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Case Report

The use of indocyanine green angiography in arterialized-venous free flaps: Case report and insight into flap vascular physiology[☆]

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ABSTRACT

Arterialized venous flaps (AVFs) are an innovative option in hand reconstruction. Their exact vascular physiology and survival mechanisms remain unclear. We report on two hand reconstruction cases with AVFs. Indocyanine green laser angiography was used to assess vascular perfusion of the flaps. A notable change in flap perfusion was seen by 48 h post-operatively with normalization of shunting and progression to a diffuse perfusion pattern resembling traditional flaps. Flap survival was attributed to reversed shunting at the microvascular level occurring within the first 48 h post-operatively.

Introduction

Free tissue transfer remains a challenge in reconstructive hand surgery. The need for thin and pliable skin limits the choice of potential donor sites.[1] Arterialized venous flaps (AVFs) present several

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Figure 1. Squamous cell carcinoma of the right middle finger with margins and superficial dorsal veins outlined (left). The full-thickness deficit after excision (middle). The design of the flap is shown on the volar aspect of the wrist (right).

advantages: great flexibility in design, minimal donor site morbidity, no major artery harvested, and an easy suprafascial dissection.[2–5]

AVFs have remained unpopular due to their tendency to develop venous congestion and flap necrosis.[1,3–10] Literature reports have proposed hypotheses with regards to survival mechanisms, yet their physiology remains unclear.[1–5]

Indocyanine green (ICG) laser angiography (SPY Elite, Stryker) is a valuable asset in microsurgery. It provides real-time assessment of tissue perfusion and improves perioperative management of flaps.[6]

We report on the use of ICG laser angiography intra-operatively and at 48 h post-operatively in two cases of AVFs for hand reconstruction. Clinical examination of flaps was compared to ICG angiography findings at the various timepoints to clarify vascular physiology. Written consent was obtained for both patients.

Case 1

A 53-year-old patient underwent excision for a recurrent squamous cell carcinoma (SCC) on the dorsum of the proximal phalanx of his right middle finger resulting in a 3.5 cm deficit (Figure 1).

The flap was harvested from the ipsilateral distal volar forearm, centered over a rich venous network including three proximal and four distal veins, using a mixed pattern perfusion as described by Woo et al. (Figure 1).[1,7] A small afferent vein was selected for arterial inflow and larger efferent veins were selected in order to favor venous return. The flap also included additional drainage veins that are discontinuous to the central afferent for the same reasons.

The flap was transferred to the defect and end-to-end microanastomoses were performed. The small proximal afferent vein was first anastomosed with the radial digital artery. A total of three efferent veins were microanastomosed with two distal and one proximal recipient veins. Immediate flow was noted in the arterialized vein and the two distal efferent veins. No immediate outflow was observed in the proximal efferent vein. The AVF showed a pale coloration and a subtle capillary refill (Figure 2). Intraoperative ICG angiography showed direct luminal shunting from the arterialized afferent vein into its two distal efferent veins, without perfusion of the ulnar flap (Figure 2). Donor site closure was performed using a split-thickness skin graft.

On the first postoperative day, the flap was pale, poorly turgescent, and capillary refill was present on the radial side only. A hand-held doppler detected normal signals in both afferent and efferent veins. On the second day, its appearance had considerably changed. It was pink, turgescent, and showed normal capillary refill on its entire surface (Figure 2). ICG angiography revealed complete perfusion with absence of the previously observed arteriovenous shunting (Figure 2).

Figure 2. Flap inset following microanastomosis (upper left). Intraoperative SPY indocyanine green imaging showing direct luminal shunting from the arterialized afferent vein into its two distal efferent veins (upper right). AVF showing a pink coloration and fully turgescent on postoperative day 2 (lower left). The AVF showing complete perfusion of its entire surface measured by SPY angiography on day two (lower right).

During follow-up, the flap was completely viable, showed great color and texture match and, the donor site healed inconspicuously. The patient recovered full range of motion and resumed full activities within 2 weeks.

