Standardization of Wound Photography Using the Wound Electronic Medical Record

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INTRODUCTION

Clinical decisions regarding the treatment of chronic wounds often rely on the synthesis of information from multiple sources (radiology, pathology, vascular and culture reports, current treatments, etc). The utilization of technology, specifically digital photography combined with a Wound Electronic Medical Record (WEMR), can simplify the evaluation and treatment of chronic wounds. A standardized wound photography protocol, as presented in this article, is vital to the accuracy and objectivity of digital wound recording.

BACKGROUND

Definition, Prevalence, and Cost of Chronic Wounds

Wounds can be divided into 2 categories: acute and chronic. Acute wounds heal in an orderly and timely manner,[1] whereas chronic wounds fail to do so because of underlying physiological impairments.[1–3] According to the Centers for Medicare and Medicaid Services, the treatment of chronic wounds in the United States totals more than $20 billion annually.[4] Common types of chronic wounds include venous ulcers, diabetic foot ulcers, and pressure ulcers. Venous ulcers are a break in the integument, most often resulting from deep vein thrombosis or a dysfunctional valve in the lower extremity deep veins.[5] Venous ulcers affect approximately 1.7% of persons older than 65 years,[6] frequently causing pain and disability,[7] and have high rates of recurrence despite aggressive treatment.[8] Diabetic foot ulcers are defined as any skin breakdown on the foot of a diabetic person[9] and categorized as a chronic wound because diabetes impairs angiogenesis,[10] innervation,[11] immune function, and wound healing.[12–14] Persons with type 1 or type 2 diabetes have a 9.1% risk of developing a foot ulcer in their lifetime,[15] and people with diabetes are 15 to 40 times more likely to have a lower limb amputation as compared with the general population.[16] Pressure ulcers are a break in the integument caused by prolonged pressure to skin and muscle, as well as local physiological impairment.[17,18] Pressure ulcers have a reported prevalence between 10% and 26% among hospitalized patients and those in an acute care setting,[19,20] and the number of hospital stays in which pressure ulcers were recorded increased by 63% over a recent 10-year period.[21] There is evidence that pressure ulcers are associated with increased mortality rates,[22] and between 1990 and 2001, pressure ulcers were reported as a cause of death among 114,380 persons in the United States.[23]

Electronic Medical Records in Wounds

Electronic medical records (EMRs) have been shown to promote patient safety, facilitate communication between providers, reduce costs, and facilitate an evidence-based practice.[24,25] Electronic records have also been successfully used in chronic wound healing,[26] although they have yet to become a standard of care in the field. Implementation of the wound photography protocol as described in this article involves the use of a specific wound electronic medical record (WEMR); however, the following protocol is not dependent on any specific EMR.

Objective Wound Evaluation

Objective wound evaluation and documentation are integral to chronic wound care. Multiple methods of wound evaluation can be used to track an ulcer over time, including area,[27] volume,[28] linear growth of wound edges,[29] and the Pressure Ulcer Scale for Healing (PUSH) score.[30] Each of these methodologies has strengths and limitations that have led to varied use across clinical settings. Measurement of the wound area is a simple and accurate way to record wound size[31] but does not account for depth-related wound changes. Volume is a measurement that accurately records all aspects of ulcer size[31] but has limited coverage in the literature, likely because of the practical difficulties of wound volume measurement. Linear advancement of wound margins toward the center of a wound is a useful measure for establishing wound-healing rates, as this measurement takes into account the initial circumference of the wound and allows for comparison between wounds, regardless of the initial wound area.[32–34] The complexity of this methodology has limited its use in daily clinical practice.[33] The PUSH score—a combination of wound length, width, exudate amount, and tissue type—is a valid and sensitive

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measure of pressure ulcer healing.[35] The clinical usefulness of PUSH scores could be increased, however, by including wound depth and refining the test scales.[36]

The authors' decided to track ulcer progression through wound area measurements using planimetry, due to the simplicity and reliability of this method.[31] The primary clinical goal is to assess whether a patient's wound is healing and to allow for quality assurance reviews that highlight nonhealing wounds for case discussion and management changes.

