascular perforator flaps, ICG-FA may be useful in pedicled perforator flaps to assess perfusion. The aim of the study is to retrospectively evaluate our experience with ICG-FA to determine safe flap dimensions of pedicled flaps based on a single perforator intraoperatively.

MATERIALS AND METHODS

Data from patients who underwent soft tissue reconstruction with a pedicled perforator flap utilizing ICG-FA were reviewed retrospectively. Five cases from January to

From the Department of Trauma-, Hand-, Plastic- and Reconstructive Surgery, University Hospital Wuerzburg, Germany
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March 2019 were identified where clinical assessment of flap perfusion was supported by intraoperative ICG-FA. Preoperative flap planning consisted of marking potential perforators with a handheld Doppler device. After intraoperatively confirming the location of the perforator and its suitability to serve as a vascular pedicle, the flap was elevated completely and rotated into the defect. Besides clinical evaluation by means of capillary refill and tissue turgor, flap perfusion was assessed with real-time laser fluorescent angiography (Spy-PHI, Stryker, Mich.). Immediately after flap transfer, ICG was injected once in a standard dose (0.1 mg/kg) to visualize ingress of ICG into the flap and the distribution to its edges. Observation of the flap was continued over 4 minutes to evaluate egress of ICG. Tissue would be resected only when no perfusion could be confirmed clinically before flap inset. After suturing, skin grafts were used to close the donor site.

RESULTS

Five patients were included in our retrospective data analysis (Table 1). The mean follow-up was 4 months. Three patients presented with an unstable abdominal wall after tumor resection. In 2 of these patients, multiple attempts utilizing both local flaps and mesh repair or component separation failed previously and left patients with exposed abdominal contents (Figs. 1, 2). A pedicled anterolateral thigh (ALT) flap based on a single perforator including a part of the fascia lata was transferred in all cases. The flap was tunneled underneath the rectus femoris muscle. Two patients with soft tissue defects of the distal lower extremity received a perforator-based 180° propeller flap (Fig. 3). ICG-FA confirmed adequate perfusion of the flap in all cases. A decreased signal intensity characterized by a prolonged ingress and egress of contrast medium at the tip of the flap was noted in 1 ALT flap and 1 propeller flap (Figs. 4, 5). However, as the clinical evaluation revealed adequate bleeding from the wound edges in that area,

the tissue was preserved. Superficial epidermolysis resulting in prolonged wound healing by secondary intention occurred in these 2 patients. In 1 patient, a lymphocutaneous fistula at the donor site of the ALT flap healed with dressing changes within 3 weeks. No secondary operative interventions were required (Figs. 6–8).

DISCUSSION

ICG-FA can be regarded as a clinically established tool to assess tissue perfusion in reconstructive plastic surgery with distinct merits in autologous breast reconstruction.^{2,5,7–10} Although some studies have evaluated its application in visualizing the extent of perfusion in conventional pedicled flaps such as muscle flaps or the sural artery flap, little can be found regarding its value in pedicled perforator flaps based on a single perforator.^{11–13} Although the intraoperative use to confirm the position of perforators has been described, we see the potential benefit mostly in determining the peripheral perfusion of the harvested flap. Pedicled flaps represent a different entity as contrary to free flaps, only a limited amount of tissue with a limited reach is available. This presents a challenge to the reconstructive surgeon as no advancement of the flap is possible if ill-perfusion at the tip of the flap requires resection.¹⁴ Tip necrosis of a local flap often functionally equals a flap failure. Although wound healing complications in autologous breast reconstruction can often be managed conservatively, the tip of a local flap often covers the most vital structure and tip necrosis requires a second flap.¹⁵ In this study, no full-thickness tip necrosis was encountered. Despite ICG-FA showing reduced perfusion of the tip of 2 flaps, we chose to preserve the tissue as the clinical evaluation contradicted the ICG-FA result. In retrospect, the ICG-FA accurately delineated a tissue area which underwent superficial epidermolysis to heal by secondary intention. Although the intraoperative decision to preserve the tip was based on its clinical appearance, it also

