CASE REPORT

Is indocyanine green angiography a reliable tool for the assessment of venous congestion in muscle flaps?

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Abstract: Indocyanine green (ICG) angiography is a useful technology for assessing flap perfusion in reconstructive procedures. Flap clearance of ICG can help in assessing venous congestion. To the best of our knowledge, although a few reports have evaluated its use for venous congestion, no reports have assessed the viability and applicability of this technology for this purpose in muscle flaps. A 63-year-old female patient with right leg leiomyosarcoma post-tumor resection underwent reconstructive surgery with a hemi-gastrocnemius flap. A scan of the flap using ICG angiography showed slow clearance of dye in the flap compared to the rest of the body. On postoperative day (POD) 1, the flap was re-examined using an infrared camera and it showed evidence of retained dye. On the contrary, there were no clinical signs of flap congestion. Ultimately, the patient had a successful reconstruction and an uncomplicated postoperative course despite the inconsistent findings in ICG angiography. ICG angiography is a useful tool in assessing arterial perfusion of flaps. However, further evaluation is needed to gain clinical reliability and validity in the evaluation of venous congestion in muscle flaps. Its overall utility with respect to pedicled muscle flaps has yet to be established.

Keywords: muscle flap; pedicled flap; free flap; indocyanine green angiography

Introduction

Flap compromise due to inadequate blood perfusion or congestion is a common complication in reconstructive procedures[1-3]. Arterial compromise or severe venous congestion can disrupt wound healing and is secondary to decreased oxygenation, nutrient supply and removal of metabolic wastes. In cases of non-self-limiting venous congestion, it can lead to partial or total flap ischemia. Consequently, prompt detection with intraoperative or early postoperative intervention is important in reducing complications[4-6].

Clinical assessment (monitoring flap color, temperature, capillary refill, Doppler signal, etc.) is the most commonly used method for flap assessment. However, the clinical judgment is subjective and largely observer-dependent. As a result, reconstructive surgeons have been actively seeking for a more objective method of assessing flap perfusion. Several methods have already been utilized in an attempt to achieve this goal. These include continuous polarographic tissue oxygen tension monitoring, laser Doppler flowmetry (LDF), tissue pH monitoring and indocyanine green (ICG) near-infrared video angiography[7-15].

ICG angiography has popularly become a commonly used technique to measure vascular perfusion of flaps. ICG angiography enables the surgeon to quantify perfusion throughout the flap, and patency of the pedicle[16-19]. Recent studies have shown that a perfusion cut-off can predict the likelihood of flap survival, and supplement clinical judgment for flap design and the need for trimming in both muscle and fasciocutaneous flaps[13,14,18].

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Venous congestion can also be assessed using ICG angiography by measuring the rate of dye clearance from the flap\(^{20}\). However, few studies have evaluated the appropriate technique, cut-offs, sensitivity and reliability of this method\(^{21,22}\). To date, no available studies have assessed the difference between fasciocutaneous flaps and muscle flaps using this technology. In this case report, we documented a prolonged ICG clearance in a muscle flap with no presence of clinical congestion or complications.

**Methods**

The SPY Elite imaging system (Novadaq Technologies Inc., Florida, USA) utilizing ICG angiography was used to visualize flap perfusion. ICG binds to plasma proteins in the intravascular space and circulates throughout the intravascular volume. The plasma half-life of ICG is 3–5 min\(^{19}\). This pharmacokinetic property allows rapid dye clearance and can theoretically indicate venous congestion if ICG clearance is diminished.

SPY Elite technology uses a near-infrared laser and high-speed camera to visualize ICG fluorescence. After the administration of ICG, the compound absorbs photons at 806 nm, thus exciting ICG electrons which emit photons at a lower energy and longer wavelength. The camera then captures the emitted photons\(^{15,20}\).

ICG angiography used in this case was performed per SPY Elite protocol with 3 mL dose of ICG solution (ICG 2.5 mg/mL in saline diluent) administered intravenously. The flap perfusion was directly assessed after 30 seconds using an operative camera.

