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Case Report

Indocyanine green fluorescence angiography: A critical intra-operative assessment tool to aid decision making in complex hand trauma

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ABSTRACT

Indocyanine green fluorescence angiography (ICG-FA) is a validated non-invasive imaging tool used to assess tissue perfusion and guide intra-operative decision making in many surgical disciplines. Clinical assessment of tissue perfusion following crush or degloving traumatic hand injuries presents a significant challenge. This case report supports the critical role of intra-operative ICG-FA as a decision aid in complex hand trauma. We propose ICG-FA will minimise unnecessary tissue debridement, negating complex soft tissue reconstructive surgery and ultimately expediting tissue healing and return to function for hand trauma patients.

A 35-year-old right hand dominant manual labourer presented to the emergency department after sustaining a crush injury to his right hand. Examination under anaesthetic revealed a comminuted open fracture of middle finger P2 with compromised soft tissue coverage. A formal assessment of hand perfusion was performed using a triad of clinical assessment, critical judgement and ICG-FA. The ICG-FA revealed a small skin flap affecting the dorsoradial P2 skin which was not perfused. This prompted meticulous minimal debridement of this tissue and prevented unnecessary over-debridement that would have resulted in complex soft tissue reconstruction.

Currently the gold standard assessment for tissue perfusion in hand injuries is clinical judgement and is limited by subjective interobserver error [1]. IGA-FA has been proven to offer a real time assessment of tissue perfusion. This case demonstrates the use of ICG-FA as an adjunct to clinical examination and judgement, to optimise the accuracy of soft tissue perfusion assessment in complex hand trauma.

Introduction

Indocyanine green fluorescence angiography (ICG-FA) is a validated non-invasive imaging tool used to assess tissue perfusion and guide intra-operative decision making in many surgical disciplines [1–3]. Clinical assessment of devitalised tissue following traumatic hand injuries presents a significant challenge, especially in the context of resuscitation, systemic hypoperfusion or in patients with co-morbid vascular pathology [4].

Abbreviations: ATLS, Advanced Trauma Life Support; ICG-FA, Indocyanine Green Fluorescence Angiography; P2, middle phalanx.

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Fig. 1. Pre-operative clinical photograph demonstrating post crush injury compromised perfusion of the right middle finger with underlying comminuted open fractures.

We demonstrate the safe use of ICG-FA to optimise the accuracy of tissue viability assessment in a complex hand trauma case. We propose this approach improves the accuracy of the surgeons decision making and avoids unnecessary return to the operating theatre for further surgical debridement.

Case summary

A 35-year-old right hand dominant manual labourer presented to the emergency department by ambulance following a workplace accident whereby he sustained a crush injury to his right hand. He reports his right hand was trapped under a cement container weighing approximately 500 kg for a period 15 min, prior to emergency removal of the load by an on-site crane. His past medical history was significant for active cigarette smoking (10 pack year history).

Following initial emergency management as per Advanced Trauma Life Support (ATLS) protocol, his hand injury was addressed in the secondary survey. Clinical examination revealed an abnormal hand cascade with moderate oedema and burst lacerations of the thumb, index, middle and ring fingers. Capillary refill was reduced to the middle finger upon nailbed compression assessment (3 s) and the soft tissue envelope appeared poorly perfused [Fig. 1]. Radiographs and a cone-beam CT of the right hand revealed multiple fractures [Fig. 2].

Examination under anaesthetic revealed a comminuted open fracture of middle finger P2 with a large flap laceration concerning for compromised perfusion and an open comminuted fracture of P1 thumb with overlying burst laceration. Following copious wound lavage, the hand was placed in a resting splint with moderate elevation to prevent acute compartment syndrome and intravenous anti-

Fig. 2. Radiograph demonstrating multiple hand fractures, namely comminuted fracture and dislocation of P2 of middle finger, comminuted fracture of P2 ring finger, comminuted fracture of proximal phalanx of thumb.

