RESEARCH LETTERS

Digital Image Analysis: A Reliable Tool in the Quantitative Evaluation of Cutaneous Lesions and Beyond

Quantitative evaluation of cutaneous lesions in clinical trials can be problematic for diseases such as lower extremity ulcers, vitiligo, and alopecia. Because of the irregular shapes of these lesions, calculation of their circumference, diameter, and area can be cumbersome using traditional manual tracings. As a result, most trials using manual tracings will measure the longest diameter or approximate circumference of a target lesion. To compound the problem, in some diseases, access to the lesions is difficult. These lesions include erosions of the oral or genital mucosa. New software is now readily available that incorporates digital technologies and allows for digital image analysis (DIA) to circumvent these traditional problems. Digital image analysis provides a means to calculate desired target diameter and area with ease.

Our objective was to compare the interrater reliability and application feasibility of Image Pro Express (Media Cybernetics, Silver Spring, Maryland) DIA software with traditional manual tracings to determine the area of lower extremity ulcers.

Methods. Our study was imbedded in a larger randomized, double-blind, placebo-controlled trial, and inclusion and exclusion criteria was previously described by Sumpio et al.[1] After approval from the respective institutional review boards, participants were recruited from vascular surgery and podiatry clinics from a total of 16 sites in the United States.

Each site provided both digital images and transparencies with manual tracings of the target ulcers (**Figure 1**). Of the 3 possible readers, 2 readers outlined the target ulcers from both the digital images and the transparencies. At all sites, digital images were obtained using a Nikon (Melville, New York) Coolpix 8800 camera. Furthermore, all images were obtained using standardized procedures; notably, the target ulcers were positioned 6 inches away from the camera and facing the light, to avoid any shadows. A metric ruler was placed on both the digital images and transparencies to allow for measurement calibration. Once the digital images were obtained, they were uploaded into an IBM (Chicago, Illinois) desktop computer, and the perimeter of each ulcer was outlined electronically by the 2 readers using a wireless mouse (**Figure 2**). Concurrently, the respective transparencies with manual tracings outlined by the 2 readers were scanned into the computer using a standard IBM flatbed scanner. We then used the Image Pro Express DIA software to determine the diameter and subsequent area of the target ulcers for both the digital images and the manual tracings.

Continuous variables were calculated as means ± SDs and were compared by *t* test or analysis of variance where appropriate. Categorical variables were compared by χ^2 analysis. Finally, agreement between raters was determined by intraclass correlation coefficient. Reliability of DIA was determined by comparing the area obtained from DIA to the area obtained from manual tracings. $P < .05$ was considered statistically significant.

Results. A total of 99 patients with lower extremity ulcers were recruited into the study. The mean ± SD patient age was 66 ± 13 years; 65% were men (n = 65), and 64% were white (n = 64). In addition, 77% of the lower extremity ulcers were from participants who were diagnosed as having diabetes mellitus (n = 76).

Of the 99 patients in the study, 91 patients had manual tracings and 91 had digital images; 87 had both. The mean ± SD lower extremity ulcer area measured by reader 1 was 3.27 ± 3.53 cm^2 in the manual tracings and 3.08 ± 3.15 cm^2 in the digital images. Similarly, the lower extremity ulcer mean ± SD area measured by reader 2 was 3.28 ± 3.50 cm^2 in the manual tracings and 3.11 ± 3.18 cm^2 in the digital images. The intraclass correlation coefficient between the 2 readers for manual tracing and digital images was 0.9994 and 0.9978, respectively. There was no statistically significant differences in areas between manual tracings and digital images (paired *t* test $P = .12$; 95% confidence interval, –0.51 to 0.06 cm^2).

Comment. In our study, we demonstrated that area can be reliably measured across raters using DIA in targeted lower extremity ulcers. Also, we have shown that the results from the DIA approach are not significantly different from those of traditional manual tracings.

While traditional manual tracings have been the gold standard method by which to evaluate lower extremity ulcer circumference, diameter, and area, manual tracings can be cumbersome given the irregular shapes of these lesions. However, DIA can provide quantitative evaluation of target lower extremity ulcers with greater ease and efficiency. Therefore, we propose that if DIA is as reliable as traditional manual tracings, DIA may be used to estimate the size of lower extremity ulcers when the investigator sees fit.

