Intraoperative Benefits of Integrating Fluorescence Imaging into the Management of Complex Wounds: A Suggested Workflow Algorithm

Misael C. Alonso, MD, FACP, CWSP, FAPWCA[1,2], Michael N. Desvigne, MD, FACS, CWS, FACCWS[3], Arti Karmur, DPM[1], Justin Singh, DPM[4], Stacey Hancock, DO[5], Genaro Valladolid, MD[6], Prabhakar Pandey, MD, FACS, FRCS[7]

[1]Abrazo West Campus, Goodyear, AZ, [2]MCA Medical, PLLC, Goodyear, AZ, [3]Plastic & Reconstructive Surgery, Wound Care & Hyperbaric Medicine, Goodyear, AZ, [4]HealthyU Clinics, Avondale, AZ, [5]American Vascular Specialists, Avondale, AZ, [6]Valladolid Plastic Surgery, Phoenix, AZ, [7]Arizona Urology, Goodyear, AZ.

Introduction and Background

- Chronic wound management requires a multidisciplinary approach, particularly in complex cases involving surgical debridement, grafting, or wound reconstruction.
- Early detection and targeted management of bacteria at pathogenic loads (>10^4 CFU/g) is crucial for preventing infections, reducing complications, and optimizing outcomes.
- Fluorescence (FL) imaging is an innovative, non-invasive technology designed to help clinicians locate bacteria linked to poor outcomes in complex wound procedures like grafting, amputation, and reconstruction.
- FL imaging aids in targeted debridement and post-debridement assessment, improving outcomes across various wound types and care settings[1-3].

We aim to provide a **general guide on integrating fluorescence imaging into standard wound reconstruction practices** for surgeons who are unfamiliar with this device.

Material and Methods

- A fluorescence imaging device (MolecuLight i:X) was utilized during complex wound cases involving surgical debridement, reconstruction, and skin substitute placement.
- Positive fluorescence indicated the presence of pathogenic bacterial loads >10^4 CFU/g.
- Red fluorescence indicates Gram +/- bacteria and cyan fluorescence indicates *Pseudomonas aeruginosa*, while biological tissues fluoresce green.

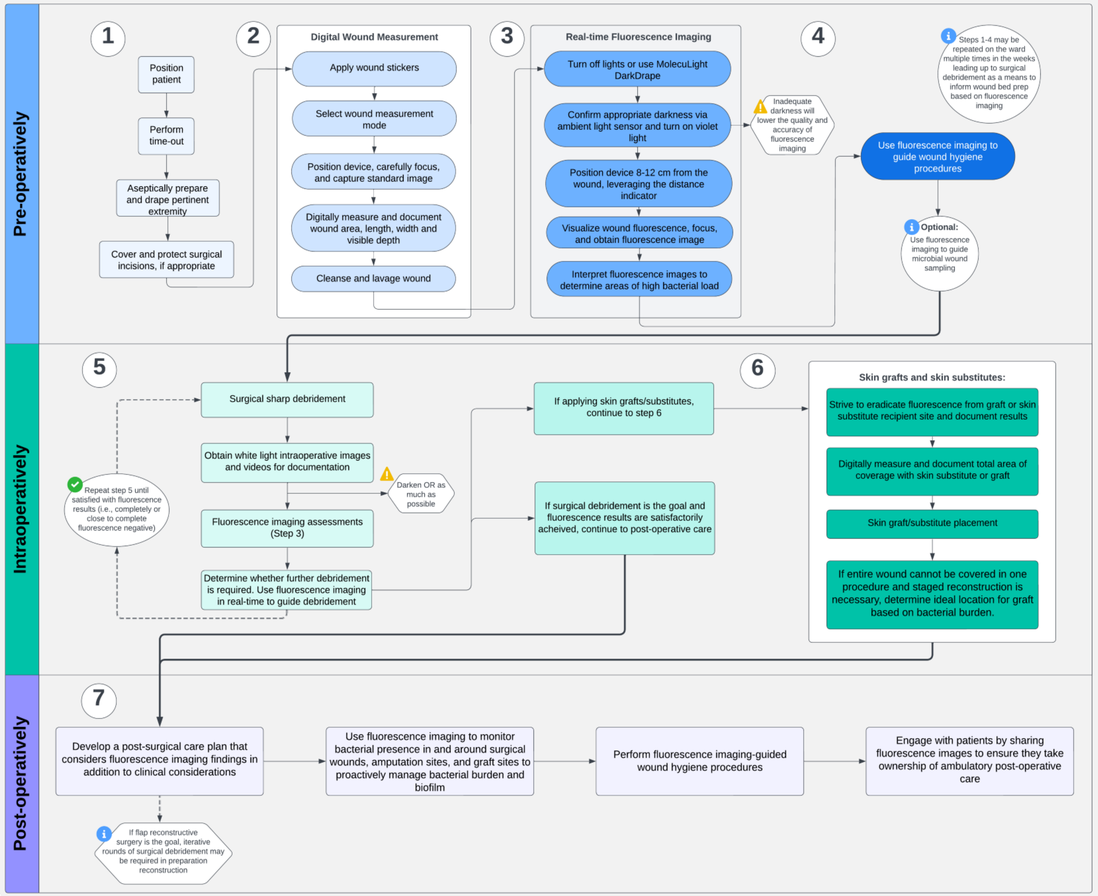
Caution must be exercised when FL imaging near tendons and bones, as they may appear similar to cyan fluorescent signals. To reduce uncertainty, standard and FL images must be compared to rule out the presence of these structures.