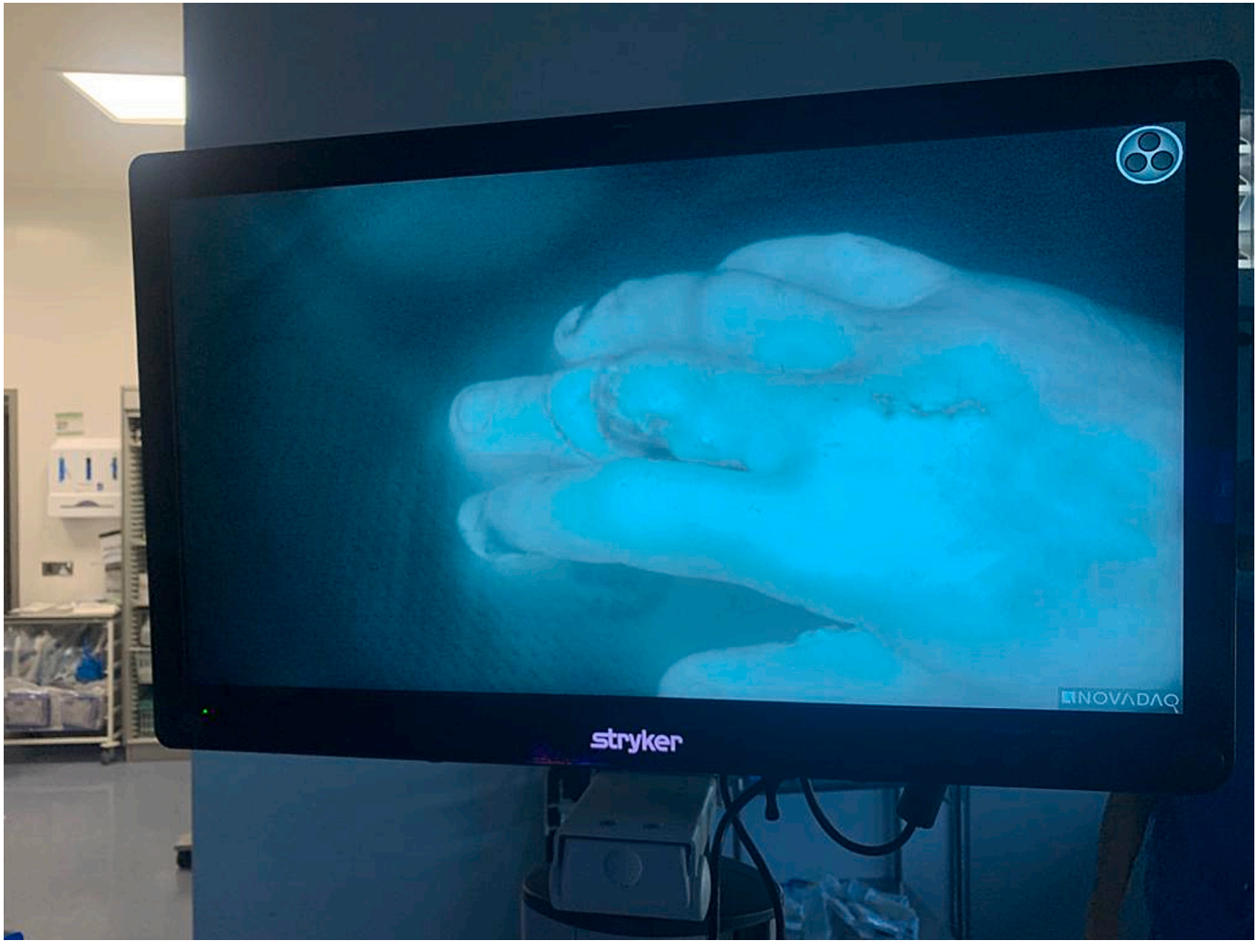

Fig. 3. Intra-operative image generated using ICG-FA demonstrating adequate perfusion of soft issues of the right hand post crush injury which is represented subjectively by vivid green fluorescence. The darker region over the dorsoradial middle finger identifies a region of soft tissue requiring surgical debridement.

microbials were prescribed in the context of open fracture bone infection prophylaxis. The patient was kept well hydrated, commenced on aspirin and low-molecular weight heparin combined with a warming blanket, in attempt to reduce risk of vascular spasm and thrombosis of the digital vessels. Definitive bony fixation and further tissue handling of traumatised tissue was delayed until the following day to allow recovery of soft tissue perfusion.