The use of DIA is not limited to lower extremity ulcers but also potentially extends to other difficult-to-measure lesions. Specifically, DIA may serve a vital role in the quantitative evaluation of other diseases involving irregular-border cutaneous lesions, such as vitiligo and alopecia, as well as difficult to access lesions, such as erosions of the oral or genital mucosa. In fact, DIA may prove to be not only useful and reliable but also more precise than traditional manual tracings.

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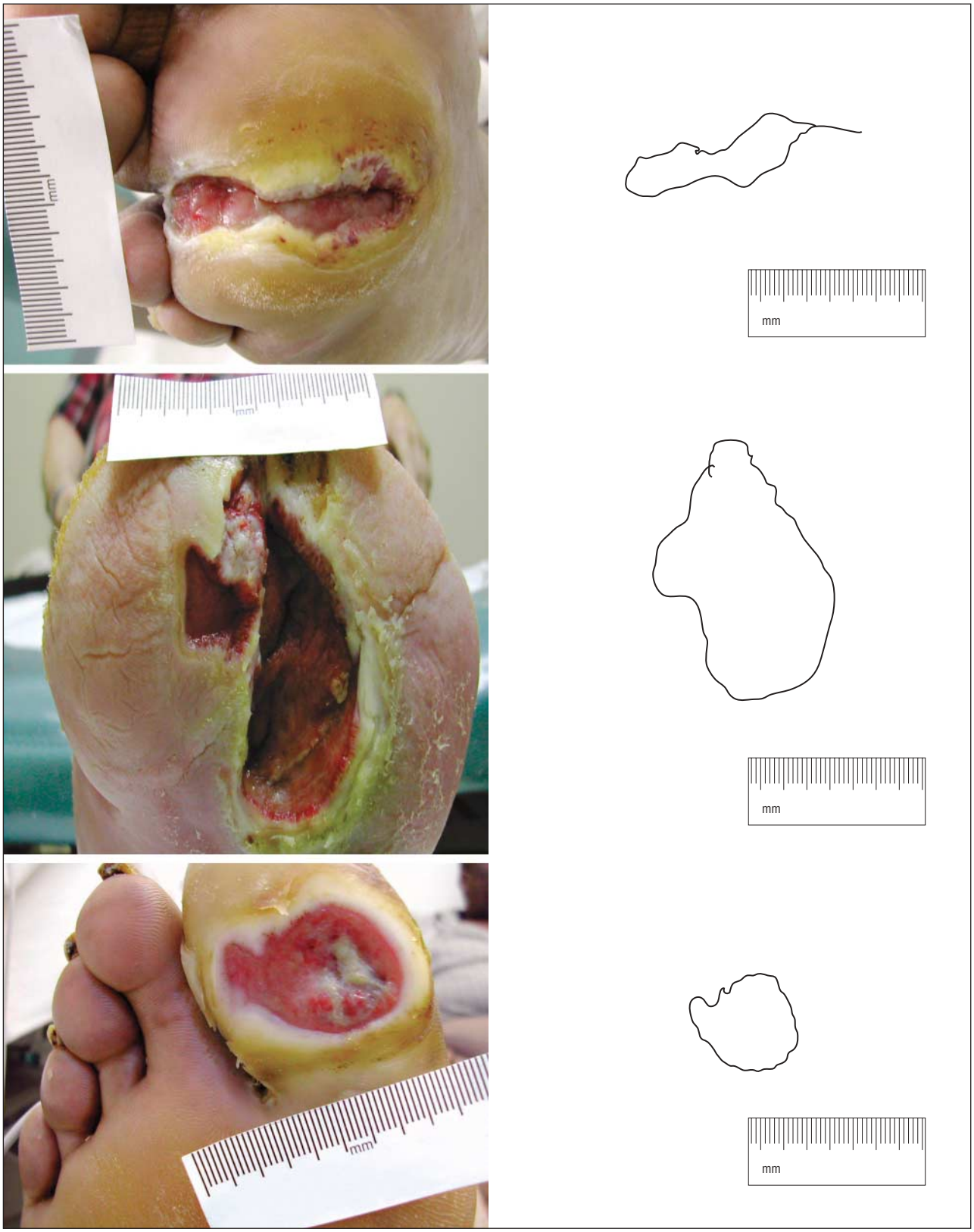

Figure 1. Three digital images with electronic manual tracings (left) and corresponding traditional manual tracings (right). All scales are given in millimeters.

