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Office-based indocyanine green fluorescent angiography for surgical planning of pedicled flap division

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Abstract

Delayed pedicled flaps are a reliable reconstructive tool for limb salvage. Determining the optimal timing for pedicle division is critical for surgical success and minimizing complications. Assessment of optimal timing has traditionally relied on arbitrary timing or subjective measures. This study explores the use of indocyanine green (ICG) angiography in the office setting as an objective guide for timing the delayed pedicled flap pedicle division, aiming to improve surgical outcomes and resource efficiency. In the outpatient setting, ICG is administered intravenously while the flap pedicle is under tourniquet control. If the distal flap opacifies with the tourniquet still applied, appropriate revascularization has occurred, and the pedicle may be safely divided. We present the example of a 47-year-old male with multiple previous flap reconstructions who eventually required a reverse sural artery flap. Initial intraoperative ICG imaging on postoperative day (POD) 23 revealed insufficient perfusion, prompting the postponement of pedicle division. Subsequent office-based imaging on POD 47 revealed a persistent lack of neovascularization. Adequate vascularization was demonstrated on POD 81, enabling successful pedicle division in the operating room on POD 121 without complications. ICG fluorescent angiography can guide the timing of division for delayed pedicled flaps. We recommend its use in the outpatient setting to decrease unnecessary operating room usage and anesthetic events and reduce the risk of wound healing complications from early pedicle division.

Keywords: Flap delay, ICG, indocyanine green, reverse sural flap, limb salvage, delayed pedicled flap

INTRODUCTION

Pedicled flaps with delayed division are one of the oldest known techniques in reconstructive surgery, dating to over 2,000 years ago in India[1]. Gustavo Branco first used the technique in Renaissance Italy, and Gaspare Tagliacozzi published it, hoping to promulgate its use. The delayed pedicled flap was reintroduced to Europe by Joseph Carpue centuries later[2]. It reached its peak in the "walking" flaps described by Shrady[3] and Halsted, and immortalized by Harold Gillies[4].

The timing of flap division has been the subject of discussion as long as delayed pedicled flaps have been used. Three to six weeks is often described as a "usual" timeframe[5]. Still, the neovascularization of a delayed pedicled flap may vary substantially depending on patient factors and the characteristics of the wound bed. Detailed animal and clinical studies in the 1950s suggested that flap pedicles could be safely divided at 2 weeks, but the authors also advocated confirmation using elaborate thermal measurement methods[6]. The flap may be assessed using clinical criteria such as color, temperature, turgor, and visualization of capillary bleeding, but these are all subjective and may give false confidence if the flap is congested rather than arterially insufficient. Finally, the decision to postpone pedicle division may be made in the operating room - costing time, hospital resources, and the patient's unnecessary exposure to an anesthetic. We present the novel use of indocyanine green (ICG) imaging to define the timing of delayed pedicled flap pedicle division.

Previous reports describe the use of intra-operative ICG imaging to confirm the safety of pedicled flap division within the conventional timeframe[7] and to inform the decision to delay pedicled flaps after elevation but before rotation and inset[8]. In this note, we demonstrate the ability of ambulatory, awake ICG angiography to guide the course of surgical planning and to prevent both surgical complications and waste of resources and time.

TECHNIQUE DESCRIPTION

The goal of this technique is to objectively define the optimal timing of delayed pedicle flap division. It may be performed in various settings, including the office, the preoperative area, or the operating room. Among these, the office setting is most advantageous as it facilitates surgical planning, enhances efficiency, and optimizes resource utilization.

The pedicled flap should be imaged three weeks after the transfer of the pedicle flap, or when the flap has been deemed ready for division based on empirical evidence or physical examination. Any near-infrared ICG fluorescent imaging system, including SPY-PHI (Stryker), PDE-NEO (Hamamatsu), or others, may be utilized. A peripheral intravenous (IV) catheter is placed for the systemic administration of the dye and is removed immediately following the imaging procedure. A tourniquet is applied to the flap pedicle in a manner that allows for easy removal during imaging. The technique of lower extremity ICG imaging described by Wilke was followed[9]. Three mL of reconstituted ICG (2.5 mg/mL in sterile water) is injected into the IV line, followed by a 10 mL saline flush. The pedicle and flap are then examined within 3 min of instilling the solution using the selected imaging system.

