Photographic Assessment of the Appearance of Chronic Pressure and Leg Ulcers

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ABSTRACT

The purpose of this paper was to examine the validity and reliability of using photographs of wounds to accurately assess wound status. The results of assessing wound appearance using wound photographs was compared to results obtained from a bedside assessment using the Pressure Sore Status Tool (PSST). The photographic wound assessment tool (PWAT) used in this comparison represents a modified version of the PSST and includes the six domains that can be determined from wound photographs. The PWAT was used on photographs of both chronic pressure ulcers (n = 56) and leg ulcers due to vascular insufficiency (n = 81). The photographic tool has excellent intrarater (ICC = 0.96) and interrater (ICC = 0.73) reliability and good concurrent validity (r = 0.70) compared with a full bedside assessment PSST. The PWAT has also shown to be sensitive to change in wound appearance of healing ulcers, but not nonhealing ulcers. These results would suggest that in the event that a full bedside assessment is not possible, wound photographs may be used to accurately assess wound appearance of both chronic pressure ulcers located on the trunk and vascular ulcers of the lower extremity. Establishing a valid and reliable assessment of wound healing using photographic images is of great relevance to the advancing fields of computer image analysis and telemedicine.

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An accurate and thorough wound assessment is an essential component of optimal wound care.[1–4] A wound assessment serves two important purposes: 1) to determine wound severity in order to predict expected rate of wound healing and develop a comprehensive plan of care and 2) to act as a reliable outcome measure that can be used to assess the effectiveness of a given wound treatment program. A key parameter that should be included in a wound assessment is the measurement of wound extent.[5] Several methods of determining wound size have been developed and validated including wound depth,[3] surface area,[6,7] length and width,[8] and volume.[9] These methods have been compared. And although each method of estimating wound size has inherent strengths and weaknesses, those used to determine wound surface area, rather than wound depth or volume, are believed to be most accurate and reliable.[8,10–13] A comparison of several different methods available to assess wound surface area has also been performed, and although stereophotographic determinations may be most accurate, the use of a wound tracing onto a transparent acetate or calculations made from length/width measurements are considered reliable and easy to use.[12–15]

Other determinants of wound healing that should be included in a wound assessment are the evaluation of wound bioburden and wound severity.[5] This requires examining wound exudate and necrotic tissue type, the

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amount and characteristics of necrotic tissue, granulation tissue, and reepithelialization, and assessing the viability of the wound edge and periulcer skin.[16] To assess these components of wound healing, several assessment tools have been developed including the pressure sore status tool (PSST),[17–19] the pressure ulcer scale for healing (PUSH Tool),[20] the Sussman wound healing tool (SWHT),[21] the Sessing Scale,[22] and the wound healing scale (WHS).[23] Recent reviews of these wound status measurement tools found that at least two of these scales (PSST and Sessing Scale) have sufficient published information to be considered valid and reliable measures of wound healing in chronic pressure ulcers.[24,25] All of these wound status tools or scales require that an expert healthcare professional who is trained in wound evaluation perform a bedside assessment of the wound bed, wound edge, and periulcer skin and assign a number to the wound that best describes the observations made. All of the instruments currently available to assess wound status (except for the WHS) were developed specifically for use on pressure ulcers. None have been shown to accurately assess the appearance of chronic vascular leg ulcers such as diabetic, venous, or arterial ulcers.

A recent survey of home healthcare agencies in the United States revealed that 75% of agencies included a wound photograph as part of the documentation procedures.[26] Additionally, numerous publications that describe how to perform a wound evaluation advocate the use of wound photographs to capture wound status.[27–29] Using wound photographs has some major advantages including the fact that photographs do not require that the provider come into contact with the wound. Photographs also identify the physical dimensions of the ulcer as well as the type of tissue present within the wound bed. According to Hughes,[28] "A medical photograph can transfer more information to a health professional than subjective descriptions, which are open to misinterpretation." In one reported case, photodocumentation was useful in obtaining medical reimbursement for a patient.[30] Several new types of automated and computerized technologies that capture and analyze photographic images of chronic wounds have been developed to assist the clinician with wound healing documentation.[14,15,18,31] Furthermore, visual images of wounds could be used to electronically transmit information about healing status to a remote location for consultation by a wound care expert. This application of telemedicine has been used to facilitate optimal wound care in patients who have chronic wounds and are not located in major health centers.[32] To date, as many as 83% of dermatologic conditions have been accurately diagnosed using telemedicine services.[33] Recently, Wirthlin et al[34] demonstrated that physicians viewing a wound image using computerized imaging technology were able to determine the presence or absence of wound descriptors and showed agreement on basic wound management decisions such as whether the patient required further investigation. Despite the relatively frequent use of wound photographs to document wound healing, it is unknown whether these visual images of the wound can be used to provide a valid and reliable assessment of wound status.

