Intraoperative Laser-Assisted Indocyanine Green Imaging for Objective Measurement of the Vascular Delay Technique in Locoregional Head and Neck Flaps

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IMPORTANCE Reconstruction of oncologic or traumatic head and neck defects often requires complex planning of locoregional, pedicled, or interpolated flaps. In cases with a higher risk of flap failure, vascular delay with staged reconstruction can help improve tissue perfusion and increase chances of flap survival. An objective tool is needed to help guide reconstructive surgeons with the intraoperative decision to pursue vascular delay.

OBJECTIVES To describe a pilot study using a novel application of a technique that quantifies and validates the benefit of the vascular delay procedure in locoregional flaps and to demonstrate a practical and broadly applicable technology that can be easily incorporated into intraoperative decision making and improve outcomes for high-risk flaps.

DESIGN, SETTING, AND PARTICIPANTS A pilot study using intraoperative laser-assisted indocyanine green imaging measurements and fluorescence videos to objectively measure the benefit of vascular delay procedures in patients with head and neck defects and wound healing risk factors requiring locoregional flap reconstruction at an academic tertiary care center.

MAIN OUTCOMES AND MEASURES Intraoperative laser-assisted indocyanine green imaging with video documentation and quantitative measurements was used to evaluate flap perfusion before a vascular delay procedure. Measurements were repeated after a 3-week vascular delay procedure.

RESULTS Two patients were identified based on comorbid conditions that resulted in a higher risk of flap failure, as well as the need for a locoregional flap for reconstruction. At the initial elevation of the flap, quantitative results from flap imaging demonstrated low perfusion numbers and minimal fluorescence, suggesting poor tissue perfusion and increased likelihood of postoperative flap compromise or failure. Following a vascular delay of 3 weeks, repeat measurements were substantially improved. No wound healing issues were observed.

CONCLUSIONS AND RELEVANCE This is the first study to date to quantitatively demonstrate the benefit of the vascular delay technique in patients with potential vascular compromise in locoregional head and neck flap reconstruction. Data obtained suggest that this technology can be used to guide intraoperative decision making in complicated reconstructions and help optimize patient outcomes.

LEVEL OF EVIDENCE NA.
Traumatic and oncologic head and neck defects often require complex reconstructions, including locoregional flaps, pedicled or interpolated flaps, and free tissue transfer. The goal for reconstructive surgeons is to use the least invasive technique that will provide the best functional and aesthetic result. For every locoregional or pedicled flap, several potential risk factors exist that can compromise flap viability, including a history of smoking, prior radiation therapy, diabetes mellitus, previous surgery, and scarring.

For more complex cases, vascular delay procedures can be used to help increase the likelihood of flap viability. Delay procedures are thought to improve flap vascularity through ischemia-induced dilation of choke vessels, changes in tissue metabolism, and stimulation of neovascularization. These changes occur at the microvascular level and accordingly are unable to be assessed with traditional Doppler techniques.

Disadvantages of using a vascular delay procedure include the need for an additional operative procedure and added time until the defect is fully reconstructed. In the head and neck, these defects can often have substantial deleterious effects on quality of life such as loss of time from work and social activities until the defect is repaired. However, not performing a delay procedure when a patient requires it can be disastrous: flap loss in a patient with limited locoregional flap options typically results in having a less desirable local reconstructive option or committing the patient to free tissue transfer. These factors should be strongly considered when deciding how to proceed in reconstruction of a defect in a high-risk patient.

To date, no clear, objective criteria exist to help reconstructive surgeons determine which patients require delay procedures. Such decisions have historically been based on subjective, case-by-case criteria, with increased consideration for pursuing a vascular delay procedure in patients who harbor significant risk factors for poor tissue perfusion.

Laser-assisted indocyanine green (ICG) imaging is a novel technology that was recently approved by the US Food and Drug Administration for use in reconstructive plastic surgery procedures to help objectively evaluate perfusion and vascularity of various types of flaps. In the plastic surgery and reconstructive literature, a laser angiographic system (SPY Elite; LifeCell Inc/Novadaq Technologies) has been reported to be helpful for designing and altering perforator microvascular free tissue transfers and for assessing optimal timing for take-down of an interpolated flap. This technology is a useful and powerful adjunct to the traditional clinical assessment modalities of tissue perfusion, including capillary refill, flap color, and character of bleeding from the flap. Studies have described the use of the laser angiographic system in the management of these cases, often leading to a change in flap design to capture perforators, the removal of compromised tissue, or take-down of an interpolated flap earlier than clinical judgment would have otherwise dictated.