If the distal portion of the flap does not opacify with the tourniquet applied, the flap has not yet been revascularized via the wound bed and is not ready for division. This observation can be confirmed by removing the tourniquet and noting the opacification of the distal portion of the flap via the pedicle. Conversely, if the distal flap opacifies while the tourniquet is applied, the pedicle may be safely divided. If there is ambiguity, quantification may be performed using imaging software provided by the manufacturer.

Of note, although allergic reactions to ICG are extremely rare (1:42,000-1:62,000)[10], allergy testing and consultation with an allergist are recommended for patients with a documented allergy to iodine or iodinated contrast media. Further, any setting in which ICG is used should have antihistamine and epinephrine autoinjectors available. Contraindications to ICG use include allergic asthma, closed-angle glaucoma, hepatic failure, renal failure, and pregnancy.

CASE STUDY 1

A 47-year-old man sustained a right distal tibia and fibula fracture after a motorcycle collision. Following two unsuccessful free flap procedures for wound breakdown and hardware exposure, a cross-leg flap was ultimately used for definitive closure. However, re-elevation of the flap was necessary for debridement of osteomyelitis and removal of infected hardware. Due to scarring, swelling, and poor vascularization, additional vascularized soft tissue was required for coverage. A reverse sural fasciocutaneous flap was elevated, rotated, and inset [Figure 1].

On postoperative day (POD) 23, the patient was taken to the operating room for pedicle division. ICG imaging [Figure 2 and Supplementary Video] revealed a lack of perfusion via the wound bed to the flap [Figure 2A] more than 30 s after the surrounding tissue was fully opacified, which resolved when the pedicle tourniquet was removed [Figure 2B]. Given the slow progress of the delay phenomenon on initial evaluation, it was decided to re-image in the office before scheduling flap division surgery again to optimize the allocation of resources. Re-evaluation with the same technique on POD 47 again revealed insufficient flap neovascularization. On POD 81, the flap was imaged again. The flap was fully perfused compared to the surrounding tissue within 30 s under tourniquet control, clearly revealing that adequate vascularization was achieved [Figure 2C]. The patient underwent division of the flap pedicle on POD 121 without further imaging [Figure 3A]. The flap healed well with no complications [Figure 3B]. Seven months after flap division, the patient is able to wear normal footwear and ambulate without assistance [Figure 3C].

CASE STUDY 2

A 38-year-old morbidly obese female presented with calcaneal osteomyelitis and a complicated overlying wound as a result of complications from calcaneal osteotomy. She underwent debridement of the calcaneus and overlying tissue, requiring durable vascularized soft tissue coverage. Given her comorbidities, body habitus, and location of the wound, a fascia-only reverse sural flap with split-thickness graft was performed. On POD 34, office-based ICG fluorescent imaging revealed the flap to be well perfused within 30 s, while a tourniquet was applied to the pedicle. There was no significant change in opacification after removing the tourniquet and it was determined that the flap was ready for division. Division and inset were completed on POD 39 with no complications.

DISCUSSION

ICG near-infrared angiography is a well-established technology in the evaluation of tissue perfusion and has demonstrated superiority to clinical assessment in multiple surgical fields[11-13]. Because ICG fluoresces at a peak 830 nm wavelength, the signal can be detected through up to 15 mm of tissue[14]. While clinical evaluation has been traditionally used to evaluate delay flaps for division, the tourniquet effect may lead to ambiguity when assessing the bleeding from raw surfaces: pooled blood within the flap may appear to represent adequate bleeding, or mild but appropriate venous congestion may be interpreted as a signal to defer pedicle division.