The greatest limitation of the DIA technology is for use on lesions that cannot be accurately represented in 2 dimensions, such as large ulcers that wrap around the curvature of the limb. In this circumstance, several standardized images of the ulcer and complex reconstruction may be necessary. However, In general, patient positioning, body curvature, or tapering of the limbs, as well as compromised accessibility can be

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Figure 2. Procedure for using the Image Pro Express (Media Cybernetics, Silver Spring, Maryland) digital image analysis (DIA) software: (1) position target lesion toward camera at a set distance and toward a light source for standardization; (2) place ruler for calibration (present scale is in millimeters); (3) take digital photograph; (4) download image into computer running DIA software; (5) trace target, as demonstrated in this image; and (6) query DIA software to perform diameter and area calculations.

sources of measurement error for manual tracings, and in general, DIA provides a technology that can at least partially overcome these problems. Finally, it is important to note that DIA provides information beyond the quantitative evaluation of traditional manual tracings. Because DIA involves digital photography, it provides an image and thus a basis for objective evaluation of other end points such as infection, lesion thickness, granulation status, surrounding edema, and lesion progression over time, if used at sequential time points. Overall, additional studies are needed to further assess the uses of DIA in quantitative evaluation of other cutaneous lesions and beyond.

Zakiya M. Pressley, MD
Jovonne K. Foster, MS
Paul Kolm, PhD
Liping Zhao, MS
Felicia Warren, BA
William Weintraub, MD
Bauer E. Sumpio, MD, PhD
Suephy C. Chen, MD, MS

Correspondence: Dr Chen, Department of Dermatology, Emory University School of Medicine, 101 Woodruff Cir, Atlanta, GA 30322 (schen2@emory.edu).
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Wound Assessment by 3-Dimensional Laser Scanning

Recent advances in our understanding of the biology of cutaneous tissue repair have influenced current therapeutic strategies for chronic wound management and will continue to influence chronic wound management strategies into the future.[1]

An effective and accurate monitoring of skin lesions should be performed by measuring in an objective, precise, and reproducible way the complete status and evolution of the wound.[2] The main goal of current research projects is to design an easy-to-use technological system that can monitor the qualitative and quantitative evolution of a skin lesion.

This level of monitoring can be achieved by using 3-dimensional scanners: in particular, systems based on active optical approaches.[3] There are 2 different areas of potential applications of such types of devices: in medical treatment (to improve the efficacy of therapeutic regimens)[4] and pharmacologic scientific research (to assess the quality and effectiveness of new chemicals or clinical procedures).[5]

Methods. We prospectively examined 15 patients with venous leg ulcers. The patients who underwent sequential imaging of chronic wounds for this study all attended the leg ulcer clinic of the Wound Healing Research Unit at the University of Pisa, Pisa, Italy.

Our sequential imaging system is equipped with a Vivid 900 laser scanner (Minolta, Osaka, Japan), which is used for digitizing or scanning the wound shape. With regard to the calculation of the "external" surface and volume of a wound, it is necessary to assess its original shape to determine the missing volume virtually. At the time of patient presentation, information on the shape of the skin before the wound occurred is missing, and the technique for virtual reconstruction of the original wound surface must be as easy and user-friendly as possible. The system, relying on an analysis of the shape of the surface immediately outside the wound perimeter, creates an interpolating virtual surface that is continuously connected to the existing surface outside the wound and to that covering it.

The parameters we studied were the mean wound area (measured in square centimeters) and mean volume (cubic centimeters). To assess interrater reproducibility, scans were evaluated by 2 independent investigators. For assessment of intrarater reproducibility, a single investigator performed 2 consecutive measurements 5 minutes apart. Immediately after the first wound assessment of the first observer, a second observer, blinded to the findings of the first analysis, measured the same wound.

The means and standard deviations of duplicate determinations for each wound were used for analysis. The reproducibility of measurements was evaluated by means of an intraclass correlation coefficient (ICC) and its 95% confidence interval (CI).

Results. The measured total areas and volumes for independent raters and for subsequent measures of 1 rater are

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