Can Imaging Put the “Advanced” Back in Advanced Wound Care?

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An effective, scientifically validated, diagnostic tool helps clinicians make better, timely, and more objective medical decisions in the care of their patients. Today, the need for such tools is especially urgent in the field of wound care where patient-centric care is the goal, under ever tightening clinical budget constraints. In an era of countless “innovative” treatment options, that is, advanced dressings, negative pressure devices, and various debridement instruments available to the wound care clinical team, one area that has arguably languished in the past decade has been *innovation* in wound diagnostics. Whereas medical imaging is a mainstay in the diagnostic toolkit across many other medical fields (oncology, neurology, gastroenterology, orthopedics, etc.), the field of wound care has yet to realize the full potential that advances in imaging technologies have to offer the clinician. In this issue, the first of a series in wound imaging and diagnostics, four articles have been assembled, highlighting some of the recent advances in wound imaging technologies.

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IN THE PAST DECADE, conventional imaging tools have remained an integral part of the clinical diagnosis algorithm, allowing clinicians to capture and track the course of wound healing (or failure to heal). Although many readers will appreciate the role that standard photography has played in modern wound care (e.g., cataloguing wounds over time), the excitement behind the promise of emerging imaging technologies cannot be overlooked. The development of highly sophisticated imaging technologies is allowing us to see deeper (e.g., mm to cm with near-infrared imaging) and understand more about the underlying tissues and their microenvironments including vasculature, microvasculature (discussed in Qin *et al.*), tissue

oxygenation (saturated oxygenation, oxy- and deoxy-hemoglobin), melanin concentration, complex microbial flora, and biofilms. Wound pathophysiology is complex. However, our growing ability to noninvasively observe through imaging methods and quantitatively track changes at the tissue, cellular, microbial, and molecular level is improving our understanding of the wound healing process and underlying host response. Furthermore, these abilities are beginning to provide clinicians with useful tools to improve clinical decision making at the bedside.

Many of the technologies described in this edition are in early precommercial stage of development and will require substantial multicenter evidence-based data before regulatory

approval and widespread adoption. However, if successful under clinical evaluation, they have the potential to deliver an objective and possibly quantitative means of wound diagnosis, treatment guidance and treatment response monitoring.

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In their article "Non-Invasive Optical Technologies for Wound Imaging: A Review," Jayachandran *et al.* provide a comprehensive overview of recent advances in optical imaging and the application of these technologies in the field of wound care. They describe, in basic terms, the physics underlying these imaging technologies and the fundamental components that make up each instrument. Their review, which focuses on ulcers, covers a spectrum of imaging technologies (hyperspectral imaging, multispectral imaging, near-infrared spectroscopy, diffuse reflectance spectroscopy, optical coherence tomography, laser Doppler imaging, laser speckle imaging, spatial frequency domain imaging, fluorescence imaging, and digital camera imaging) and discusses the preliminary results of an ongoing clinical study investigating the use of a newly developed handheld near-infrared optical scanner developed at the Florida International University Optical Imaging Laboratory.¹ They demonstrate the ability to qualitatively differentiate healing and nonhealing tissue areas within the same diabetic foot ulcer without contact or the use of contrast agents.

Burn wound clinicians face unique diagnostic challenges owing to the fact that, in some cases, the severity of a burn wound is often difficult to assess at the time of injury. Whereas first-degree and superficial partial thickness (second degree) burns are fairly straightforward to diagnose, there are no reliable and practical methods to differentiate deep partial-thickness (second degree) and full-thickness (third degree) burns. In their review, "Imaging techniques for clinical burn assessment with a focus on multispectral imaging," Jeffery *et al.* present an overview of commercially available and experimental imaging modalities under investigation for burn wound assessment. They highlight the fact that, under the current standard of care, the accuracy of burn size and depth assessment is abysmal, yet the clinical requirements for adoption of new methods are rigorous, which may be why the adoption of laser Doppler imaging in this arena has been slower than expected. Importantly, they identify which optical imaging modalities may be best suited to

varying clinical needs during the course of burn wound diagnosis, treatment planning, and post-treatment monitoring.

Given the widely recommended protocol of early surgical excision and grafting, it is necessary for clinicians to be able to accurately identify areas of deep-partial and full-thickness injury in a timely manner. Burn wound conversion and progression is a poorly understood process, further limited by lack of defining methods to evaluate burn depth. Accuracy of bedside depth assessment is widely considered to be suboptimal, often due to error attributed to depth overestimation and considerable variation between assessments by different clinicians.² Advances in diagnostic techniques will lead to better informed debridement decisions and improved management to optimize scarring and functional outcome. Dutta *et al.* provide compelling evidence to suggest that terahertz (THz) imaging may fulfill this need, while offering clinicians a portable system, which can be used in a variety of clinical settings (*e.g.*, field and community hospitals and tertiary care centers).

One of the major challenges of noninvasive imaging is the ability to see deep within tissues with sufficient resolution to provide meaningful information. The optical coherence tomography system employed by Qin *et al.* achieves submillimeter axial ($\sim 3\ \mu\text{m}$) and lateral ($9\ \mu\text{m}$) resolution, providing a $3\times 3\ \text{mm}$ three-dimensional image within 8 s. Using this system, Qin *et al.* showed they can use optical micrography imaging to quantitatively track changes in the microvasculature immediately after superficial burn injury and during the healing process with capillary-level detail.

Translational research aims to *bridge the divide* between fundamental scientific discovery and new approaches to meaningfully improve patient care. In the field of medical imaging, this means bringing together the expertise of physicists, engineers, biologists, clinical researchers, and clinicians to identify areas where new emerging technologies or repurposed existing technologies may be able to address a previously unmet clinical problem. In this issue, the editor has brought together imaging experts to highlight the potential of select imaging technologies in *driving innovation* in wound diagnostics, treatment, and monitoring. It is our intention that this issue will inspire a discussion between imaging scientists, wound care clinicians, and industry stakeholders who will propel us away from the antiquated "advanced wound care" of the past and toward the revolution in advanced wound care that is so urgently needed to improve the lives of an ever-increasing patient population and

reduce healthcare costs. Indeed, the evolution of wound care beyond the generally empirical methods employed today will largely rely on new innovations, evidence of their value, deeper collaborations between clinicians, scientists, industry, and regulators, as well as visionary clinical champions to drive adoption. Echoing the sentiments of wound care pioneers Douglas Queen and Keith Harding,³ we urge the wound care clinical community, policy makers, and industry to not only take note but also take action.

AUTHOR DISCLOSURE AND GHOSTWRITING

RSD is Founder, Chief Scientific Officer, and a Director of MolecuLight, Inc. that is commercializing an optical imaging technology for wound care. The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Department of the Army or the Department of Defense.

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