**Abstract:** Traditional wound tracing technique consists of tracing the perimeter of the wound on clear acetate with a fine-tip marker, then placing the tracing on graph paper and counting the grids to calculate the surface area. Standard wound measurement technique for calculating wound surface area (wound tracing) was compared to a new wound measurement method using digital photo-planimetry software ([DPPS], PictZar® Digital Planimetry). *Methods.* Two hundred wounds of varying etiologies were measured and traced by experienced examiners (raters). Simultaneously, digital photographs were also taken of each wound. The digital photographs were downloaded onto a PC, and using DPPS software, the wounds were measured and traced by the same examiners. Accuracy, intra- and interrater reliability of wound measurements obtained from tracings and from DPPS were studied and compared. Both accuracy and rater variability were directly related to wound size when wounds were measured and traced in the traditional manner. *Results.* In small (< 4 cm²), regularly shaped (round or oval) wounds, both accuracy and rater reliability was 98% and 95%, respectively. However, in larger, irregularly shaped wounds or wounds with epithelial islands, DPPS was more accurate than traditional measuring (3.9% vs. 16.2% [average error]). The mean inter-rater reliability score was 94% for DPPS and 84% for traditional measuring. The mean intrarater reliability score was 98.3% for DPPS and 89.3% for traditional measuring. In contrast to traditional measurements, DPPS may provide a more objective assessment since it can be done by a technician who is blinded to the treatment plan. Planimetry of digital photographs allows for a closer examination (zoom) of the wound and better visibility of advancing epithelium. *Conclusion.* Measurements of wounds performed on digital photographs using planimetry software were simple and convenient. It was more accurate, more objective, and resulted in better correlation within and between examiners.

**The treatment of acute and chronic wounds continues to be a challenge in the medical community.** Today, a clinician has more choices than ever to select a particular treatment regimen for a patient. Investigating the wound etiology and classifying the wound is only the beginning.
of the decision process. Treatment decisions are based on clinical impressions and observations, most notably, the response of a wound to the chosen treatment. For most wounds, wound closure is the goal or end point that is desired by both clinicians and patients alike. Patients often become frustrated and disappointed with the process when wounds deteriorate or respond less than optimally during treatment. Patients and clinicians tend to forget the original presentation of the wound when the treatment plan is selected. Many weeks and months may pass during the treatment period of a chronic wound. The initial presentation and evaluation of a wound is important to archive and should include the wound morphology (size, shape, location, etc.) along with photographic documentation. Additionally, there are other reasons medically and legally to adequately record and archive wound images during treatment.1,2 Wound photographs and measurements provide a history, along with objective information by which progress, or lack thereof, can be monitored. More importantly, accurate wound measurements that signal improvement after 4–6 weeks may be a reliable predictor for complete healing. For example, the percent signal improvement after 4–6 weeks may be a reliable predictor (93% sensitivity) of complete closure within 12 weeks.5 Furthermore, a retrospective analysis of a large multicenter venous ulcer trial to establish prognostic factors for healing concluded that ulcers that were slow to heal (< 40% decrease in surface area) after 3 weeks are unlikely to heal rapidly and might benefit from alternative therapies.6 The predictability of healing based on reduction in wound area after 4–6 weeks can help determine if a patient should continue with standard wound care, requires more advanced wound care therapy, or whether the goals for treatment should be modified to include other non-healing (palliative) endpoints.