Here, we present…

1. **A suggested workflow** integrating fluorescence imaging in pre-, intra-, and post-operative surgical care, which can be adapted across multiple specialties.
2. **Case examples** of the utilization of fluorescence imaging technology in the guidance of intraoperative debridement are provided to visually illustrate its application in distinct settings.

[1] Rahma S., Woods, J., Brown, S., *et al*. The Use of Point-of-Care Bacterial Autofluorescence Imaging in the Management of Diabetic Foot Ulcers: A Pilot Randomized Controlled Trial. *Diabetes Care*, 2022. Jul 7;45(7):1601-1609.
[2] Kelso, M.K., and Jaros, M. Improving Wound Healing and Infection Control in Long-term Care with Bacterial Fluorescence Imaging. *Adv Skin Wound Care*, 2024. Sep 1;37(9):471-479.
[3] Price N. Routine Fluorescence Imaging to Detect Wound Bacteria Reduces Antibiotic Use and Antimicrobial Dressing Expenditure While Improving Healing Rates: Retrospective Analysis of 229 Foot Ulcers. *Diagnostics*, 2020. Nov 10;10(11):927.

Surgical Workflow Integrating Fluorescence Imaging



Conclusions

- **Integrating fluorescence imaging into the surgical workflow offers significant advantages in the management of complex wounds**, improving the detection of bacteria/biofilm, enhancing surgical debridement precision, and reducing the risk of post-operative infections and/or graft failure.
- **Our suggested clinical algorithm for the operative use of fluorescence imaging provides a general guide to easily integrate and adapt for clinical staff who are unfamiliar with fluorescence imaging.** As its use expands, this system may become a standard practice in managing complex wounds during surgery.

Case 1 – Aggressive Surgical Debridement of Necrotizing Fasciitis

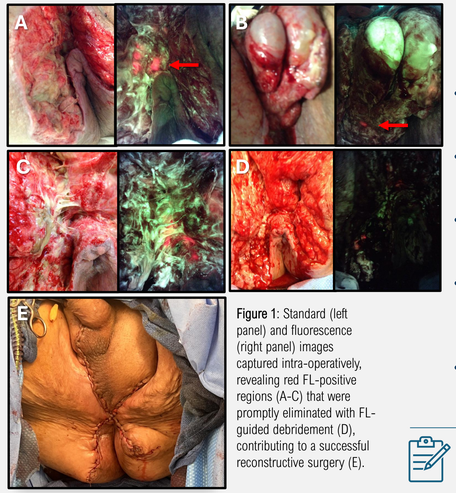


Figure 1: Standard (left panel) and fluorescence (right panel) images captured intra-operatively, revealing red FL-positive regions (A-C) that were promptly eliminated with FL-guided debridement (D), contributing to a successful reconstructive surgery (E).