In addition to the above types of procedures, we have recently extended the application of intraoperative laser angiography to a new area of reconstruction, namely, predicting whether the delay procedure has resulted in sufficient neovascularization to improve chances of flap survival. To our knowledge, no studies have described the use of the laser angiographic system to objectively quantify changes in tissue perfusion induced by vascular delay techniques in locoregional flaps.

We describe a pilot study using a novel application of the laser-assisted ICG technique that directly influenced intraoperative management of patients requiring locoregional flaps, likely preventing loss of the flap or other associated complications. Two case examples are reported.

Methods

Study approval was obtained from The Johns Hopkins Medicine Institutional Review Board. Oral informed consent was obtained from the participants. Retrospective review was performed of patients in whom the laser angiographic system was used to predict the need for vascular delay. Two patients were identified based on comorbid conditions that resulted in a higher risk of flap failure, as well as the need for a locoregional flap for reconstruction.

Indocyanine green is a water-soluble tricarbocyanine dye contrast agent that is injected intravascularly through peripheral venous access. It binds to plasma protein in the blood, and the laser angiographic system is then used to measure the resultant fluorescence from the flap. The half-life of ICG is 150 to 180 seconds, with rapid hepatic metabolism and renal excretion. Spectral absorption peaks at 800 nm, and emission peaks at 835 nm within the infrared spectrum. Indocyanine green is contraindicated in patients with contrast dye allergy because of the risk of anaphylaxis, which has been reported in 1 in 42,000 patients. The overall dose of ICG dye should not exceed 1 mg/kg per case. Because of the hepatic metabolism and renal excretion, ICG dye is a relative contraindication in patients with poor hepatorenal function.

In our practice, the protocol for ICG angiography involves dilution of 10 mg/mL of ICG in 4 mL of normal saline. After the laser angiographic system is directed toward the flap, the anesthesia provider injects the reconstituted ICG intravenously, followed by a saline flush. Video recording begins immediately after the normal saline flush.

Intraoperative ICG images were evaluated using a software program (SPQ-Q; Novadaq Technologies Inc). The fluorescence of the selected area was measured on an absolute scale on a 255-level grayscale system, and a point value was assigned based on the gray scale that corresponded to the image signal intensity. Scores were reported from 0 to 250, with higher values representing superior perfusion and a value of 6.0 being the lower limit of acceptable perfusion.

Results

This study demonstrates a new, simple, and practical way to apply the laser angiographic system technology. It objectively and reliably predicts the need for vascular delay in real-time.
time and helps improve patient outcomes in difficult reconstructive cases.

Case 1
A 43-year-old woman with multiple recurrent basal cell carcinomas of the auricle required a total auriculectomy, lateral temporal bone resection, and adjuvant radiation therapy. She was seen in consultation for reconstruction and underwent a bone-anchored hearing aid and total auricular reconstruction in multiple stages. She had undergone a prior temporalis flap for mastoid obliteration, anotia reconstruction with autologous costal cartilage, and a radial forearm free flap for soft-tissue coverage. Unfortunately, she developed a wound infection and dehiscence, with exposure and resorption of the superior helical cartilage.

She provided informed consent for a modified temporoparietal fascial flap (TPFF) for coverage of the cartilaginous construct. During surgery, significant scarring was encountered, and a TPFF flap was elevated with a wide anteriorly based pedicle (Figure 1). The laser angiographic system with ICG imaging was used to evaluate perfusion to the TPFF flap, which demonstrated minimal perfusion (Figure 2). Based on the perfusion result, a decision was made to perform a vascular delay of the flap. After a vascular delay of 3 weeks, the flap was again elevated. The laser angiographic system demonstrated dramatically improved perfusion of the TPFF flap (Figure 3). The flap was then inset over the superior helical cartilage. After surgery, her wound healed uneventfully, without any dehiscence or necrosis.

Case 2
An 82-year-old man with years of significant sun damage from a prior skiing career and a history of multiple recurrent nodular basal cell carcinomas of the nose required a subtotal rhinectomy to achieve negative oncologic margins. The final nasal soft-tissue defect involved the columella, nasal tip, bilateral ala, and partial dorsal and lateral sidewall skin. Informed consent was obtained for repair with a soft-tissue interpolated flap. A large paramedian forehead flap was designed using a template from the defect. Given his low hairline and long midface, a standard paramedian forehead flap would incorporate a significant amount of hair-bearing skin into the nasal tip and columella. Therefore, a modified laterally angled partially random paramedian forehead flap was designed. The flap was elevated, and the laser angiographic system with ICG imaging was used to evaluate perfusion to the most superior portion of the flap. Minimal perfusion was demonstrated in the randomly perfused distal portion of this locoregional flap, and the decision was made to perform a vascular delay of the flap. The flap was delayed 3 weeks. After the delay, the flap was again elevated, and the laser angiographic system demonstrated dramatically improved perfusion of the flap. The flap was inset with additional composite auricular grafting and septal mucosal flaps.
for the cartilaginous support and inner mucosal nasal lining. After surgery, the flap remained viable, with no wound breakdown.

