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A Challenging Case of Thumb Replantation Aided by Intraoperative Indocyanine Green Fluorescence Angiography

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Background: This study presents a case of thumb replantation performed despite several risk factors: age, comorbidities, and trauma mechanism are major adverse prognostic factors directly impacting thumb replantation. Most of the literature backs up this claim that a thumb that works, even partially, is a better outcome for the patient than amputation.
Methods: We performed thumb replantation on a 94-year-old patient with type 2 diabetes mellitus who arrived at the emergency department with a thumb avulsion due to a dog bite. The intraoperative indocyanine green fluorescence angiography method aided us in carrying out the operation.
Results: We successfully used indocyanine green angiography intraoperatively to guide surgical debridement and evaluate the efficacy of anastomosis and reperfusion of the replanted segment during surgery. Two months after the operation, the patient had regained satisfactory hand function.
Conclusions: Although indocyanine green angiography is not a technology created for revascularization procedures, it is instrumental in assessing vascular function and predicting a successful outcome. Given its undeniable potential, more research is needed on the possibility of widespread use in hand surgery and its indications.
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INTRODUCTION

After the first successful replantation by Komatsu and Tamai,[1] several factors have led to increased replantation indications. Some of the main factors are the increased functional and social demands of the population of all ages and the improvement of the microsurgical techniques. This is especially true concerning thumb replantation.[2,3]

Even if the mechanism of trauma, the condition of the vascular pedicles, advanced age, and comorbidities may constitute a limit to replantation,[4,5] a study by Barzin et al in patients aged 65 years and older demonstrated that age does not affect the survival of free tissue transfer, but postoperative complications are significantly higher in older patients.[6]

It is stated that the presence of atherosclerotic vessels and hypertension in the older population are among the main factors found to increase the complications[7]; however, most authors recommend considering both the functional requirement and the patient's general status when replanting; therefore, finger replantation should be independent of advanced age.[8]

The most immediate way to evaluate tissue perfusion is a physical examination and clinical judgment, which undoubtedly depends on the surgeon's experience. Several methods have been designed over the years to predict anastomotic success. For instance, patency testing (even with the aid of high-speed video data) could increase the accuracy of vascular flow observation.[9]

Techniques have also been developed to assess intravascular flow, which finds its main application in evaluating free flaps in reconstructive microsurgery. Some of those techniques include laser Doppler flowmetry,[10,11] portable Doppler ultrasound,[12] transit time volumetric flow,[13] and indocyanine green fluorescence angiography (ICGA).

It is stated that ICGA is an established tool for the intraoperative assessment of tissue perfusion. In our case report, we present the use of ICGA in real-time tissue perfusion evaluation of a complex case of thumb replantation.

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Fig. 1. A photograph of preoperative evaluation (proximal stump).

We explored possible applications during replantation, such as debridement guidance, peripheral perfusion assessment, and anastomotic patency assessment.

Indocyanine green is a dye that emits diffuse fluorescence when exposed to light with near-infrared wave frequencies. The functioning of the system relies on the generation and observation of fluorescence emitted by a fluorescent agent called indocyanine green. The VERDYE (Diagnostic Green GmbH, Otto-Hahn-Str. 20, 85609 Aschheim-Dornach, Germany) is administered at a dosage of 0.3 mg per kg of body weight.

The angiography device is equipped with a camera for real-time tissue perfusion assessment,[14] and angiography images are obtained using the IC-FlowTM imaging system. This system comprises a medical chamber designed for fluorescence angiography. Using a near-infrared LED light source and a highly sensitive sensor, it enables the quantification of superficial tissue perfusion.

The Clinical Case

A 94-year-old diabetic patient was referred to our clinic with a thumb amputation due to a dog bite avulsion (Fig. 1). Upon arrival, the amputated finger was stored correctly in gauze soaked in a physiological solution, wrapped in a plastic bag, and immersed in a bag with water and ice (Fig. 2).

After discussion with the patient and relatives, we opted for replantation, with a cold ischemic time of about 5 hours. Despite his age, the patient lived alone with complete autonomy. His only comorbidity was type II diabetes mellitus, under treatment with drugs. The loss of the thumb of the dominant hand would have significantly worsened the quality of life and undermined the patient's autonomy.

Takeaways

Question: How can we improve the reliability of anastomosis and vascular perfusion in more complex finger replantations?