Figure 1. Flap in place before division.

In our case, the adequately perfused areas of the flap were easily discernable to the casual observer compared to non-perfused areas. When this is not the case, quantitative measurement of ICG fluorescence can aid in decision making for flap perfusion. Moyer *et al.* used ICG to predict skin flap viability by quantifying tissue perfusion[15]. Through Gaussian Modeling, it was determined that a cutoff perfusion of 33% (*vs.* normal, surrounding skin) indicated viable skin with a sensitivity of 84.6% and a specificity of 87.5%. SPY-PHI includes software for perfusion quantification of areas of interest compared to normal surrounding tissue. The surrounding normal tissue is targeted by the user with the handpiece, and a timer is automatically started once the system detects perfusion. After a set period of time, the fluorescence assessment window begins and the normal tissue perfusion is assessed and assigned a value of 100%. The area of interest may then be targeted to quantify its perfusion as a percentage of the normal area's perfusion. Combining tissue viability prediction models with quantitative software tools can provide objective guidance to the surgeon in situations with ambiguous subjective interpretations.

In addition to the units used in the operating room, our center has a SPY-PHI unit, which is normally used in the office for lymphatic mapping. If a unit is not available in the office and cannot be brought from the operating suite to the office, an alternative option is to bring the patient to the preoperative area of the operating suite and perform imaging there. Although this may be more resource-intensive than office imaging, it still avoids unnecessary anesthesia and costs for the patient and hospital.

Other authors have used this technology in the assessment of delayed pedicled flaps. Christensen *et al.* used ICG to confirm appropriate perfusion in flaps that could not be accurately confirmed using clinical criteria[7]. In doing so, they were able to confirm vascular perfusion and divide the pedicle sooner than clinical examination would suggest. Lee *et al.* used fluorescence angiography to evaluate perfusion in head and neck locoregional flaps[8]. Flaps with poor perfusion based on their testing were instead de-rotated and