The purpose of this paper was to examine the validity and reliability of using wound photographs to accurately assess the status of wounds. The ability to accurately assess wound appearance using the photographic wound assessment tool (PWAT) was compared to a bedside assessment using the PSST. Since the characteristics of different types of wounds (venous, pressure, diabetic, and

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KEY POINTS

- Valid and reliable wound assessment instruments that are responsive to change greatly facilitate care and documentation.
- Utilizing six components of one of two pressure ulcer assessment instruments that have sufficient published information to be considered valid and reliable measures of wound healing in pressure ulcers, the researchers examined the validity and reliability of a photographic assessment instrument to assess wound status.
- One hundred and thirty-seven photographs, taken with two different cameras, were assessed by three experienced clinicians and three students without clinical experience.
- Intrarater and interrater reliability was high, but lower in inexperienced than in experienced clinicians. Excellent agreement between the photographic scores and bedside scores was observed and responsiveness to change was good.
- The researchers conclude that photographic assessments of wound extent and appearance using this instrument may be valuable when a bedside assessment cannot be made. However, the size of circular wounds, wound depth, undermining/tunneling, and odor cannot be assessed using photographs. This study also confirms that wound assessments (regardless of the instrument used) are best performed by experienced clinicians.

Figure 1
Chronic venous ulcer with a total PWAT score of 9. The first five domains of the PWAT were assessed a score of 1 (edges, necrotic tissue type and amount, skin color, and granulation tissue) while the first domain of epithelialization was scored at a level 4.

arterial ulcers) vary markedly, determining the reliability and validity of using the PWAT to assess wound appearance for both chronic pressure ulcers and leg ulcers due to vascular insufficiency is important. The effect of previous clinical experience on the accuracy of this wound assessment tool was also assessed by comparing the scores obtained from untrained students with those of healthcare professionals who had at least 5 years of experience with patients with chronic wounds.

Methods

Photographic techniques. Photographic images included in the analysis were recorded by either an Olympus OM-2 or a Nikon FM-2 camera. Photographs were taken in a variety of clinical settings in which lighting conditions were optimized to reduce glare and shadows and increase image contrast. Both cameras were equipped to adjust automatically to varying light and with a macro lens to permit close-up images of the wound (3 to 6 feet away). Before photos were taken, a 15-cm ruler with clear millimeter divisions was placed next to the wound as well as a patient identification number and the date of the assessment. Care was taken to ensure that the camera was angled perpendicular to the wound bed; however, the distance between the camera and the wound was varied in order to capture the entire wound, the ruler, patient identification number, date, and a sample of the surrounding skin. Photographs were taken after having received the patient's written permission with the understanding that the patient's identity would be concealed at all times. The study was conducted according to procedures previously outlined and approved by the institutional human ethics committee.

Wound photographs. Photographs were randomly ordered and patient identification numbers and dates were concealed. The photographs were divided into two ordered sets according to ulcer type. The first set of images (n = 56) were of pressure ulcers located on the trunk of 13 patients. A second set of images (n = 81) were of leg and foot ulcers taken from a total of 46 patients. Serial images of the wounds that had been taken over a period of time during which the wound may or may not have improved were included in both sets of wound photographs. Ulcers that had extensive tunneling or undermining, were too deep and could not be fully visualized, or were wrapped around the limb or bony prominence were excluded from this study.

Three trained healthcare professionals including a nurse practitioner, physician, and physical therapist assessed the wound photographs. Collectively, these individuals had between 5 and 10 years of clinical experience with chronic wounds and had previous experience with the PSST. In addition to these qualified wound care specialists, three inexperienced students also assessed the wound photographs. The students received training on the wound assessment tool but did not have any clinical experience with chronic wounds.