Reimbursement is another reason to record accurate, serial wound measurements. Medicare and insurance companies require wound surface dimension data to determine the amount to pay for specialized (advanced) treatments, such as negative pressure wound therapy (NPWT), specialty support surfaces, and bioengineered skin constructs.7–9 Today, the US Centers for Medicare & Medicaid Services (CMS) reimbursement for wound debridement is based on the total surface area and not on the number of wounds debrided.10

**Wound Measurement Techniques**

**Linear measurements.** Simple dimensional assessment may be performed using a ruler or tape measure. Two linear measurements of a wound are taken; the first is made along the body axis (length) in the longest distance of a wound, margin to margin. A second measurement (width) is made perpendicular to the length across the body axis (also at the widest distance in this second plane). It is not sensitive enough to detect minor changes in wound area. Also, the places where the measurements are taken on the wound are subject to significant inter-rater variability and change at each clinic encounter. Linear measurements are the most popular methods because of the low cost and minimal time involved to acquire wound parameters. Also, the majority of electronic medical records only have fields for these parameters. Using linear measurements to calculate surface area imply that the wound is rectangular; therefore, surface area is more accurately assessed using a tracing of the wound and planimetry.

**Wound tracings to determine surface area.** Currently, the most efficient way to measure wounds is by tracing the perimeter of the wound margin with a marker on clear acetate or other similar film. This has been considered the gold standard and is most widely used in research studies.11–16 The surface area of the tracing is usually calculated by superimposing the clear (transparent) acetate (containing the tracing) over a graph paper grid. A problem that introduces errors in counting grid squares

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**Keypoints**

- Many weeks and months may pass during the treatment period of a chronic wound. The initial presentation and evaluation of a wound is important to archive and should include the wound morphology (size, shape, location, etc.) along with photographic documentation.
- Reimbursement is another reason to record accurate, serial wound measurements. Medicare and insurance companies require wound surface dimension data to determine the amount to pay for specialized (advanced) treatments, such as negative pressure wound therapy (NPWT), specialty support surfaces, and bioengineered skin constructs.
is when the tracing line divides the squares in half, thirds, or quarters.\textsuperscript{12,13} It is time consuming and difficult to estimate the size of these partial squares. Performed properly, this method may be accurate and reproducible if the tracing and the measurements are done by the same individual and the wound is relatively small and uniform in shape.\textsuperscript{11} In addition to the time to trace and manually calculate the surface area, there are other disadvantages to this method. Tracings are often complicated by condensation that causes “fogging” of the film surface, which obscures the wound margins. Lighting conditions often cause reflections and shadows that can prevent the clinician from seeing the wound. Clinicians performing the tracing procedure must also be adequately trained to recognize migrating epithelium and to determine wounded from unwounded skin. Tracings can also contaminate the wound surface and are sometimes painful to the patient. A number of studies have reported the reliability of this tracing method when it is performed properly.\textsuperscript{1,11–16}

**Computerized Tablets and Other Devices**

Improvements to the tracing procedures include computerized assisted tablets (Visitrack\textsuperscript{\textregistered} Smith & Nephew, Inc., Largo, FL) to determine surface area as the wound is traced. First the wound is traced on a transparent grid (a clear acetate sheet) directly on the patient. The wound tracing (obtained on the clear acetate sheet) is then retraced onto a digital tablet. The default result is wound area, but other functions also provide width and length measurements. This provides a more accurate assessment than manual area calculations obtained from placing a tracing over grid paper and counting the squares. The accuracy calculated by the tablet is dependent upon proper tracings and therefore are subject to the reliability of two tracings (one on the patient and a retracing on the tablet). One advantage of this device is that the surface area calculation results are available immediately after the two tracings have been performed.

