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SYMPOSIUM

Applying 21st Century Imaging Technology to Wound Healing: An Avant-Gardist Approach

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Abstract

A significant arising complication in the care of patients with diabetes is increased susceptibility to chronic wounds, including diabetic foot ulcers and pressure sores. This is driven by, e.g., neuropathy and peripheral arterial disease. It is well recognized that best practice in wound care requires wound assessment, including measurement, on presentation and regularly throughout the treatment program. Proper assessment is necessary to ensure that the most appropriate and cost-effective therapy is used at all times, with quantitative measurement necessary to track the efficacy of the chosen approach. A documented assessment can also assist patient–clinician dialog and discussion within the multidisciplinary team. Remote evaluation and assessment of the wound is also of increasing importance and practicality through the use of a telemedicine approach. There has been considerable progress in the space of imaging for wounds, including systems that include three-dimensional measurement and telemedicine features. This literature review examines the available options and reviews the clinical evidence for measurement accuracy, scope for remote assessment, and published user feedback on the systems.

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Foot ulcers are one of the most common complications of diabetes, affecting up to 25% of patients during their lifetime[1] and frequently resulting in hospitalization.[2–4]

Diabetic foot ulcers are also associated with significant morbidity and mortality,[5] with 80% of all diabetes-related lower extremity amputation being preceded by a foot ulcer.[6] Together with prevention strategies, proper management must be a mainstay in the approach to curbing the burden associated with foot ulcers.

Accurate recognition and monitoring of ulcer characteristics facilitates benchmarking therapeutic response. Further, if research into new agents/interventions for wound healing should continue to inform practice, it is essential that ulcer characteristics are well defined in order to (i) enable comparison between studies, (ii) determine which patients/ulcers derive the most benefits from a particular therapeutic approach, and (iii) allow accurate monitoring of wound healing in order to guide clinical decision making.

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Abbreviations: (2D) two-dimensional, (3D) three-dimensional, (app) application, (EMR) electronic medical record

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In fact, wound care is a complex and time-consuming process that involves many different disciplines within the foot care continuum. It is well established that best practice in wound care is to perform regular assessment of the wound, including measurement.[7] Measurement can inform the clinical decision making process to optimize the therapeutic approach[8] and can improve communication between the multidisciplinary team and between clinician and patient. High-quality communication can, in turn, motivate and empower the patient, improving compliance.[9] There is also an increasing drive for efficiency in wound care, leveraging technological advances to utilize telemedicine approaches to allow remote assessment and monitoring of wounds.[10,11]

We have reported on the importance of measurements in a thematic series on diabetic wound healing in general.[12] Numerous academic and commercial groups have developed systems aimed at facilitating the goals mentioned earlier. A major component of many of these systems is to provide tools to facilitate the accurate and repeatable measurement of wounds; it is well understood that this can be time-consuming and ultimately inaccurate using conventional means, e.g., a ruler or tracing paper and "depth probe."[13] Typically, the process involves computerized image capture and processing, then input of data, demarcation of wounds, and so forth in order to generate measurements and health records. These systems typically center around the use of a bespoke clinical imaging device; however, with the burgeoning smartphone economy, there have also been several applications (apps) developed for this space.

Methods

In this nonsystematic review, the clinical evidence underpinning the most significant of the wound imaging systems available is reviewed. Three main evidence areas are considered:

1. *Measurement accuracy*. Has the measurement capability of the system been clinically validated by comparing measurements "like-for-like" with conventional measurements?

2. *Potential for remote assessment*. Has the potential for the system to be deployed in a remote assessment context been examined, and is there supporting evidence or case studies?

3. *User feedback on system efficacy*. To what extent have external parties used and benefited from the system and provided feedback on use in practice?

In addition to clinical evidence, it is also useful to consider the feature set of the system, with the most critical features being

- *Two-dimensional (2D) or three-dimensional (3D) imaging*. To perform measurements of, e.g., wound volume, a 3D image map of the wound is required. This is technically challenging, and many systems instead provide measurements based on 2D images (a planimetric approach).

- *Electronic data capture*. Some systems support data capture beyond imaging and measurement, moving toward an electronic medical record (EMR) type application. This may be useful if the clinical site does not already have such a system.

- *Networking and interfacing*. In a collaborative hospital environment, it is important that the images and measurements acquired with the system can be shared and reviewed throughout the clinical team. It may also be beneficial to clinician workflow to integrate with existing EMR systems.

Results

Perhaps the most well-known system is the Aranz Silhouette (Aranz Medical, Christchurch, New Zealand). Two versions of the system exist; the first is a handheld unit based on a portable data assistant with a camera and laser striping attachment (SilhouetteMobile), and the second, later-released offering is a bespoke tethered device akin to a webcam, with a more advanced laser striping system (SilhoutteStar). The system provides 2D color images with correction

for distance, skew, and shape based on analysis of projected laser stripes. The Silhouette system supports detailed EMR keeping and integration with third-party electronic systems through the SilhoutteCentral server product. There is a good quantity of clinical evidence both on measurement accuracy[14–17] and system efficacy[18,19] for the Silhouette system.