Photographic Wound Assessment Tool (PWAT). The PWAT used in this study is a modified version of the pressure sore status tool (PSST),[16] which has been used extensively to assess wound status and has a published record of validity and reliability.[17–19] Six domains that can be determined from photographs alone and do not require a bedside assessment were included in the PWAT. These six domains include wound edges, necrotic tissue type and amount, skin color surrounding wound, granulation tissue type, and epithelialization (see Figure 1 and Table 1). Assessors assigned a number from 0 to 4 for each of the six domains. This scale was changed from the 1 to 5 scale previously used in domains of the PSST so that a completely healed ulcer could be represented by a score of zero. The total PWAT score for each wound photograph was calculated by summing the scores assigned to each of the six domains. Thus, the range of possible total PWAT scores was between 0 and 24 with zero representing a completely healed ulcer.

TABLE 1
PHOTOGRAPHIC WOUND ASSESSMENT TOOL

Domain	Assessment	Date Score
1. Edges	0 = Indistinct, diffuse, none clearly visible 1 = Distinct, outline clearly visible, attached, even with wound base 2 = Well-defined, not attached to wound base 3 = Well-defined, not attached to base, rolled under, thickened 4 = Well-defined, fibrotic, scarred or hyperkeratonic	
2. Necrotic Tissue Type	0 = None visible 1 = White/gray nonviable tissue and/or nonadherent yellow slough 2 = Loosely adherent yellow slough 3 = Adherent, soft, black eschar 4 = Firmly adherent, hard, black eschar	
3. Necrotic Tissue Amount	0 = None visible 1 = < 25% of wound bed covered 2 = 25% to 50% of wound covered 3 = > 50% and < 75% of wound covered 4 = 75% to 100% of wound covered	
4. Skin Color Surrounding Wound	0 = Pink or normal for ethnic group 1 = Bright red 2 = White or gray pallor or hypopigmented 3 = Dark red or purple 4 = Black or hyperpigmented	
5. Granulation Tissue	0 = Skin intact or partial-thickness wound 1 = Bright, beefy red; 75% to 100% of wound filled and/or tissue overgrowth 2 = Bright, beefy red; < 75% and > 25% of wound filled 3 = Pink, and/or dull, dusky red and/or fills ≤ 25% of wound 4 = No granulation tissue present	
6. Epithelializatio n	0 = 100% wound covered, surface intact 1 = 75% to < 100% wound covered and/or epithelial tissue extends > 0.5 cm into wound bed 2 = 50% to < 75% wound covered and/or epithelial tissue extends > 0.5 cm into wound bed 3 = 25% to < 50% wound covered 4 = < 25% wound covered	
TOTAL SCORE		
SIGNATURE		

Data Analysis

The intraclass correlation coefficient (ICC) is the standard statistical method used for assessing test-retest reliability for a single rater (intrarater reliability) or between several raters (interrater reliability) since it not only assesses the correlation between the values, but also determines the degree of agreement between assessments.[35,36] An ICC represents the degree to which two scores are identical or interchangeable regardless of whether these scores have been obtained on different occasions, from different observers, or using different tools. An added advantage of using an ICC to assess instrument reliability is that the degree of correspondence and agreement among ratings can be determined simultaneously for two or more raters.[35,36] An $ICC_{(1,1)}$ was the type of ICC used to assess the intrarater and interrater reliability of the PWAT since not all wound photographs were assessed by the same three raters and because the data represented a

single assessment of each photo rather than a mean of several assessments. An $ICC_{(2,1)}$ was used to assess the concurrent validity of the wound size measurements since the same rater performed both of these assessments and the scores used in the data analysis were from a single observation not a mean of several observations. A Pearson *r* coefficient is appropriate to assess correlation between two assessments where the assessment scores would not be expected to be identical. Therefore the Pearson *r* coefficient was used to assess the concurrent validity of the total PWAT scores derived from wound photographs compared with scores obtained from a bedside assessment of the same wounds using the PSST. Both ICCs and the Pearson *r* coefficients are statistical methods that have been used previously to provide estimates of reliability and concurrent validity for other wound status tools including the PSST.[19–23] All values calculated for ICCs and Pearson *r* coefficients were interpreted as follows: excellent (1.0–0.75), modest (0.40–0.74), and poor (0–0.39).[35]