There are other digital planimetry methods that also use wound outlines. A tracing (wound perimeter) is acquired from the wound using a clear film and a fine-point marker. The tracing is again retraced on a digital artpad with a stylus (Model ET0405-L1, Wacom Co. Ltd, Taiwan). The tracing is then digitized and saved to a computer where it is visualized with Imagej software (ver. 1.09y, National Institutes of Health), which calculates area and other surface measurements.\textsuperscript{13,14} Other digital planimetry methods have been described where a photograph of the wound is projected on a paper screen with or without grids. The image can be retraced, at which point, computer aided drafting software is used to calculate surface area.\textsuperscript{13,14} There is also a newer hand-held personal digital assistant ([PDA], Silhouette\textsuperscript{\textregistered} Mobile, Aranz Medical, Christchurch, New Zealand) that employs a camera with two fan laser beams that are used to both capture the wound image and provide measurements found within a drawn perimeter.\textsuperscript{17} First, the camera within the field takes a photograph of the wound within the projected laser beam field. Then the perimeter of the captured wound image on the PDA is traced with a stylus and the surface area is computed in real time. Inaccuracy in tracing the image of the wound can occur with larger, irregularly shaped wounds because the image is significantly reduced given the screen size of the Silhouette device (approximately 6 cm x 5 cm). The device also offers the option to include wound depth measurement.

**Digital Photo Planimetry**

Newer software has made it possible to calculate wound area from digital photographs. One program (VeV MD, Vista Medical, Winnipeg, Canada) involves capturing the image with a video camera and orienting the image using a disposable target plate used for calibration. Wound area and surface calculations may be obtained after the orientation procedure is performed on the digital photograph. The software provides a dotted frame perimeter that surrounds the wound photograph. Using the computer mouse, each dot can be pulled in to outline the perimeter of the wound. This method is fairly simple to use with wounds that have regular margins. However, with wounds that have serpiginous (irregular) margins or

**Keypoints**

- Two hundred wounds of varying etiologies were measured and traced by experienced examiners (raters). Simultaneously, digital photographs were also taken of each wound.
- Wound tracings were acquired by placing a clear sterile acetate film over the wound and tracing an outline of the wound margin (circumference) with a fine point permanent marker. Five trained examiners made the tracings for the interrater variability portion of the study. Wound length and width were measured at the time of the tracing. All digital photographs were taken immediately after the tracing procedure.
- Accuracy, intra- and interrater reliability of wound measurements obtained from tracings and from DPPS were studied and compared.
wounds that are populated by epithelial islands, the surface area calculations are more difficult to perform.

Another software program that utilizes photo-digital planimetry is PictZar® Digital Planimetry Program Software (BioVisual Technologies, LLC, Elmwood Park, NJ). This technology is able to fill in the wound surface area without relying on a drawn perimeter. The program also allows the evaluator to define and measure specific tissue types within the wound by varying the color of the digital paint. This method defines different surface areas and calculates percentages of each type for the clinician (Figure 1A).\textsuperscript{18,19}

**Methods**

In this study, digital photographs (3 megapixels and higher) were obtained with either a Fuji FinePix F-440, Nikon D5000, or Sony T300 digital camera. A ruled adhesive sticker or a ruler was placed next to the wound and was included in the framed photograph (a ruler must be included in the photograph for image calibration). The ruler was also used to show the date the image was captured and patient identification. The digital photographs were downloaded to a PC via a USB connection or wirelessly and securely using an Eye-Fi SD memory card (Eye-Fi, Mountain View, CA) making the photograph instantly available for analysis on a tablet PC. Digital photo planimetry software (DPPS) was used to perform the wound measurements from the digital photographs. Images are captured by pointing the camera straight over the wound. Pictures are taken at any distance from the wound surface insuring that the wound fills the majority of the picture field with a border comprised of the peri-wound surface. Length, width, surface area, and circumference are calculated automatically after a simple 2-step calibration and tracing with a computer mouse (Figure 1B). When prompted, a manual measurement can be entered if wound depth is desired to calculate wound volume. A

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**Figure 1A.** Original photo (left) comprised a wound bed of varying tissues. The clinician may assign a color and paint the tissue (right). In this example, blue is eschar, green is fibrin, and yellow is granulation tissue. The program calculates surface areas of the tissue sub types along with the percentages of each type in the wound bed.