Regardless of the approach used in analyzing wound size, data collection requires accurate wound measurements. All wounds seen by the author are digitally photographed and monitored through the WEMR. A real-time graph of the wound area is generated upon each visit. This allows clinicians to more easily identify nonhealing wounds and to thereby recognize patients who require debridement or other changes in management. The WEMR can also be used by researchers to provide measurement information to evaluate the efficacy of new therapies via clinical trials, as it can prospectively track wound measurements from both the experimental and control arms. The authors are currently testing the hypothesis that the utilization of the WEMR, in conjunction with protocols and guidelines[37–42] for wound measurement and treatment, will decrease the incidence of both Stage IV pressure ulcers and lower limb amputations among persons with diabetes.

Digital Photography in Chronic Wounds

Wound photography is recognized for its utility in the care of chronic wounds.[43,44] Wound area calculated from a digital photograph of a wound, either by tracing it with computer software or photographing a manual contact tracing, was demonstrated to be a quicker and more accurate method than contact tracing of the wound itself in the cases of venous and diabetic foot ulcers.[43,44] The digital photograph can also be used to accurately assess pressure ulcer appearance.[45] Despite these advantages, interobserver variability can be high in regard to digital tracing.[43] Wound margins may be poorly defined or complicated by slough, necrotic tissue, or multiple adjacent ulcerations. In this article, the authors define guidelines for the photography and digital tracing of chronic wounds based on an understanding of the underlying physiology. The purpose of these guidelines is to decrease interobserver variability and facilitate a consistent, accurate clinical assessment of changes in the wound area over time.

DESCRIPTION OF THE PROGRAM

Wound Electronic Medical Record

Every ulcer has a unique WEMR entry and is treated in accordance with published clinical protocols.[37,40,42,46] The WEMR is a Health Insurance Portability and Accountability Act–compliant digital data sheet that contains the following data on a single screen: a digital photograph of the wound; a real-time graph of the wound-healing rate (length, width, and area over time); wound location (this is as specific as toe or malleolus); presence of drainage, cellulitis, pain and/or fever; ambulation status; degree of undermining; current treatment; a summary of the patient's medical history; hematology and chemistry laboratory data; radiology, pathology, and vascular reports; deep wound culture reports; and other wound treatments, including systemic antibiotics. The data entry front end is written in Microsoft Access (Microsoft Corporation, Redmond, Washington). Data are entered into the system and uploaded to a backend database also written in Microsoft Access. Images are uploaded to a secure, networked drive in a noncompressed format and stored in folders noting the date the photographs were taken. The WEMR displays the initial and most recent photograph of a wound, along with its measurements. A graph dynamically reflects each new data point as soon as those data are entered into the database and provides the clinician with a real-time summary of wound-healing trends. Data are easily queried to answer research questions.

PHOTOGRAPHY

Choosing the Proper Equipment

Ease of use and photographic quality are the most important considerations when selecting a digital camera. All staff should be able to quickly and easily capture high-quality images with the digital camera. Digital cameras are optimal for wound photography because they allow the user to review the photograph as soon as it is taken, to easily store or delete photographs based on output quality, and to rapidly upload photographs into the WEMR. In general, higher-resolution cameras facilitate a more accurate identification of wound detail and margins; the resulting images can be enlarged to a greater extent while maintaining clarity.

D-SLR Versus Point-and-Shoot

Digital Single-Lens Reflex (D-SLR) cameras, as opposed to point-and-shoot cameras, have the added versatility of increased user control and the option of interchangeable lenses. D-SLR cameras, however, are typically larger and more expensive than point-and-shoot cameras. An advantage of a D-SLR camera is that the view seen by the user is representative of the photograph that will be taken, whereas in non-SLR digital point-and-shoot cameras, the image seen by the user may not represent the entire image captured on the photograph. The ease of use and small size of the point-and-shoot digital camera may make it well suited for home health care.