Case 2

A 52-year-old patient presented an enlarging 2.4 × 1.7 cm subcutaneous hemangioendothelioma of the right thenar eminence and underwent tumor excision. The full-thickness deficit measured 3 × 6 cm (Figure 3). Two palmar veins were dissected proximal to the defect. A segment of the radial

Figure 3. Hemangioendothelioma of the right thenar eminence with margins outlined (left). The full- thickness deficit after excision (middle). The design of the flap is shown on the volar aspect of the wrist (right).

digital artery of the index finger was resected with the tumor. The proximal and distal ends of this artery were dissected.

The AVF was harvested in a similar fashion to Case 1. The flap's proximal afferent vein was anastomosed with the proximal radial digital artery, and a distal efferent vein was anastomosed with the distal end of the artery. Two additional non-contiguous efferent veins were microanastomosed with two proximal recipient veins. Intra-operatively, the AVF was pale with subtle capillary refill (Figure 4). A palpable arterial pulse was detected directly overlying the flap. Intraoperative ICG angiography showed direct shunting from the arterialized afferent vein into its distal efferent vein, with only the proximal part of the flap perfused (Figure 4). The donor site was closed primarily.

On the first postoperative day, the flap had a purple hue, a brisk capillary refill, and was highly turgescent. A palpable arterial pulse was still detected. On the second postoperative day, the flap color was similar, but the capillary refill had slowed down to 2 s. ICG angiography was repeated. No shunting was observed, and the flap was entirely perfused (Figure 4).

During follow-up, the flap remained viable, and the donor site healed inconspicuously. The patient achieved full range of motion and returned to normal activities within a month.

Discussion

AVFs are an excellent alternative to conventional free flaps with survival rates greater than 97%.[7–9] The original classification was expanded by including those with afferent arterial flow to mitigate the poor survival rates of pure venous flaps, attributed to low oxygen concentrations of the afferent venous blood supply.[2,3,5,7] Congestion of these flaps is largely due to a high-pressure flow into thin-walled veins with limited intrinsic flow regulation ability. Lower resistance of the efferent flap outflow would allow for preferential blood flow through the arterio-venous shunt bypassing the peripheral vasculature. Subsequent equilibration of afferent and efferent pressure exceeding that of the peripheral tissue prevents drainage and results in flap congestion.[10] Proposed survival mechanisms include reversal of venous flow in capillaries, a vascular thoroughfare channel between arterioles and venules, plasmatic imbibition and neovascularization.[1,2,9]

The authors believe that maximizing the number of venous anastomoses, utilizing retrograde flow across valves, and designing the flap over an extensive venous network has the greatest impact on flap survival. As demonstrated by ICG angiography, this report shows a drastic change in the perfusion pattern of the AVF, with disappearance of the initial shunt and appearance of a diffuse vascularisation through peripheral tissues similar to classic free flaps within 48 h. The authors believe this goes to show that plasmatic imbibition may participate in the early process of flap survival but is certainly not the main mechanism responsible for its viability. Also, given the rapid timeframe in which perfusion changed, neovascularization can doubtfully be involved in the short-term. The authors support that