**Figure 1B.** After image acquisition (left) and a simple calibration, the clinician may perform measurements (right) that can include length (red line), width (blue line), surface area (purple area), and circumference (green line).
tablet computer (ASUS EEE Slate, Asustek Computer Inc, Taipei, Taiwan), a digital tablet pad and stylus (Bamboo Pen & Tablet, Wacom Technology, Ltd, Japan), or touch screen monitors make the software easier to use compared to using a standard computer mouse. The software manages the images and data in patient folders in addition to serving as an image viewer. Stored data show calculating percent change in wound surface area, as well as the surface area of other identified tissue types (Figures 2A, 2B). Graphs are generated that display the changes in wound surface area providing a clear picture and healing progression over time. Reports containing the images and data can be imported into the electronic medical record or another data software program (Editor’s Note: Please refer to the online version of this article on woundsresearch.com to view additional figures). Software validation for DPPS was performed by the appropriate ANSI/ASME compliant procedure and in accordance with good engineering practice for optical- and video-based metrology systems.

**Comparison of DPPS and Manual Wound Tracings**

Two hundred patients whose chronic wounds were being treated on an outpatient basis participated in this study. A variety of wound types, including diabetic foot ulcers, venous stasis ulcers, inflammatory ulcers, and pressure ulcers, were measured.

Wound tracings were acquired by placing a clear sterile acetate film over the wound and tracing an outline of the wound margin (circumference) with a fine-point permanent marker. Five trained examiners made the tracings for the interrater variability portion of the study. Wound length and width were measured at the time of the tracing. All digital photographs were taken immediately after the tracing procedure (Figure 3).

The tracing method (most common measurement in wound healing studies) was performed as detailed previously. The acetate tracing was placed over a 5-mm grid and the squares that fit inside the wound circumference were counted to determine surface area. All partial grids divided by the tracing line were included. The number of grids that fit within the traced circumference were counted (4 squares x 0.5 cm = 1 cm²) and the surface area in square centimeters was determined.

Inter-rater variability was determined by comparing the tracings of the same wound performed by the five examiners. Surface area was the only measurement compared. The five examiners also measured and traced the digital photographs from the same wounds using the DPPS. Intra-rater variability was determined by comparing...
triplicate tracings of wounds in each of three size categories (small wounds: 1 cm²–4 cm²; medium wounds: 5 cm²–10 cm²; large wounds: 11 cm²–40 cm²). Only three trained examiners participated in the intra-rater variability study.

Reliability was assessed using the intra-class correlation coefficients (ICC) equation. The type of ICC was selected based on a one-way ANOVA as described previously. A minimally acceptable ICC of 0.75 was chosen arbitrarily. A two-sample t test was used to determine whether there was a significant difference between the mean wound areas and standard errors for each of the two methods.

Results

All measured wounds were divided into three groups: small (1 cm²–4 cm²), medium (5 cm²–9 cm²), and large (10 cm²–40 cm²). The surface areas and standard errors (examiner variability) of wounds measured by manual tracing and DPPS are presented in Table 1. Examiner variability was directly related to the size of the wound regarding both traditional and photo-digital methods of wound measurement. When the wounds were manually traced, the rater variability (standard error) was 3.4 times greater in the medium and 12 times greater in the large wound category when compared to the variability observed in the small wound group. The standard error for DPPS was 1.08 times greater in the medium and 10.3 times greater in the large wound category. The rater variability was lower in all wound size categories when the wounds were measured with DPPS (P < 0.05 in the medium and large wound categories). The inter-rater reliability was 94% using DPPS and 84% with the manually tracing method. Intra-rater variability was also greater in larger wounds regardless of measurement method (Table 2). However, there was greater intra-rater variability with the manual tracing technique. The intra-rater reliability was 98.3% using DPPS and 89.3% with the traditional tracing method.

Linear measurements were also accurate (97% correlation when compared to DPPS) when the wound size was small. Linear measurements were considerably less accurate when the wound’s shape was irregular. In large wounds that contained epithelial islands there was a distinct advantage when using the DPPS method (Figure 4). When these wounds were traced manually, examiner variability was ± 16.2% compared to 3.9% when the same wounds were measured with DPPS. Figure 5 demonstrates the correlation between manual tracing and DPPS wound measurement procedures. The degree of correlation was directly proportional to wound size.