Reliability. To assess intrarater reliability, scores assigned to the same set of wound photographs by the same assessor on two separate occasions at least 1 week apart were compared using an ICC. A one-way ANOVA was used to obtain the variance components for calculating the $ICC_{(1,1)}$. Calculation of $ICC_{(1,1)}$ was also used to assess the degree of agreement of measures between scores obtained for three professionals, three students, and experienced and inexperienced assessors. In this way, the interrater reliability could be determined for both experienced and inexperienced individuals and the effect of previous clinical experience on assessment reliability could be examined. Intrarater and interrater reliability were assessed by calculating the ICCs for scores assigned to wound photographs of both chronic pressure ulcers and vascular ulcers of the lower extremity. In addition, scores assigned to each of the six domains of the PWAT were compared between different raters (interrater reliability) and for each individual rater (intrarater reliability) using Pearson *r* coefficients.

Concurrent validity. To determine the validity of the PWAT, the scores obtained from the six-item assessment of wound photographs were compared with the scores obtained from the 13-item PSST performed by the same individual during a full bedside assessment. The total score for the PSST that included only the six domains contained in the photographic assessment tool was also calculated. The degree of agreement of the total scores of the PWAT, the 13-item PSST, and the 6-item PSST were compared by determining the Pearson *r* coefficient. The concurrent validity of the PWAT was assessed by examining its relationship to scores obtained using the PSST for both pressure and leg ulcers (n = 46).

The authors also examined the ability to assess wound size using wound photographs. Wound size was estimated in the photograph by determining the maximum wound length and width using the ruler that had been placed next to the wound at the time the photograph was taken. These estimates of maximum wound length (l) and width (w) obtained from the wound photograph were then used to calculate wound surface area (wsa = l x w). These calculated estimates of wound size were compared to wound surface area measurements obtained directly using acetate tracing and planimetry. Tracing the wound edge onto a transparent acetate and using planimetry to determine surface area from the wound tracing have both been shown previously to be accurate and reproducible.[6,7] These comparisons were accomplished by calculating an $ICC_{(2,1)}$.

Responsiveness to change. The change in PWAT scores that occurred over time was determined for both chronic pressure and leg ulcers in which serial photographs were available (n = 38). To determine this, the net change in the total PWAT score that occurred over the total time lapsed between photographs was calculated for each wound and expressed as the PWAT change score. A negative value for the PWAT change score indicated that wound healing was occurring over the time period examined. The greater this value was away from ze ro, the more improvements in wound appearance had occurred. The mean ± SEM of the PWAT change score was determined for both "healing" and "nonhealing" wounds. The independent criteria used to define a "healing wound" was a net decrease over time in wound surface area determined by acetate tracing and planimetry techniques. A student's *t* test was used to determine whether the mean ± SEM of the PWAT change score was significantly different from zero or significantly different between healing and nonhealing ulcers. For both of these comparisons a *P* value of less than 0.05 was considered statistically significant.

Results

Reliability. The ICCs calculated for total PWAT scores assigned by one trained rater after viewing 56 photographs

of 13 pressure ulcers on two separate occasions was $ICC_{(1,1)}$ = 0.96. Similarly, the intrarater reliability for PWAT scores assigned on two occasions for 81 photographs of 34 different leg ulcers was $ICC_{(1,1)}$ = 0.86. Wound size estimates from using internal calibration scales (rulers) in the photographs of pressure and leg ulcers also had a ve ry high intrarater reliability $ICC_{(1,1)}$ = 0.96.

Agreement between raters was determined by calculating an $ICC_{(1,1)}$ from scores assigned by several raters that evaluated the same set of photographs of pressure ulcers of the trunk. The interrater reliability for pressure ulcers was high for experienced healthcare professionals ($ICC_{(1,1)}$ = 0.75), but much lower for students who lacked clinical experience ($ICC_{(1,1)}$ = 0.58). When examining photographs of leg ulcers, the interrater reliability for experienced individuals was $ICC_{(1,1)}$ = 0.83, which was much higher than ICCs calculated for inexperienced students ($ICC_{(1,1)}$ = 0.34).