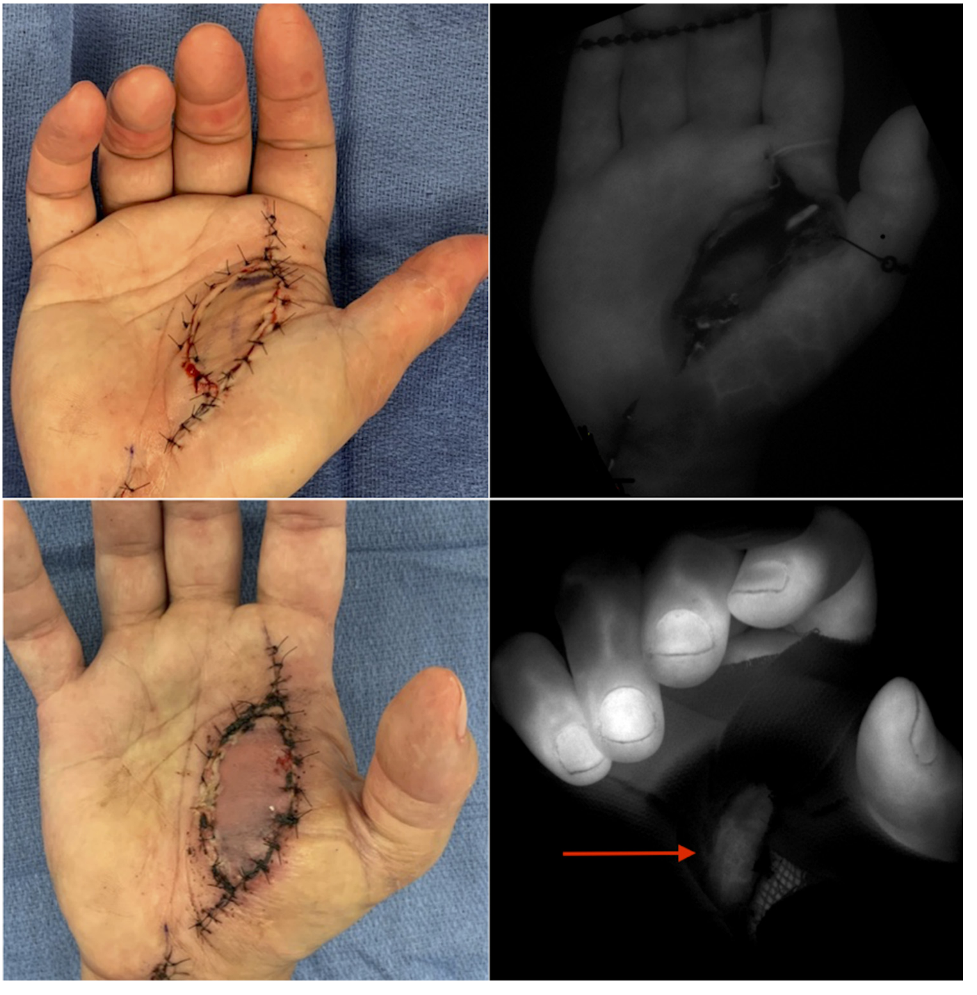

Figure 4. Flap inset following microanastomosis (upper left). Intraoperative SPY indocyanine green imaging showing direct luminal shunting from the arterialized afferent vein into its distal efferent vein (upper right). The AVF on post-operative day 2 (lower left). SPY angiography on post-operative day 2 showing perfusion of the flap over its entire surface. Red arrow indicates flap in thenar eminence (lower right).

survival of these flaps is largely dependent on restricted vascular inflow creating a higher-pressure gradient proximally, which subsequently favours the opening of shunts between venules and arterioles. Restricted inflow was accomplished by utilizing retrograde flap design against venous valves, and preferentially selecting small afferent and large efferent veins. While others have advocated for central vein ligation, studies have yet to establish which technique is superior.[10] Furthermore, flap design over a rich vascular network, with non-contiguous efferent veins, should result in increased opening of microvascular shunts and drainage towards low pressure gradient efferent veins.

Conclusion

This report describes two cases of hand reconstruction using AVFs. Perioperative use of ICG laser angiography was used to clarify vascular physiology. Perfusion patterns changed during the first 48 h with disappearance of arteriovenous shunting and installation of a pattern resembling traditional free flaps. Authors hypothesize that flow reversal with opening of microvascular shunts between venules and arterioles is responsible. Future studies plan to use sequential ICG angiography in AVF monitoring at multiple time points, up to 2 weeks post-operative, to draw firm conclusions. Further understanding of flap vascular remodeling will allow for improved flap design and reliable outcomes.

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Ethical approval

Approved by the IRB at Maisonneuve-Rosemont Hospital

Patient consent

Written consent obtained.

Declaration of Competing Interest

None.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jpra.2022.02.010.

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