Twenty-four hours later, under general anaesthesia, a formal assessment of hand perfusion was performed using a triad of clinical assessment, critical judgement and ICG-FA. 3 milliliters of 10 mg/ml Verdye was administered as a rapid intravenous bolus through a peripheral canula followed by a 10 ml flush of normal saline. One minute later immunoflouresence was visible in all digits of the right hand bar a 2 cm × 2 cm area of soft tissue on the dorsoradial aspect of the middle finger. This enabled accurate meticulous minimal debridement of the hypoperfused soft tissue which is visible in this clinical photograph as a black-coloured region on the middle finger [Fig. 3]. The diagnostic accuracy afforded by ICG-FA in this case prevented unnecessary over-debridement. Debridement of the large soft tissue flap would have presented a very challenging reconstructive conundrum in the context of a patient who was a longstanding smoker, with a severe crush injury and multiple soft tissue burst lacerations in adjacent digits. Bony stability of the phalangeal fractures was then achieved with simple cross Kirschner-wire fixation to prevent further tissue handling. Clinical follow-up at 6 weeks post injury revealed a fully healed skin graft. No further debridement was required [Fig. 4].

Discussion

Currently the gold standard assessment for tissue perfusion in hand injuries is clinical judgement however this is limited by subjective interobserver error [1–3]. Intra-operative perfusion assessment provides surgeons with the ability to interpret additional information that enhances surgical decision-making in real-time. Technologies include various dye-based and non-dye-based near-infrared angiography, tissue oximetry measurements, and ultrasound-based tools. An emerging technology using near-infrared angiography with indocyanine green (ICG) dye may significantly improve the immediacy and accuracy of the assessment of tissue perfusion [2–5].

IGA-FA has been proven to offer a real time assessment of tissue perfusion and can have a wide range of applications in surgery. It is very safe to use and has a low adverse event profile in approximately 1 in 42,000 people. IGA-FA has also been shown to have a short half-life (3–5 min) which can allow for multiple injections through the course of a surgery for multiple assessments. ICG binds rapidly to plasma proteins and remains within the blood vessels. It has a half-life of 3 to 4 min and following intravenous injection, it can be visualised in less than 1 min [6–8].

Hyun Joh et al. published a case series of patients demonstrating the benefits of IGA-FA to assess tissue perfusion in patients with peripheral arterial disease and vascular trauma. They concluded that IGA-FA can determine the surface tissue viability in patients with ischaemic wounds and found it beneficial in aiding decision making in relation to resection margins [1]. To date, the most common application of IGA-FA in plastic and reconstructive surgery is assessment of perfusion in the context of free and pedicled flap reconstruction. Conducting an evaluation of the arterial perfusion and venous drainage of traumatic upper limb injuries is a difficult but important task [3]. To date, prospectively conducted studies have suggested ICG-FA provides significant predictive value for

Fig. 4. Wound healing demonstrated at 6 weeks post skin resurfacing.

clinical outcome in cases of severe upper limb trauma [9,10].

This case highlights the critical role of ICG-FA as an adjunct to clinical examination and judgement, to optimise the accuracy of soft tissue perfusion assessment in complex hand trauma. We have demonstrated how this tool minimises unnecessary tissue debridement. Debridement of the large soft tissue flap affecting the dorsoradial middle finger would have presented a very challenging reconstructive conundrum. Exposure of underlying open fracture and extensor tendon mechanism would have necessitated soft tissue coverage. Local advancement or cross-finger flaps were not an option due to the segmental pattern of soft tissue injury affecting the middle finger in addition to multiple soft tissue burst lacerations affecting adjacent digits. Therefore the use of ICG-FA was an essential factor in preventing this patient from requiring a complex free flap reconstruction to dorsal middle finger.

A proof of concept study is now required to formally validate ICG-FA as an assessment method for hand perfusion in elective and trauma hand surgery.