Table 1. Demographic Data

Sex, Age	Etiology	Defect Location / Size	Comorbidities	Previous Reconstructive Measures	Exposed Structures	Flap Type, Dimension	ICG-FA Perfusion	Clinical Result
M, 72	Exulcerated squamous cell carcinoma bladder	Lower abdomen, 15 × 10 cm	Multiple sclerosis	Mesh reconstruction, NPWT	Colon, bladder	ALT, 20 × 10 cm	Normal tip perfusion	Complete survival
M, 65	Recurrence of urothelial carcinoma	Lower abdomen, 20 × 18 cm	Renal insufficiency, hypertension	Component separation, mesh reconstruction, local flap, NPWT	Colon, neobladder	ALT, 25 × 15 cm	Tip perfusion reduced	Prolonged wound healing
M, 45	Recurrence of dermatofibrosarcoma protuberans	Lower abdomen, 15 × 18 cm	None, prior radiation	Mesh reconstruction, NPWT	Mesh	ALT, 20 × 15 cm	Normal tip perfusion	Complete survival, lymphocutaneous fistula at donor site
M, 32	Open fracture, soft tissue loss	Proximal tibia, 10 × 15 cm	Smoking	NPWT	Fracture site,	Propeller flap, 30 × 8 cm	Tip reduced perfusion	Prolonged wound healing
M, 67	Open fracture, soft tissue loss	Distal tibia, 4 × 5 cm	PVD, prior recanalization	NPWT	Medial malleolus	Propeller flap, 15 × 5 cm	Normal tip perfusion	Complete survival

NPWT, negative pressure wound therapy; PVD, peripheral vascular disease.



Fig. 1. Abdominal wall defect with exposed mesh after multiple attempts of soft tissue reconstruction with local flap. Perforators marked preoperatively.



Fig. 2. ALT flap harvested on the proximal perforator. Pedicle is tunneled under the rectus femoris muscle to gain length.



Fig. 3. Propeller flap from the medial thigh harvested on a distal perforator to reconstruct a infrapatellar soft tissue defect. View before flap rotation.

must be acknowledged that the propeller flap remains a unique flap type of which we still have limited understanding regarding its perfusion.^{16,17} Twisting the pedicle alters flow dynamics, which is seen clinically by the often slow initial reperfusion after flap inset. This was confirmed in ICG-FA with a markedly slowed ingress and egress. A larger study assessing parameters such as transit times and signal intensity specific to this flap type is needed. Transit time was not utilized as a parameter in this study. This can be justified as this parameter has so far only been studied in free tissue transfer and is influenced by a myriad of parameters such as flap type, size, volume, and anatomic

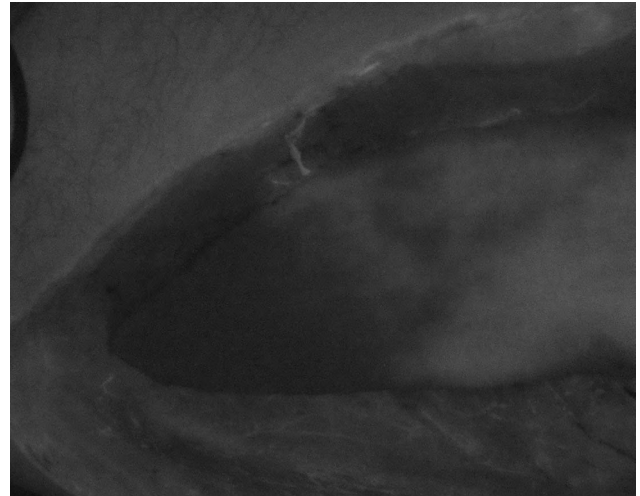


Fig. 4. ICG-FA of the tip of the ALT flap seen in Figure 2.