Discussion

The ICG fluorescence laser angiographic system initially received approval by the US Food and Drug Administration in 1957 and has been used for decades in specialties, including cardiology, ophthalmology, hepatology, and urology. In 2007, US Food and Drug Administration approval was granted for plastic surgery reconstructive procedures and has since been used mostly in designing perforator microvascular free tissue flaps.

Previous studies in the plastic surgery literature demonstrated good correlation between laser angiographic system perfusion results and clinical flap outcomes, especially in perforator free flaps. In 2002, Holm et al showed that intraoperative ICG-filling defects were always associated with delayed wound healing and that regions of clinical flap necrosis corresponded to regions of dye-filling defects. The laser angiographic system was updated in 2010, and this second-generation technology has demonstrated improved sensitivity of the laser over the prior technology.

The main benefit of this novel technology over Doppler and traditional methods to evaluate tissue perfusion is the ability to gain information on a microvascular level, which can be paramount to locoregional and random flap survival. In the past, traditional fluorescence angiography has not become well incorporated into the reconstructive surgeon’s practice with locoregional flaps, but several pharmacokinetic differences exist between the laser angiographic system and traditional fluorescence angiography that make it much more practical for a surgeon to incorporate into daily practice. Indocyanine green has a much shorter half-life, it binds efficiently to blood lipoproteins without significant diffusion into the interstitium, and the fluorescence is in the infrared range of 835 nm. All of these improvements lead to increased ease of use, with decreased time intensity, making it more practical to incorporate this technology into routine cases.

In the area of head and neck reconstruction, investigations of the laser angiographic system to date have mostly focused on free flaps, with 2 recent studies of interpolated flaps. To our knowledge, this is the first study of its use in the vascular delay technique for locoregional flaps. The 2002 study by Holm et al included a case of bilateral ulcers defects in the heels. One sural island flap was performed as a single stage, and the contralateral flap was performed after a 1-week vascular delay. The laser angiographic system imaging was compared for the 2 flaps, with significantly higher vascularity seen in the delayed local flap. This differs from our study in 2 significant ways. In their study, the imaging was performed in the lower extremity, and the perfusion results were compared in 2 different extremities, with potential variables between the 2 extremities and between the 2 flaps. Our study is the first to date on locoregional flaps in the head and neck region, and our measurements are performed on the same flap before and after a vascular delay.

A main difference between free tissue transfer (in which the laser angiographic system is becoming more popular) and locoregional or random flaps is the amount of intraoperative time required for the cases. Locoregional or random flaps are typically much shorter cases, and for a technology to be widely accepted by reconstructive surgeons, it must be technically easy to use, efficient, and intuitive and demonstrate a clear benefit in outcomes. We have found that this is particularly the case for complex reconstructive cases, in which many of the available local flaps have already been used. Moreover, this technology could be particularly useful in darker Fitzpatrick skin types, in whom capillary refill and skin color changes are not as easily assessed as markers of compromised tissue perfusion.

Decision making in locoregional flap surgery is subjective and is often based on a surgeon’s experience and clinical judgment to determine the acceptable dimensions of a flap (traditionally a 3:1 ratio of length to width), while accounting for patient-specific factors, including smoking, radiation therapy, vascular anomalies, diabetes mellitus, and prior surgical procedures. This novel technology could be useful as an objective, real-time measure of flap vascularity to guide critical intraoperative management. As an additional tool in the reconstructive surgeon’s armamentarium for complicated cases, this technology could reduce perfusion-related complications, decrease the need for revision surgery, and increase predictability of wound healing in local flaps. This tool can also help surgeons confidently determine that sufficient time has passed during a vascular delay and that reconstruction can proceed. Ultimately, the adoption of this novel technology should be a practical method of improving flap survival and optimizing patient outcomes.

Conclusions

Limitations of this study include the small sample size and the retrospective nature. Because these initial results are so promising and because these cases led to substantial changes in our clinical practice, we are using the technology in all similar cases that are complicated or have high risk of flap failure. Further prospective study with increased sample sizes is needed and is ongoing.
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Conflict of Interest Disclosures: None reported.

REFERENCES