The authors found a strong correlation (r > 0.75) between scores assigned by the same experienced observer for each of the individual domains of the PWAT except for the domain on skin color, which had a Pearson r coefficient of 0.56. Correlation between raters of each of the six domains of the PWAT were above 0.75 except for the assessment of wound edges (r = 0.68) and skin color (r = 0.19).

Concurrent validity. Wounds that were assessed by the same observer using both the PSST performed at the bedside and the PWAT performed using wound photographs (n = 46) had a Pearson r coefficient of r = 0.70 for the total score of the 13-item PSST and r = 0.66 for the sum of the six-item PSST. The degree of agreement between surface area calculations obtained from wound photographs (n = 46) and surface area assessed using wound tracings was $ICC_{(2,1)}$ = 0.87.

Responsiveness to change. An analysis of serial photographs taken from 38 individuals revealed that the mean ± SEM of the PWAT change score was -1.82 ± 0.26 score/day, which was significantly different from zero (P < 0.05). This negative value is indicative of a net decrease or overall improvement in wound scores that had occurred over the time period between wound photographs. After dividing the ulcers into "healers" and "nonhealers" based on the change in wound surface area, the mean ± SEM of the PWAT change score for "healers" was -4.29 ± 0.08 score/day, which was significantly greater than zero (P < 0.001). The mean ± SEM of the PWAT change score for "nonhealers" (-0.77 ± 0.51 score/day) was not different from zero (P = .250). A comparison of the change in PWAT scores that occurred over time in healers versus nonhealers revealed that mean ± SEM of the PWAT change was higher for healers (4.29 ± 0.08 score/day) compared with nonhealers (1.37 ± 0.06 score/day) at a level that was almost statistically significant (P = 0.07).

Discussion

Trained healthcare professionals using the photographic wound assessment tool (PWAT) to assess wound appearance yielded intrarater and interrater reliability scores that were both considered to be excellent (ICC 0.75).[34] These values for ICC scores were slightly lower than the coefficients determined for PSST intrarater (0.99) and interrater (0.91) reliability previously reported.[19] Making these comparisons in reliability scores is difficult since the methods for calculating coefficients of intra- and interrater reliability in the two studies were different. However, the use of an ICC to assess rater reliability is considered a more rigorous statistical method than calculating a kappa coefficient since it takes into account any systematic bias between the two determinations.[35]

The results of this study demonstrate that the reliability of the PWAT is greater in individuals who have at least 5 years of clinical experience with chronic wound management. Presumably, this clinical experience provides the necessary training to recognize various components of wound beds such as necrotic tissue, epithelium, and granulation tissue. This need for prior clinical experience has also been reported with other wound appearance tools such as the PSST.[17,19] Therefore, the PWAT, like other tools that have been developed to assess wound appearance, must be used by individuals with clinical experience since the validity and reliability of this tool is compromised in the hands of inexperienced trainees.

The coefficients of intrarater reliability were higher when the photographic assessment tool was applied to pressure ulcers compared to leg ulcers due to vascular insufficiency such as diabetic, ischemic, and chronic venous ulcers. This is not surprising since the PWAT is a modification of the PSST, which was originally designed for the assessment of pressure ulcers. Although the PSST is commonly used to assess leg ulcers, publications that have tested the validity and reliability of this tool are only

available for pressure ulcers.[17,19] This report demonstrates that the PWAT not only has excellent reliability when applied to pressure ulcers, but also has intra- and interrater reliability coefficients of > 0.8 when used to assess the appearance of chronic leg ulcers. The PWAT represents the first of many such wound status tools[19–23] for which excellent intra- and interrater reliability has been established for use on chronic vascular ulcers of the lower extremity.

The results of this study showed a strong correlation between the total scores obtained using the PWAT on wound photographs and the scores obtained from a bedside assessment of the same wounds using the PSST. Furthermore, except for skin color, scores assigned to each of the individual domains within the PWAT were strongly correlated with similar domains of the PSST. Therefore, examining a photograph of the wound and viewing the wound bed directly during a bedside assessment appears to yield a similar assessment of wound appearance.