Clinical Context: Effective management of necrotizing fasciitis requires careful, extensive, and repeated procedures to control infection while maximizing tissue preservation. However, the boundary between infected and healthy tissue may not be easily discernable.

- A 61-year-old male with a significant medical history of hypertension, hypothyroidism, benign prostatic hyperplasia, and uncontrolled type 2 diabetes, developed Fournier's gangrene.
- Several surgical debridements of the scrotal wall and bilateral groin were initially completed without FL imaging. Wound cultures showed growth of *Candida sp*.
- Initial intra-operative FL-guided debridement revealed red FL signals (arrows) along the inner thigh extending towards the buttocks (**Fig. 1A**) and near the scrotum (**Fig. 1B**).
- Two days later, a subsequent FL-guided surgical debridement revealed a resurgence of red FL signals (**Fig. 1C**), leading to extensive excision of necrotic tissue. FL-guided debridement continued until red FL was nearly eliminated (**Fig. 1D**).
- The next day, the patient underwent plastic reconstructive surgery to close the wounds and was discharged after 3 days of post-operative care (**Fig. 1E**).

Case Summary: FL imaging aided intra-operative assessment and debridement of infected tissues in an aggressive case of necrotizing fasciitis that may have otherwise been missed.

Case 2 – 3rd Digit Amputation and Skin Substitute Application

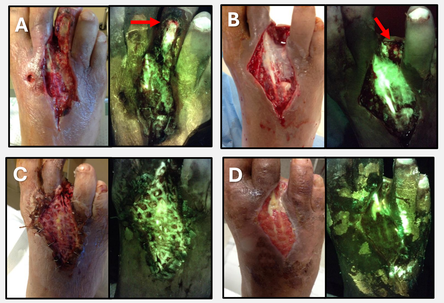


Figure 2: Standard images (left panel) and FL images (right panel). Pre-operative wound assessment revealed red FL-positive regions (A). Following debridement and amputation, intra-operative FL-imaging revealed additional red FL (B), which was excised prior to the application of skin substitutes (C). 1-month post-operative images demonstrate the skin substitute integrated well without infectious complications (D).

Case Summary: FL imaging enhanced the precision of surgical debridement and reduced the risk of post-operative infections and skin substitute failure.

- A 46-year-old male with a history of hypertension, hyperlipidemia, and uncontrolled type 2 diabetes presented with right dorsal and plantar diabetic foot ulcers.
- Tendon, necrotic muscle, joint, and bone were exposed. The wound bed showed poor granulation and slough, and the periwound showed signs of infection. FL assessment revealed red signals indicative of high bacterial loads (**Fig. 2A**) and wound cultures confirmed infection with *Staphloccocus aureus* and *Streptococci sp.* Topical antibiotics were prescribed.
- Re-assessment 2 days later confirmed the FL had resolved; thus 3rd digit amputation was scheduled for the following day.
- Surgical debridement and amputation was undertaken. Small areas of red FL were detected at the beginning of surgery, but were easily removed with FL-guided debridement. However, once the digit had been removed, additional red FL was revealed (**Fig. 2B**). This was completely eliminated via further surgical debridement and irrigation, after which SomaGen® and Salera® skin substitutes were applied to the wound bed.
- Complete removal of bioburden is crucial the success of integration and survival of dermal matrices. 4 days post-surgery, the skin substitutes were integrating well (**Fig. 2C**). 1-month post-operative FL images showed no evidence of bacterial burden and full integration of the skin substitute (**Fig. 2D**).