Optimizing Debridement Using ICG-Based Fluorescence Imaging

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Purpose: Dysvascular tissues have limited potential to regenerate, heal, or fight infection due to insufficient delivery of inflammatory cells, growth factors, osteprogenitor cells, endogenous immune cells, and antibiotics. The goal of open fracture and osteomyelitis management is therefore complete debridement of poorly perfused tissues. However, palpation and visual inspection is not always sufficient to discriminate between healthy and nonviable tissue. The aim of this work is to apply indocyanine green (ICG)-based fluorescence imaging (FI) methods and analytic tools to objectively and quantitatively assess bone perfusion in orthopaedic trauma settings.

Methods: We performed dynamic ICG-based FI in the operating room in 10 patients to date. This is a patient with a Gustilo Type 3A open tibia fracture complicated by osteomyelitis and recalcitrant nonunion. The Stryker SPY Elite was used to acquire fluorescence time series. Data were analyzed by in-house software, including fluorescence maximum (Fmax), and ingress (IS) and egress slopes (ES). We sought to understand the spatial variation in fluorescence and the effect of debridement on fluorescence.

Results: In Fig. 1, region of interest (ROI) 1 was at the recalcitrant infected/nonunion site; 2, 3, and 4 were progressively more proximal and away from the zone of injury. The more proximal ROIs (3 and 4) were better perfused than ROIs close to the fracture, with these brighter regions corresponding to about a 12-fold difference in Fmax. Ingress and egress were also markedly different in ROIs 1 and 2 (average 0.05 relative fluorescence unit (RFU)/s and –0.01 RFU/s, respectively) compared with ROIs 3 and 4 (average 6.1 RFU/s and –0.12 RFU/s, respectively).

Conclusion: Based off this early application of ICG-based FI in human patients, we believe FI-based methodologies assessing bone and soft-tissue perfusion in an objective manner will improve assessment and effective debridement of traumatic and infected wounds.

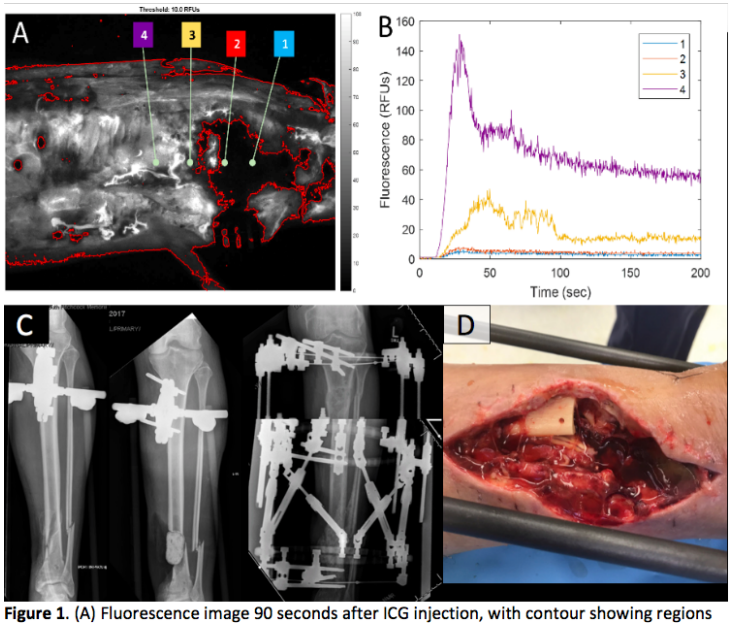

Figure 1. (A) Fluorescence image 90 seconds after ICG injection, with contour showing regions of fluorescence lower than 10 RFUs, and annotated with numbers indicating four regions of interest (ROI). (B) The time-concentration curves of ICG for each of the four ROIs in Panel A. (C) Radiographs at time of initial infection, post-debridement for infection and post-distraction osteogenesis to fill defect. (D) Clinical image at time of debridement.