Discussion

Traditionally, wound care has been thought of as more

**Keypoints**
- When the wounds were manually traced, the rater variability (standard error) was 3.4 times greater in the medium and 12 times greater in the large wound category when compared to the variability observed in the small wound group.
- The inter-rater reliability was 94% using DPPS and 84% with the manually tracing method. Intra-rater variability was also greater in larger wounds regardless of measurement method (Table 2).
- Measurement of wounds performed on digital photographs using DPPS was more accurate, more objective, and resulted in better correlation within and between examiners.
of an art than a science. However, within the last 40 years the science of wound care has advanced considerably. As scientific knowledge of wound healing increases, the choice of treatments has become easier since it can be based on scientific evidence. Currently, wound care research relies on wound measurements to determine wound improvement and healing. If performed by the same examiner, traditional linear wound measurements and tracings provide useful information about healing; however, as demonstrated in the present study, linear measurements are only reliable in smaller wounds. In larger or irregularly shaped wounds, traditional measurement methods lack accuracy and reproducibility. Recent CMS guidelines on reimbursement following a debridement procedure require surface area measurements. Typically, length x width will provide a surface area greater than the actual wound size since it converts all shapes to a rectangle. In the post-debridement setting, DPPS provides accurate measurements of surface area regardless of wound shape (Figure 6).

To the authors’ knowledge, this is the first study that compares the reliability of traditional wound measurement

Table 1. Standard error and inter-rater reliability of wounds measured by manual tracing and DPPS.

<table>
<thead>
<tr>
<th>Measurement method</th>
<th>Small wound (1 cm²–4 cm²)</th>
<th>Medium wound (5 cm²–10 cm²)</th>
<th>Large wound (11 cm²–40 cm²)</th>
<th>Interrater reliability (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual tracing</td>
<td>0.21*</td>
<td>0.72</td>
<td>2.52†</td>
<td>84</td>
</tr>
<tr>
<td>Photo-digital planimetry</td>
<td>0.12</td>
<td>0.13**</td>
<td>1.24**†</td>
<td>94</td>
</tr>
</tbody>
</table>

*Average standard error (rater variability) in each size category
**P < 0.05 compared to manual tracing
†P < 0.05 compared to small wound category

Table 2. Standard error and intra-rater reliability of wounds measured by manual tracing and photo-digital planimetry.

<table>
<thead>
<tr>
<th>Measurement method</th>
<th>Small wound (1 cm²–4 cm²)</th>
<th>Medium wound (5 cm²–10 cm²)</th>
<th>Large wound (11 cm²–40 cm²)</th>
<th>Intrarater reliability (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manual tracing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rater #1</td>
<td>0.34</td>
<td>0.64</td>
<td>2.82</td>
<td>0.893</td>
</tr>
<tr>
<td>Rater #2</td>
<td>0.25</td>
<td>0.95</td>
<td>1.77</td>
<td></td>
</tr>
<tr>
<td>Rater #3</td>
<td>0.19</td>
<td>0.39</td>
<td>1.33</td>
<td></td>
</tr>
<tr>
<td>Photo-digital planimetry</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rater #1</td>
<td>0.02</td>
<td>0.03</td>
<td>0.76</td>
<td>0.983</td>
</tr>
<tr>
<td>Rater #2</td>
<td>0.03</td>
<td>0.04</td>
<td>0.68</td>
<td></td>
</tr>
<tr>
<td>Rater #3</td>
<td>0.025</td>
<td>0.04</td>
<td>0.59</td>
<td></td>
</tr>
</tbody>
</table>

