

Efficacy and Prognostic Value of Simple Wound Measurements

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Objectives: To assess the association between planimetric wound area and simple wound measurements. To ascertain the applicability of planimetry-based research to clinical practice.

Design: A retrospective cohort study of 260 consecutive patients followed up for at least 24 weeks.

Setting: Outpatient dermatology department of a major medical center.

Intervention: Wounds were measured using computer-based planimetry and were treated according to a standard protocol for venous leg ulcers.

Patients: Two hundred sixty patients with venous leg ulcers.

Main Outcome Measures: Complete ulcer healing at 24 weeks.

Results: Using the Pearson, Spearman, and Kendall correlation coefficients, we found a tight correlation between planimetric wound area and wound width, length, width \times length, perimeter, and area based on the formula for an ellipse. The values for all correlation coefficients were greater than 0.80 ($P < .001$ for all associations). Width, length, length \times width, and elliptical area measurements all correlated closely with failure to heal ($P < .001$). The correlation between simple values and planimetric area dropped considerably for wounds more than 40 cm², which represented 6% of the wounds in this study.

Conclusions: The equivalence between simple and planimetric wound measurements allows for the extrapolation of wound measurements from clinical trials to clinical practice, and suggests that simple wound measurements may confidently be used as predictors of healing in the clinical setting.

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FOR OVER a century, dermatologists have recognized the importance of measuring wound area.^{1,2} Currently, wound area is used as an end point in clinical trials and to follow up patient progression or regression,^{3,4} and it is generally determined by using computer-based planimetry. Computer-based planimetry is a method of measuring wound area that requires the physician to trace the wound and then use specifically designed computer hardware and software to calculate the area within the trace. The physician may need to retrace the wound boundaries using a pen device attached to the computer, or the computer may compute the area from a scanned or digitally photographed image or trace.

While clinical studies adopt planimetric methods of wound analysis, most practitioners rely on simple wound measurements such as area, length, width,

and perimeter.⁵ Although it is assumed that these simple measurements adequately represent wound size and are thus interchangeable with planimetric data, this has never been systematically established.

In clinical trials, wound area is the most commonly reported property of wounds. In an effort to provide a highly accurate and precise measure of wound area, numerous studies have compared different modalities of measuring this parameter.⁶ Among the many possibilities for area ascertainment are tracing the wound and recording the trace,⁷⁻¹⁰ tracing the wound and then cutting out the trace and weighing it,⁷ tracing the wound onto block paper and then counting blocks,¹¹ photography,⁶⁻¹⁰ the use of a specifically designed coordinate measuring device,⁸ and planimetry.^{8-10,12}

The purpose of our study is to assess the association between planimetric wound area and simple wound measurements, and

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PATIENTS AND METHODS

A study was conducted on a cohort of 260 consecutive patients with venous leg ulcers at the Cutaneous Ulcer Center of the University of Pennsylvania Medical Center in Philadelphia, Pa, between 1993 and 1995. All patients were evaluated by one of us (D.J.M.) using a standard protocol, and were treated with a multilayer compression bandage.¹³ Patients were evaluated until they healed or for 24 weeks. The mean ulcer size was 10.5 cm² (range, 0.04-113.2 cm²). This cohort has been described in detail elsewhere.¹⁴ Planimetric measurements of wound size were abstracted from patient charts on the first office visit, along with other measurement variables, including length, width, and perimeter.

One parametric and 2 nonparametric methods were used to estimate the association between planimetric wound area and wound width, wound length, wound width \times length, wound perimeter, and wound size based on the area of an ellipse. The Pearson correlation coefficient provides an estimation of correlation based on assumptions similar to those used in linear regression analysis, including the presence of a normal distribution of values for each variable. Nonparametric methods do not require a normal distribution of values to be effective. The Spearman rank correlation coefficient assigns ranks to each variable in lieu of their actual values to assess a positive relationship between each bivariate pair. The Kendall rank correlation coefficient (Kendall τ) assesses the presence of a concordance or discordance between the 2 variables.

Logistic regression analysis was used to establish the relationship between individuals healed at 24 weeks and the wound measurements. These are presented as the z statistic P values of the odds ratios of association between healing and each wound measurement.