Findings: We present a case of thumb replantation performed despite several risk factors. The thumb was successfully reimplanted thanks to the implementation of the intraoperative indocyanine green fluorescence angiography technique. We used indocyanine green intraoperatively to evaluate the efficacy of anastomosis and reperfusion of the reimplanted segment.

Meaning: Indocyanine green angiography provides essential information and can guide the surgeon in intraoperative decisions during finger replantation.

Once the patient was admitted to the clinic, routine blood tests were performed, which showed no altered values except for a slight increase in leukocytes and blood glucose (albumin 3.5 g/dL; glucose 6.1 mmol/L; hemoglobin 10.0 mmol/L; lactic acid 1.2 mmol/L; leukocytes 12.2×10^9/L; platelets 200×10^9 mmol/L).

The surgery was performed under plexus anesthesia associated with deep sedation. Intraoperatively, the stump was thoroughly cleaned and disinfected with antibiotics and antibacterials.

The amputation was at the level of the proximal phalanx. The preoperative radiograph showed bone fracture at the level of the proximal phalanx shaft, without involvement of the interphalangeal and metacarpophalangeal joints.

The thumb's long flexor tendons and the thumb's extensor proper were avulsed to the forearm. We opted for the complete removal of the FPL and EPL due to the critical infectious risk for tissue contamination and considering the patient's comorbidity and arthrosis disease. We reduced and fixed the fracture with two nonparallel Kirschner wires, which included the interphalangeal joint, fixed in definitive arthrodesis. Due to the trauma, the proximal stump of the princeps pollicis and the veins were inadequate for anastomosis. The distal stump of the princeps pollicis was anastomosed to the superficial branch of the radial artery, which presented a good arterial flow. Similarly, a large caliber vein directed to the second finger as a venous receiving vessel was transposed and anastomosed to a distal stump vein. No vein or artery grafts have been used. Intraoperative monitoring with indocyanine green showed adequate perfusion of the reimplanted finger and adequate venous drainage (Fig. 3). [**See Video 1 (online),** which shows an intraoperative video of indocyanine green fluorescence angiography, 30–60 s after peripheral venous injection.] (**See figure, Supplemental Digital Content 1**, which shows an intraoperative photograph of indocyanine green fluorescence angiography, vascular anastomosis detail. **http://links.lww.com/PRSGO/D106**.)

The administration of VERDYE was carried out as a bolus injection through a peripheral catheter placed in a vein of the contralateral limb. We then proceeded with surgical debridement of nonperfused tissues

Fig. 2. A photograph of preoperative evaluation (distal stump).

guided by ICGA. We then repaired the extensor brevis and flexor brevis tendons of the thumb and the digital nerves. Intraoperatively, dexamethasone, dual antibiotic therapy according to the guidelines of our hospital, low molecular weight heparin, and cardio-ASA were administered. We monitored the patient during the first five postoperative days, to assess the vitality of the finger, promptly assess the onset of local inflammation signs, and monitor the systemic inflammation indices to

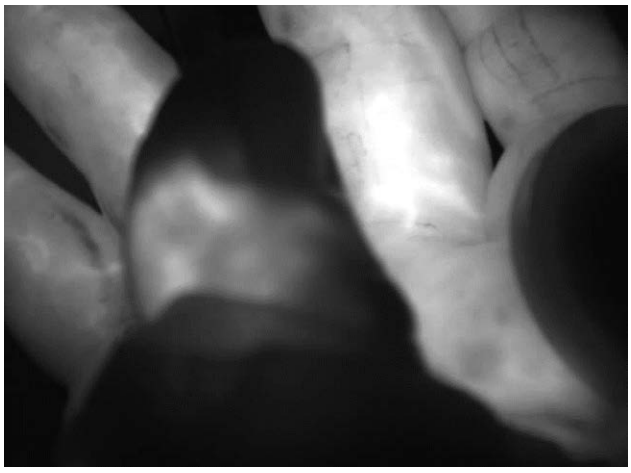

Fig. 3. An intraoperative photograph of indocyanine green fluorescence angiography 30 seconds after peripheral injection, shows starting perfusion of the finger.

Fig. 4. A photograph of postoperative evaluation after 2 months.

prevent septicemia. No signs of local or systemic infection emerged.