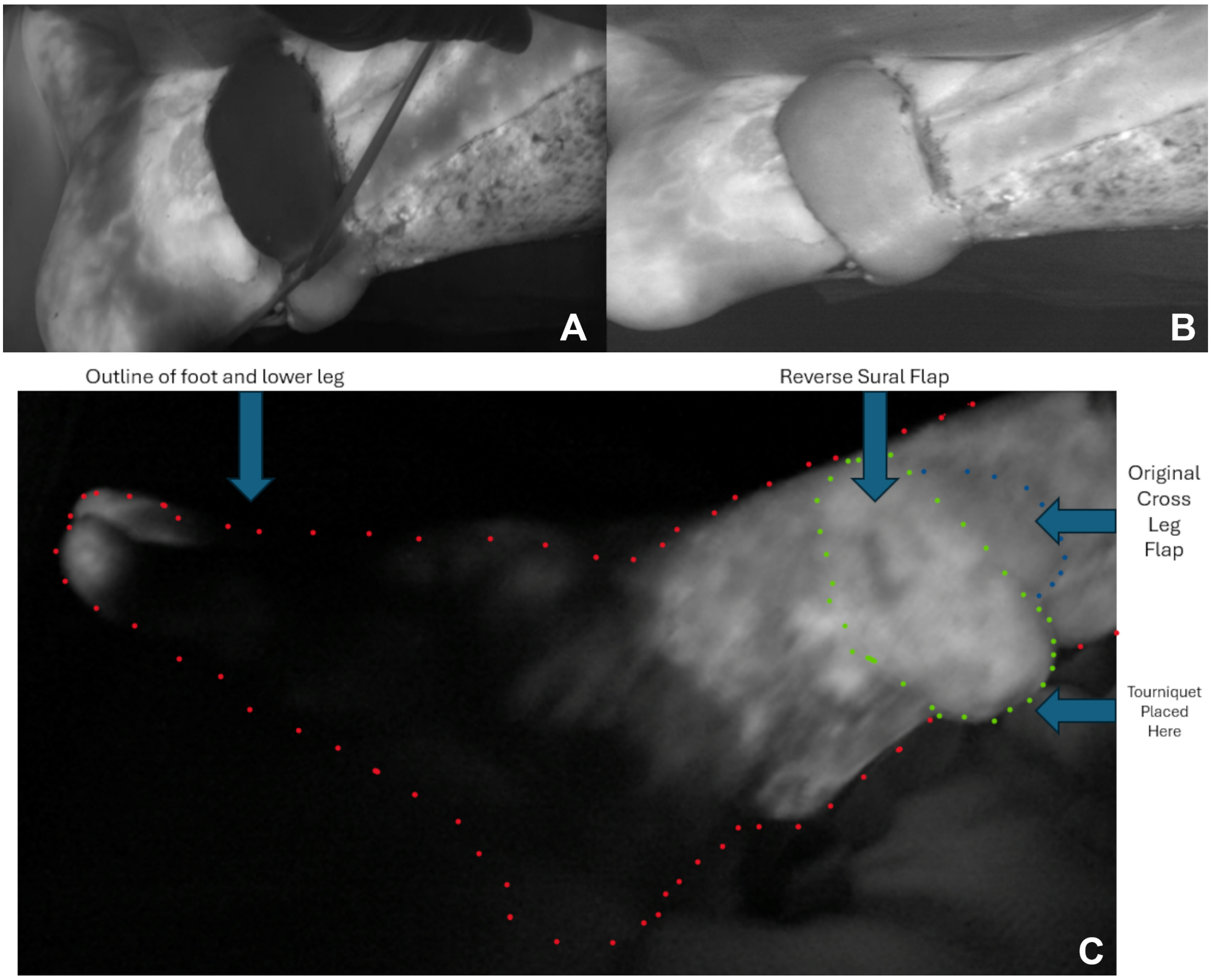

Figure 2. Indocyanine images of flap (A) at postoperative day 23 with tourniquet in place, demonstrating absent neovascularization of flap despite opacification of surrounding tissue and flap pedicle, (B) with reperfusion of flap after tourniquet release, (C) at postoperative day 81 with tourniquet in place and adequate perfusion.

delayed for 3 weeks before rotation and inset.

Both prior reports described the intra-operative use of ICG imaging. In our first case, we began with intra-operative imaging and followed up with office-based imaging after our initial findings. In light of our experience, we suggest routine use of office-based imaging as a prerequisite to scheduling pedicle division in cases of questionable flap recipient beds. Compared with an average $46 per min cost of operating room time[16,17], ICG costs around $200 per vial [18]. Thus, office-based assessment has the potential to conserve valuable operating room time and resources. If ICG is not available in the office setting, it may still be performed in a peri-operative area to avoid an unnecessary anesthetic.

CONCLUSIONS

Office-based ICG fluorescent angiography can guide the timing of division for delayed pedicled flaps. We recommend its use to decrease unnecessary operating room usage and anesthetic events, and reduce the risk of wound healing complications from early pedicle division.

Figure 3. Flap after division (A) before inset, (B) on-table results, and (C) at seven months postoperatively.

DECLARATIONS

Authors' contributions

Contributed to the conception, design and interpretation of the study: Van YR

Contributed to data interpretation, conception, design, and interpretation, as well as providing administrative, technical, and material support: Brazio PS

Contributed to data interpretation, as well as providing administrative, technical, and material support: Almadani H

Availability of data and materials

Not applicable.

Financial support and sponsorship

None.

Conflicts of interest

Brazio PS is a Junior Editorial Board member of *Plastic and Aesthetic Research*, while the other authors have declared that they have no conflicts of interest.

Ethical approval and consent to participate
Patient consent was collected for the photographs and the publication of related materials. It was determined that approval from an institutional review board was not required.

Consent for publication
All photographs were collected by the authors and the subjects gave their consent for publication.

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