The measurement of area and volume instrument system was originally developed at the University of Glamorgan in 1988. It is now in its third hardware iteration and marketed as the 3D LifeVis (Quantificare, Nice-Sophia Antipolis, France). The system consists of an imaging device (either fully bespoke or based on an off-the-shelf camera) and provides a fully 3D color representation of the wound from which a variety of measurements, including volume, can be taken. Using an array of mirrors and lenses, two laterally displaced images are first obtained and then reconstructed into a 3D image. There have been numerous clinical and technical publications around measurement accuracy.[20–23] However, data on remote assessment and user feedback are less available. Nonetheless, it is a portable and user-friendly system.

The Eykona Wound Measurement System (Eykona Medical, Oxford, England) uses a bespoke imaging device with single-use disposable targets to acquire data. The system provides a fully 3D color representation of the wound with a wide variety of measurement tools, including a form of color analysis. The system is known to support networked operation with basic data export to third-party EMR systems. Several credible publications exist on this system's measurement accuracy in well-known journals,[24,25] and a preliminary investigation into the accuracy of remote assessment supports the potential for the system to be used for telemedicine.[25] In this article, remote assessment is the validation of clinically relevant observations made from a remote view of 3D wound images. At least one published paper examines clinician and patient feedback on the system, in the context of healing wounded soldiers.[26] There are also several examples of the system being used beyond wounds, for example, quantifying inflammation due to tattooing[27] and scarring.[28]

Wound Zoom (Wound Zoom, CO) uses a bespoke handheld imaging device with projected laser dots alongside a camera sensor to acquire a 2D image with depth and skew correction. Evidence of measurement accuracy can be found in the work of Nemeth and coauthors.[29] There is presently a lack of clinical publications supporting other aspects of the system. Wound Zoom supports portable document format output, which may allow basic integration with third-party systems.

PictZar (BioVisual Technologies, LLC, NJ) is wound measurement software that can perform planimetry on 2D digital images acquired with a scale available in the image. The images themselves can be acquired with any digital camera and then loaded into the software. Measurements acquired using the system have been validated, including inter-rater reliability;[30] user experience is also documented. The system supports exports of reports, including pressure ulcer scale for healing score, which may facilitate integration with third-party systems.

In addition to the dedicated clinical imaging systems mentioned here, there are also several examples of general-purpose 3D imaging systems being used to measure wounds.[31,32] The Next Engine Laser Scanner HD (NextEngine Inc., CA) has been demonstrated to have application in the assessment of cutaneous leishmaniasis wounds.[32] The Konica Minolta Vivid 910 (Konica Minolta, Tokyo, Japan)[33] and Polhemus FastSCAN (Aranz, Christchurch, New Zealand) have similarly been shown to be of use in imaging and measurement of wounds.[34] The generalist 3D imaging space has a continual drive for decreased cost and improved image quality, making these systems increasingly attractive for the wound measurement application. However, there is not as yet an "off-the-shelf" clinical wound measurement solution available for use with these hardware platforms.

Finally, a review of smartphone app stores reveals a number several smartphone applications aimed at imaging and measuring wounds. Of these, Mobile Wound Analyzer (Health Path Srl, Rome, Italy) appears the most capable and best supported. It claims planimetric measurement capability based on having a scale in the image and the ability to determine tissue type in the wound bed (necrotic, fibrinous, and granulation). Presently there does not appear to be any published clinical evidence to support these claims.

Conclusion

Accurate, reliable, reproducible measurements have been important cornerstones in medical practice used in objective assessment and benchmarking success. Accurate determination of ulcer size is widely accepted as an indication of wound closure and, thus, of wound healing. While ruler and hand-tracing methods are simple to use, they are limited by the subjectivity of the point-of-care assessor. The newer digital methods and optical systems that have been evaluated still require clinician input to demark wound boundaries for measurement; however, they can then automate higher-order metrics, such as wound area and volume. These systems also offer an opportunity to reduce intraobserver bias, as a single clinical expert can perform the markup on data collected by potentially many different clinicians at the point of care.

It is evident that wound imaging with clinically validated measurement can be beneficial to the healing process. Continual technical improvements, alongside the burgeoning clinical evidence, suggest that eventually these techniques will be commonplace and accepted as the standard. Telemedicine, facilitated by electronic imaging and measurement systems as described in this article, has great potential to reduce cost and improve standards in wound care; this derives from reducing patient and clinician transport and providing higher-level and more immediate access to expert clinical knowledge. However, while several existing commercial products, notably the Aranz and Eykona systems, have a reasonable body of associated clinical evidence, the pace of technological development means the field remains rapidly changing; the authors are aware of several groups active in this area of research.[31,35,36] As yet, no system has demonstrated widespread adoption in routine clinical use.

Disclosure:

James Paterson is an employee, director, and shareholder of Eykona Medical Ltd.

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