Individual scores of each of the six domains of the PWAT are between 0 and 4; whereas, the same six domains of the PSST are on a scale between 1 and 5. The authors changed the scoring system to a 0 to 4 scale for each domain of the PWAT so that an ulcer that has healed completely may have a total score of zero. This scale seems much more clinically relevant and more understandable than the PSST scale in which a total score of 13 represents a healed ulcer. Changing the scale of these domains has the potential to significantly affect the validity and/or reliability of the PWAT; however, this is not the case in the present study since excellent intrarater and interrater reliability and very good concurrent validity were reported.

Estimates of wound surface area using a ruler with millimeter divisions that had been placed next to the wound edge within the photographs were found to be extremely reliable ($ICC_{(1,1)} = 0.96$). Calculations of wound surface area using length and width estimates from wound photographs strongly agreed with direct wound surface area measurements using acetate tracings and planimetry ($ICC_{(2,1)} = 0.86$). At least three previous reports have compared photographic and wound tracing methods of determining wound size. Brown-Etris et al[14] used a computerized analysis system to compare wound size determinations of digital images of either wound tracings or color slide photographs taken of diabetic or venous ulcers. Griffin et al[15] compared the reliability of the transparency method with the accuracy of tracings made from color slide photographs of the same pressure ulcers of the pelvic region that were projected onto a wall. Katelaris et al[31] improved upon this method by using a viewing box to assist the projection of slides onto paper. All of the methods that use either slides or computer images to assist in determining wound size require manual tracing of the wound image. This indirect method of determining wound size from tracings of photographic images is believed to contribute to the relative inaccuracy of the measurements. The photographic method described herein, which involves directly determining wound dimensions from an internal scale included in a photograph, seems less cumbersome to perform and perhaps may be more clinically useful than the other photographic methods described previously.[14,15,31]

To achieve accurate clinical photographs of chronic wounds, exercising as much control as possible over variables that influence photographic results such as equipment, materials, film processing, subjects, lighting, and background is necessary, according to Conn and Hughes.[27,28] Although the authors attempted to keep as many of these variables constant in the present study, the photographs were taken in a variety of clinical settings, including nursing homes, hospital rooms, and outpatient clinic offices using two different camera systems. This less controlled situation is likely representative of a realistic clinical situation. Despite these inconsistencies in the photographic methods used in the present study, good reliability and validity of the PWAT was demonstrated and a significant change in wound status over time of photographs taken of healing, but not nonhealing, ulcers was detected. If the authors were able to control more of the factors that affect photographic images, it is probable that assessments using the PWAT would be even more consistent and the results even more accurate and reproducible.

Using the PWAT to assess wound appearance has several advantages, but has some limitations as well. First, a photographic image is merely a 2-dimensional representation of a 3-dimensional problem. For this reason, the PWAT was not applied to ulcers that wrapped around limbs or bony prominences or on deep ulcers with extensive undermining or tunneling. Because this study did not examine the validity and reliability of the PWAT on these types of ulcers, using this tool to assess the wound

appearance of such wounds would be inappropriate. This represents a clear limitation for this assessment tool since numerous types of ulcers, including pressure ulcers, may have these characteristics. The added costs associated with obtaining photographic images of the wound at each assessment present a second limitation to using the PWAT. In addition, healthcare providers must obtain approval from the patient or appropriate decision-maker before taking photos of the patient's wound. Therefore, if taking wound photographs is not already a part of the current wound care program, using the PWAT to assess wound appearance may not be cost-effective. Lastly, the development of a tool that would allow the healthcare provider to perform a wound assessment using only a photograph may discourage healthcare providers from taking a holistic approach to wound care – an approach that may have numerous benefits. Therefore, the use of PWAT on wound photographs should never replace the need for all members of a wound care team to participate in periodic wound assessments performed at the patient's bedside. Optimal wound care must always involve examining "the whole patient and not just the hole in the patient."

In conclusion, the PWAT has excellent intrarater and interrater reliability when performed by healthcare professionals who have adequate clinical experience treating chronic wounds. This tool was also shown to have good concurrent validity and be sensitive to detect changes in wound healing. These results would suggest that in the event that a full bedside assessment is not possible, the PWAT might be used on wound photographs to accurately assess wound extent and appearance. The PWAT is valid and reliable for use on photographs of pressure ulcers located on the trunk as well as for chronic vascular leg wounds such as diabetic, arterial, and venous ulcers. - OWM

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