Wound width and length were chosen as measurement criteria for their obvious utility and ease of use. Width \times length was adopted as an approximation of the area of a rectangle, and thus assumes that wounds are essentially rectangular in shape. Wound perimeter was used as a variable because some studies^{11,12} have suggested that cells on the wound perimeter determine the rate of wound healing. The area of an ellipse was adopted because many wounds approximate the shape of an ellipse. The area of an ellipse is given by

$$(0.5 \times \text{Length of Major Axis}) (0.5 \times \text{Length of Minor Axis}) (\pi).$$

Statistical analyses were conducted using Stata for Windows 95 version 5.0 (Stata Corporation, College Station, Tex).

to ascertain the applicability of planimetry-based research to clinical practice. It is not our goal to determine the best method of wound measurement. However, by demonstrating the association between planimetric area and simple wound measurements we hope to allow for the extrapolation of wound measurements

from clinical trials to clinical practice. By establishing the validity of width \times length as both an effective measure of total area and as a predictor of wound healing, this study suggests that such simple measures may be substituted for wound area in clinical practice. Since these simple measures correlate closely with computer-based planimetry, health care providers should feel confident in their ability to precisely quantify wound area.

Recent research based on planimetric wound measurements has focused on wound size as a predictor of healing or nonhealing.^{3,4} Our study demonstrates that there is a close correlation between wound size based on simple wound measurements and propensity to heal within a 24-week period. Thus, physicians may not only comfortably extrapolate wound data from clinical trials but may also be confident that simple wound measurements are in themselves predictive of healing.

RESULTS

Using the Pearson, Spearman, and Kendall correlation coefficients, we found a tight correlation between planimetric wound area and wound width, length, width \times length, perimeter, and area based on the formula for an ellipse. The values for all correlation coefficients were greater than 0.80 ($P < .001$ for all associations) (**Table 1**).

The close association between planimetric area and simple measurements decreases at greater wound sizes. Thus, for wounds larger than 40 cm², the correlation between planimetric area and these values drops substantially (**Table 2**). The closer association between planimetric area and simple measurements at smaller wound sizes is also evident from the graph of planimetric area vs length \times width (**Figure**). The greater variance between planimetric area and length \times width at higher wound sizes is representative of other simple measurement figures.

As previously reported, 92 (35%) of 260 patients in this study failed to heal (did not achieve complete wound closure) after 24 weeks of therapy. Increasing planimetric wound area and failure to heal correlated closely ($P < .001$).¹³ As expected from the close correlation between planimetry and simple measurements, we found a positive association between failure to heal and wound width, length, width \times length, perimeter, and area based on the formula of an ellipse (consistently $P < .001$).

COMMENT

These data suggest that simple measurements of wound area such as length, width, length \times width, perimeter, or area based on the formula for an ellipse provide an excellent representation of planimetric wound area. Furthermore, there is a close correlation between increasing wound size (based on any one of these simple measurements) and chance of nonhealing within a 24-week period, suggesting that these simple values may be used as prognostic indicators of healing within a 24-week period.

Table 1. Correlation Between Planimetric Area and Simple Wound Measurements*

	Pearson	Spearman	Kendall
Length	0.8750	0.9578	0.8313
Width	0.9109	0.9400	0.8022
Length × width	0.9532	0.9716	0.8828
Perimeter	0.8514	0.9828	0.8938
Ellipse area	0.9532	0.9716	0.8828

*For all values $P < .001$.

Table 2. Correlation Between Planimetric Area and Simple Wound Measurements When Area Larger Than 40 cm²*

	Pearson	Spearman	Kendall
Length	0.5340	0.6529	0.4917
Width	0.7724	0.7938	0.6333
Length × width	0.7875	0.8353	0.6667
Perimeter	0.5199	0.5471	0.4500
Ellipse area	0.7875	0.8353	0.6667

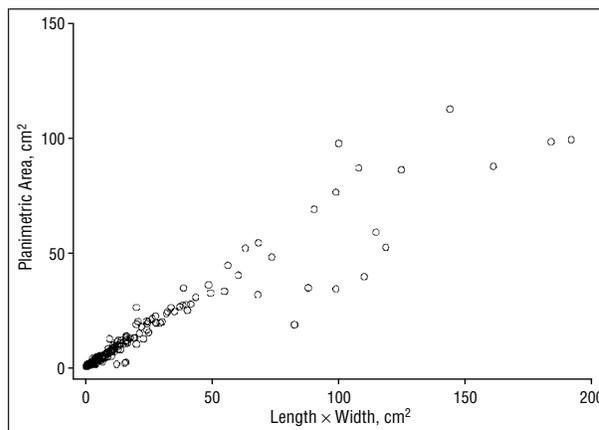
*For all values $P < .05$.