**Case presentation**

A 63-year-old female patient with a significant past medical history of cigarette smoking, marijuana use and hypertension, presented a biopsy-proven right proximal leg leiomyosarcoma. The patient underwent wide local excision with a defect measuring 14 × 7.5 cm with exposed tibia (Figure 1). Her defect was reconstructed with a medial hemigastrocnemius muscle flap with split-thickness skin graft (STSG) (Figure 2 and Figure 3). Intraoperatively, the muscle flap was assessed with ICG angiography using the SPY Elite apparatus. Angiography was performed prior to inset, using the above-mentioned protocol of SPY Elite. The flap showed appropriate perfusion with no perfusion defects or concerns. Yet, ICG clearance was noted to be sluggish in the flap.

The flap was inserted into the wound defect and ICG angiography was repeated. However, prior to administering a second dose of ICG, retained dye was noted within the muscle. Nonetheless, as the flap showed no clinical signs of congestion, it was deemed unnecessary to trim or re-insert.

On postoperative day (POD) 1, the flap remained viable. There were no signs of congestion and there was complete adherence of the STSG (Figure 4). An additional SPY Elite scan of the flap was performed on POD 1. The baseline scan before ICG injection once again showed retained dye within the flap. Post-dye administration scan showed a well-perfused flap. The patient’s
flap continued to show excellent perfusion clinically. She was discharged on POD 3 after an uncomplicated course. The patient’s last follow-up appointment was six months after surgery and the flap healed without complications (Figure 5).

Discussion

This case demonstrated that muscle flaps covered with split-thickness skin grafts and no skin paddle can be easily assessed for arterial perfusion using ICG angiography. Additionally, this case exhibited a previously unknown problem with ICG clearance seen directly in a muscle flap. This problematic finding could create a clinical dilemma as the muscle flap congestive state may be misinterpreted. Despite the clinical use of ICG angiography to assess venous congestion, there have been no reports in literature to support its reliability in assessing congestion in muscle flaps.

In the gastrocnemius flap case report, clinical observation of flap behavior seemed to provide the most reliable information, upon which the decision of no surgical intervention was safely made. This continues to be consistent with the reported literature regarding assessment of venous congestion in flaps\(^5\). ICG angiography is a reliable technique in assessing tissue perfusion. However, its predictive value, data analysis and interpretation techniques are still under evaluation \(^7,14,16,17\).

ICG angiography over-predicts venous congestion in flaps\(^21\). The presence of retained dye, up to 24 h postoperatively in this case, can be attributed to one of two factors. First, ICG angiography could have detected venous congestion that was self-limiting or subclinical, which did not require any intervention to resolve. Second, ICG dye could be retained more in muscle flaps than in fasciocutaneous flaps, which can be the result of extravasation of the dye in surrounding soft tissue, or due to some other unknown factors.

The phenomena of self-limited venous congestion can be explained by delayed venous dilatation. During harvest and inset, frequent flap tissue manipulation and handling results in initial physiological vasospasm that later subsides. Pedicled muscle flaps are known to undergo microvascular remodeling in the immediate postoperative phase, which could also contribute to the retained dye seen in the first day after surgery \(^22\). However, the presence of ICG dye 24 h after the procedure cannot be easily explained by this phenomenon.

The retained dye could also be explained by the extravasation of ICG material from intravascular system into the extravascular tissue of the flap. Although the half-life of ICG in plasma is 3–4 min, its half-life in the extravascular system can be significantly longer. Muscle flaps have more raw surface area than fasciocutaneous flaps, and could possibly explain why the dye was retained longer in the muscle compared to what is usually seen in fasciocutaneous flaps.

To support our finding, we imaged 4 muscle flaps (3 pectoralis major flaps and 1 gastrocnemius flap) 30 min after harvest. All 4 flaps had variable degrees of retained dye compared to fasciocutaneous tissues in the immediate area, in which the dye had cleared within 30 min of injection (Figure 6).

Figure 6 Images (A) and (B) displayed two pectoralis major flaps with retained ICG dye 30 min after intravenous administration
Conclusion

ICG angiography is an excellent supplemental technology for the assessment of flap arterial perfusion, both intraoperatively and postoperatively. However, ICG clearance is not a reliable method to assess venous congestion in muscle flaps due to the evidence of prolonged dye retention. Further studies are needed to evaluate its application, sensitivity and reliability, before it can be used to influence clinical decision-making.

Conflict of interest

The authors declared no potential conflict of interest with respect to the research, authorship, and/or publication of this article.

References


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