location.² We believe that the intensity measurement may be more helpful in pedicled perforator flaps. So far no threshold value differentiating between viable tissue and such bound for necrosis has been defined.^{2,18} Some studies show that values between 6.0 and 7.0 are indicative for a clinically relevant hypoperfusion of tissue progressing into tissue necrosis at a later stage.^{10,19} Contrary to this, the potential of “oversensitivity” for venous congestion of ICG-FA is well known.^{2,20} Despite initial venous congestion of tissue, subsequent recovery and stabilization of perfusion could be demonstrated on ICG-FA and tissue survival was confirmed clinically.²⁰ This exemplifies the difficulty to predict if hypoperfusion visible intraoperatively on ICG-FA automatically progresses into tissue necrosis and requires immediate resection of that tissue compartment. This perfusion recovery is supported by the concept of the choke vessel in perforator surgery.²¹ We therefore believe that rather than a simple threshold value, an intensity/time ratio may be more helpful, especially in flaps including indirectly connected perforasomes.²² In vascular surgery, ingress and egress around the maximum intensity are considered a helpful parameter.²³ We do not know the value of this parameter in flap surgery. Although its merit could be seen in the ALT group, the propeller principle requires twisting of the vascular pedicle which significantly affects both in and outflow. The ideal time of injection and evaluation of the ICG-FA remains unclear.¹⁸ When done immediately after harvesting the flap, potential choke vessels have not opened up sufficiently displaying a markedly reduced signal intensity. If the total flap extent is based on that measurement, a large amount of tissue is resected, that would be well perfused after engaging the choke vessels.^{18,20} As many questions cannot be answered by this study, we believe that further studies specifically evaluating ICG-FA are required before incorporating this technique as a clinical routine when harvesting pedicled perforator flaps. Ideally, a cut-off value could be established to differentiate between hypoperfused tissue progressing to complete tissue necrosis and areas which will stabilize over time. In pedicled perforator flaps,



Fig. 5. ICG-FA of the propeller flap seen in [Figure 3](#) after transposition of the flap into the defect. Note delayed perfusion in the tip of the flap found in the lower part of the picture.



Fig. 7. Final result 2 mo postoperatively.



Fig. 8. Superficial epidermolysis at the tip of the propeller flap seen in [Figures 3](#) and 5 1 wk postoperatively.



Fig. 6. Superficial epidermolysis of the ALT flap 2 wk postoperatively.

it is imperative to plan the flap dimensions larger than the defect to aid in positioning of the flap.^{4,16} If nonperfused zones of the flap extend beyond this and have to be excised primarily, no simple reconstructive alternative exists. Especially in traumatic soft tissue loss, nonviable tissue at the recipient site also must be considered.^{23,24} If perfusion at the tip is only delayed, a watch and wait approach seems reasonable as this tissue could potentially stabilize with time.²⁰ A delay procedure is only possible if the flap has not been elevated completely and should be avoided.¹¹ We believe that the application of ICG-FA may have value in pedicled perforator flaps in the future if a threshold value can be defined to differentiate tissue that will undergo necrosis from tissue that will recover over time. In this case, ICG-FA may reaffirm the surgeon intraoperatively to utilize a second flap immediately. This study has its weakness in the small number of cases included. ICG-FA is not always used at our institution when pedicled perforator flaps are used for soft tissue reconstruction. It is possible that only in cases where the potential for trouble regarding size and perfusion of a pedicled perforator flap had been recognized beforehand, the surgeon chose ICG-FA as a tool to guide in the intraoperative decision

process. This may have led to a sampling bias. At least in 1 case of a propeller flap, the flap dimension may have been too narrow, which could have caused hypoperfusion by undue tension during flap inset.

CONCLUSIONS

ICG-FA can be valuable in assessing the perfusion of pedicled perforator flaps intraoperatively by delineating areas with decreased perfusion. When the clinical findings such as adequate bleeding from the wound edges contradict this information, tissue resection may be withheld to allow stabilization of perfusion. As pedicled flaps do not allow significant tissue resection, it is imperative to plan flaps larger than the defect.

Rafael G. Jakubietz, MD

Department of Trauma-, Hand-,
Plastic- and Reconstructive Surgery
University Hospital Wuerzburg
Oberduerrbacherstr. 6
DE-97080 Wuerzburg, Germany
E-mail: jakubietz_r@ukw.de

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