Declaration of competing interest

This article has not been published and is not under consideration for publication elsewhere. We have no conflicts of interest to disclose.

References

[1] J.H. Joh, H.C. Park, S.A. Han, H.J. Ahn, Intraoperative indocyanine green angiography for the objective measurement of blood flow, Ann. Surg. Treat. Res. 90 (5) (2016 May) 279–286, https://doi.org/10.4174/astr.2016.90.5.279 (Epub 2016 May 2. PMID: 27186573; PMCID: PMC4865706).

[2] M. Vasella, M. Guidi, M. Waldner, M. Calcagni, P. Giovanoli, F.S. Frueh, Fluorescence angiography-assisted debridement of critically perfused glabrous skin in degloving foot injuries: two case reports, Medicine (Baltimore) 100 (22) (2021 Jun 4), e26235, https://doi.org/10.1097/MD.0000000000026235.

[3] P.A. Ghareeb, T.M. Neustein, R.C. Fang, D.E. Payne, Indocyanine green angiography: a helpful tool for intraoperative assessment of upper extremity perfusion, Tech. Hand Up. Extrem. Surg. 21 (3) (2017 Sep) 101–106, https://doi.org/10.1097/BTH.0000000000000162.

[4] B.T. Phillips, N.C.O. Munabi, R.A. Roeder, J.A. Ascherman, L. Guo, M.R. Zenn, The role of intraoperative perfusion assessment: what is the current state and how can I use it in my practice? Plast. Reconstr. Surg. 137 (2) (2016 Feb) 731–741, https://doi.org/10.1097/01.prs.0000475765.83901.80.

[5] D.Z. Liu, D.W. Mathes, M.R. Zenn, P.C. Neligan, The application of indocyanine green fluorescence angiography in plastic surgery, J. Reconstr. Microsurg. 27 (6) (2011 Jul) 355–364, https://doi.org/10.1055/s-0031-1281515.

[6] T. Pruimboom, S.M.J. van Kuijk, S.S. Qiu, J. van den Bos, F.P. Wieringa, R.R.W.J. van der Hulst, R.M. Schols, Optimizing indocyanine green fluorescence angiography in reconstructive flap surgery: a systematic review and ex vivo experiments, Surg. Innov. 27 (1) (2020 Feb) 103–119, https://doi.org/10.1177/1553350619862097 (Epub 2019 Jul 26. PMID: 31347468).

[7] J.M. Smit, V.L. Negenborn, S.M. Jansen, M.E.H. Jaspers, R. de Vries, M.W. Heymans, H.A.H. Winters, T.G. van Leeuwen, M.G. Mullender, N.M.A. Krekel, Intraoperative evaluation of perfusion in free flap surgery: a systematic review and meta-analysis, Microsurgery 38 (7) (2018 Oct) 804–818, https://doi.org/10.1002/micr.30320 (Epub 2018 Mar 25. PMID: 29577423).

[8] I. Ludolph, R.E. Horch, A. Arkudas, M. Schmitz, Enhancing safety in reconstructive microsurgery using intraoperative indocyanine green angiography, Front. Surg. (6) (2019 Jul 2) 39, https://doi.org/10.3389/fsurg.2019.00039. PMID: 31334246; PMCID: PMC6614526.

[9] C. Strauss, E. Brix, A. Anker, L. Prantl, V. Brébant, T. Aung, Perfusion control of a partial revascularized hand via application of Indocyanine green (ICG) and near-infrared fluorescence imaging, Clin. Hemorheol. Microcirc. 67 (3–4) (2017) 215–219, https://doi.org/10.3233/CH-179202 (PMID: 28869456).

[10] H. Mothes, T. Dinkelaker, T. Dönicke, R. Friedel, G.O. Hofmann, O. Bach, Outcome prediction in microsurgery by quantitative evaluation of perfusion using ICG fluorescence angiography, J. Hand Surg. Eur. Vol. 34 (2) (2009 Apr) 238–246, https://doi.org/10.1177/1753193408090399 (PMID: 19369300).