Nonparametric measurements may provide a better representation of correlation between planimetric area and simple measurements because these values are not normally distributed.¹⁴ Since Kendall τ has been said to underestimate concordances and the Spearman rank correlation coefficient to overestimate associations,¹⁵ the inclusion of both nonparametric methods, in addition to parametric data, should effectively represent the true association.

We divided our cohort into wounds larger than 40 cm² and smaller than 40 cm² to ascertain the differences in correlation between simple measurements and planimetric area at larger wound sizes. As was evident from the Figure, the correlation between these values decreases at larger wound sizes (Table 2). Nevertheless, even at wounds larger than 40 cm², which represent only 6% of the wounds in this study, there is a positive correlation between these values.

The loss of association between planimetric area and simple measurements at greater wound sizes may be a function of the heterogeneity of the shapes of large wounds. While smaller wounds approximate the shape of an ellipse, larger wounds may be more irregular in shape and thus less amenable to simple wound measurements. Although the decline in correlation between planimetric values and simple wound measurements at larger areas represents a limitation of this study, the small number of large wounds and the persistence of a positive correlation means that simple wound measurements mimic planimetric measurements most of cases.

Another limitation of this study is its focus on patients with venous leg ulcers, whose wound depth is generally not substantial and has little impact on healing. In other wounds, such as pressure ulcers, however, the depth¹⁶ and volume^{17,18} of a wound may be significant indicators of healing or nonhealing. This is a limitation of



The effect of increasing wound size on the correlation between planimetric area and simple wound measurements.

all area-based methods of wound assessment, and thus has no impact on our study per se.

We used the area of an ellipse as a formula for calculating wound area because many wounds approximate the shape of an ellipse. Since the major and minor axes of an ellipse are equivalent to the length and width of the wound, respectively, and because .25 and π are constants, it follows that the area of an ellipse based on this formula correlates directly with width \times length. Thus, while the area of an ellipse may provide a better estimate of actual wound size, it correlates with planimetric area no better than length \times width.

It has been agreed that wound measurement must be accurate, reproducible, sensitive, flexible, standardized, and informative.¹⁹ One of the recent trends in wound care research has focused on high-technology methods of wound measurement and assessment.^{9,20} While these methods may be appropriate for clinical research, where precise area measurements must be computed for treatment group comparisons,⁵ the most technologically complex methods of wound measurement are not accessible to most health care providers. To maximize generalizability, which is necessary if wound measurement is to be used to follow the progress of healing,³ it would be best to rely on the most health care provider-friendly method of measurement. This would allow clinicians to use a uniform method of measurement, and would provide a consistent measure of wound size and progression that could be used by all of an individual patient's physicians.

Our study has demonstrated that using a simple width \times length value for area, or even relying simply on wound width or length alone, provides an indicator of the wound that correlates closely with planimetric wound area. By establishing the essential equivalence between planimetry and simple wound measurements, practitioners may confidently equate planimetric measurements from clinical trials with simple measurements obtained in clinical practice. Since planimetric area has been shown to correlate closely with wound healing at 24 weeks,^{3,4} and since we have shown a close correlation between planimetric area and simple wound measurements, it would be expected to follow transitively that simple measurements are in themselves pre-

dictive of wound healing. Our analysis, based on logistic regression odds ratios for healing and wound size, confirms this conclusion. Using such simple wound measurements in lieu of planimetry in clinical trials, however, requires further study, as measurements must reflect a high degree of accuracy if they are to be used in treatment group comparisons. Therefore, the use of simple wound measurements represents an adequate and appropriate method for wound measurement in clinical settings, and these simple measurements closely reflect the more accurate planimetric measurements used in clinical trials.

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