Figure 4. Large wounds that have epithelial islands are difficult to trace accurately. Many healed areas have been missed, as seen in the manual tracing (center). The epithelial islands can be seen easily and accurately calculated with photo-digital planimetry (right).
(tracing technique) in small, medium, and large wounds. It is also the first study to compare the traditional tracing technique with a more modern (computerized) method (DPPS). A previous study compared wound measurements obtained from tracing photographs and direct wound tracings, and concluded that with inter-rater reliability scores > 96%, both methods were reliable. In another study, graph paper counting, weighing, or planimeter techniques were equally effective and reliable to calculate surface area of wound tracings. In the studies reviewed, the largest involved 20 wounds and all wounds of varying sizes were pooled for reliability assessments. The present study demonstrates that linear measurements, wound tracings, and DPPS are reliable in smaller, regularly shaped wounds (1 cm²–4 cm²). However, in larger and especially irregularly shaped wounds, both intra- and inter-rater reliability decreases significantly, especially when using traditional tracing and graph paper counting. DPPS was superior (less variability) to the traditional wound tracing technique in the present study. DPPS was also easy and convenient to use. The measurements and tracings can be performed non-invasively on the digital image of the wound where the wound can be clearly visualized. It also has the advantage that the wounds can be assessed by a trained technician who can be blinded to the treatment. This is particularly beneficial when performing multi-center healing studies. One disadvantage of DPPS is with wounds that are circumferential (that either do not completely fit in the frame or are too curved for accurate calibration). With such wounds, it might be necessary to use multiple frames that are patched together for proper measurement. Circumferential wounds were not included in this study; therefore, conclusions as to the accuracy and variability of surface area cannot be made. When a digital photos is taken, the photograph must be framed squarely (the camera should be perpendicular to the wound) in order to avoid distortion or angular perspective. Lighting may be a consideration (including a camera flash being too bright). Since digital photographs can be viewed instantaneously, framing and lighting problems can be corrected. Some planimetry programs involve specific distance restrictions while the digital photograph is being taken. The software program used in the present study does not have a distance restriction. The present study only compared traditional tracing and graph paper counting with DPPS. More studies are needed to compare DPPS with wound tracing and digitized planimetry with a computerized pad and with laser guided imaging.

**Conclusion**

Measurement of wounds performed on digital photographs using DPPS was more accurate, more objective, and resulted in better correlation within and between examiners. Traditional (linear) and tracing planimetry was only reliable when wounds were small (1 cm²–4 cm²) and regularly shaped. Wounds may be archived and studied serially with photo-digital software. Wound measurement data can also be retrieved and exported to other statistical or analytical

![Figure 5. Correlation between manual tracing (y axis [red dots]) and DPPS (x axis [black squares]) wound measurement procedures. Note the closer correlations between measurement techniques in the smaller wounds.](Image)

![Figure 6. Inflammatory ulcer (Pyoderma gangrenosum) with central healing is a challenge to measure using a ruler (L x W) or manual tracing; however, DPPS makes measuring irregularly shaped wounds easy by digitally painting the area with a mouse or tablet PC stylus.](Image)
software for tabulation. Digitally signed wound reports, graphs, and historical data can be created and available for importing into electronic medical records.

Acknowledgements
Disclosures: This study was supported by a grant to Calvary Hospital’s Wound Care Program from: The RTS Family Foundation (Woodbridge NJ) and New York State Department of Health (Offices of New York State Senator Charles J. Fuschillo, Jr). Martin Wendelken is a principal of BioVisual Technologies, LLC, Elmwood Park, NJ and was involved in the design and programming of PictZar® CDM planimetry software used in this study. William Berg, Philip Lichtenstein, Oscar Alvarez, Lee Markowitz, and Christopher Comfort disclose no financial conflicts.

References

Key points
- The present study only compared traditional tracing and graph paper counting with DPPS. More studies are needed to compare DPPS with wound tracing and digitized planimetry with a computerized pad and with laser guided imaging.