His follow-up protocol complied with the Italian Society of Hand Surgery standards of care, with regular support from hand therapists. Although the finger was immobilized, his hand therapy regimen included supportive hand therapists; after about 2 months he moved on to strengthening exercises (Fig. 4). At the 3-month follow-up, he demonstrated good functional recovery, being able to hold a pen and write despite reduced thumb sensitivity (Video 2). At 6 months, the recovery of sensation was also considered good by the patient. [**See Video 2 (online),** which shows the ability to write, showing a good functional recovery.]

DISCUSSION

A 94-year-old diabetic patient who had lost the proximal end of his thumb due to a dog bite presented to us

for thumb replantation. The will of the patient was to gain back the complete function of the thumb.

Although ICGA is now a validated technique in reconstructive microsurgery, its use is rare in the clinical practice of hand injuries. Studies on its possible application in hand surgery seem to be lacking in the literature, and there have been few studies that evaluated the performance of ICGA in identifying venous occlusion.[15]

In cases of major trauma, we believe this tool can be particularly valuable in making decisions during the surgical process and determining whether it is necessary to debride the necrotic tissues after revascularization.

Although ICGA cannot identify infected tissues, it is capable of detecting hypoperfused tissues resulting from lacerations, such as those typically associated with dog bites. These hypoperfused tissues, when necrotic, are more susceptible to infection.

If a substantial percentage of necrotic tissue was found, the surgical approach would have been modified, possibly resulting in a staged reconstruction after a thorough discussion of the options with the patient.

ICGA is a simple examination to integrate into surgical practice and easily allows the evaluation of peripheral perfusion after a microsurgical anastomosis and the assessment of venous outflow. It also provides high-sensitivity and specificity information on anastomotic patency and facilitates immediate intraoperative decision-making.[16]

The setting of the measuring instrument is intuitive, as it is a small camera connected to a monitor that records information in black and white. The chamber can also be wrapped in a sterile drape, to allow for evaluation directly in the operating field. Upon injection of the contrast (painless) into any peripheral vein, the camera detects the fluorescence within approximately 30 seconds in the entire circulation, although there may be some variations in cases involving revascularized segments. By waiting 1–3 minutes, it is possible to appreciate the capillary diffusion and, therefore, the tissue perfusion.

Implementing ICGA in this trauma helped us evaluate the good vascular perfusion of the tissues damaged by the dog bite.

Compared with traditional clinical maneuvers that can be used intraoperatively, for instance "milking" or kinking the anastomosed vessels proximally and watching them refill, ICGA is an "indirect" method of testing the patency of the microvascular anastomoses which does not carry the risk of injuring the intima. Furthermore, it enables evaluation of the microcirculation's performance in cases where the anastomosis was successful but the revascularized tissues still suffer due to microcirculation dysfunction.

Regarding hand traumas, there is currently no standardized technique, necessitating further studies to establish a clear range of adequate perfusion. ICGA serves as a relatively safe diagnostic method. However, caution should be exercised when administering it to individuals with hepatic or renal insufficiency. It must not be administered to those with a known allergy to indocyanine.

The initial cost of equipment (approximately 25,000 euros) might be considered high, especially for small clinics, but the potential long-term payoff is clear. The cost of the contrast used in each procedure is much lower (about 350 euros), and the routine use of ICGA in difficult revascularization procedures can prevent failures, additional revascularization attempts, or additional debridement procedures.

We are unaware of any studies that examine the financial effects of routinely using indocyanine green for hand trauma and their cost-effectiveness. However, ICGA is routinely used in various centers for lymphatic surgery, and for the evaluation of perfusion of free flaps and mastectomy flaps. Further studies are necessary regarding cost analysis of the routine use of ICGA in hand trauma.

CONCLUSIONS

This case report presents a thumb replantation performed despite several contraindications, thanks to ICGA monitoring. Most of the literature backs up this claim as long as a thumb that works, even partially, is a better outcome for the patient than amputation. Furthermore, although ICGA is not a technology created for revascularization procedures, it is particularly useful in assessing vascular function and predicting a successful outcome. Given its undeniable potential, more research is needed on the possibility of widespread use in hand surgery and its indications.

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DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

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All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Written informed consent was obtained from the patient before their inclusion in this study. Additional informed consent was obtained from all patients for which identifying information is included in this article.

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