Difficult-to-Capture Wounds—Photomacrography

Photomacrography is a technique used to capture images by enlarging or magnifying the object at a closer range than is normally possible; thus, it can be particularly useful for documenting wounds.[47] Photomacrography is achieved by using a macro lens on an SLR camera or with the macro setting on a point-and-shoot camera. A typical macro lens has a focal length between 50 and 100 mm, and the object should be placed a focal length's distance from the lens, that is, the focal point, to achieve the sharpest quality image.[47] Using the macro setting on a digital point-and-shoot camera may produce varied results.

Wound Photography Protocol

The first step in digital wound photography is to remove all dressings and cleanse the wound with saline (Figure 1). It is important to remove as much necrotic tissue, slough, packing material, and/or debris as can be tolerated by the patient. The entire wound is photographed to include healthy skin, surrounding cellulitis, and/or callus. A unique wound is defined as a single ulceration of the skin. However, if there are multiple open areas less than 2 cm apart resulting from the same underlying etiology, they are considered the same wound. A disposable ruler is held flat along the most distal edge of the wound (preferably outside the areas of cellulitis or callus).

To minimize error, the camera lens is oriented parallel to the plane of the wound (Figure 2). The photograph is framed by altering the distance between the lens and the wound or using the zoom function if present and focused using the auto-focus feature (accessed by holding the shutter button down halfway in many cameras). The marked lines of the ruler are crisp when the camera is properly focused. A flash is used in all settings to ensure adequate and consistent lighting. Following capture, the photograph can be viewed on the digital display screen. However, these screens are typically of low resolution and may not accurately display photographic output. A second photograph of all wounds is obtained to ensure at least 1 good-quality photograph. Pertinent information (patient name, medical record number [MRN], wound location, presence of cellulitis, or drainage, pain, etc) is recorded in a log at the time the photograph was taken to facilitate accurate data entry.

Photograph Uploading and Editing

Photographs are uploaded via a universal serial bus (USB) connection and saved onto the secure server. Cameras with wireless capacity are an emerging technology that may accelerate this process and enable remote photograph uploads. This technology, combined with Wi-Fi–capable laptops or handheld devices, may soon enable physicians and wound care specialists to remotely evaluate wound healing in real time. The available options for wireless cameras, however, are limited.

Figure 1.
WOUND PHOTOGRAPHY PROTOCOL

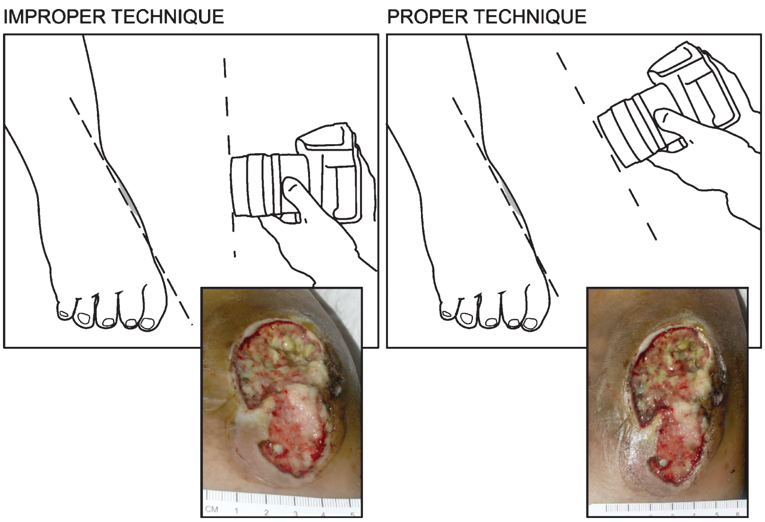
Step 1: Undress the wound. Step 2: Thoroughly cleanse the wound. Step 3: Photograph using the proper technique. Step 4: Upload the photograph and measure the wound area. Step 5: Upload information into the WEMR (representative data sheet shown).

Once uploaded, files are opened in Adobe Photoshop (Adobe Inc, San Jose, California), cropped to remove unwanted footage (eg, the ruler is beyond the necessary markings, excessive areas of healthy skin, etc), and rotated so that the ruler is along the bottom edge of the photograph. Photographs are resized according to database and software requirements.

Figure 2.

MEASURING THE WOUND AREA

Measured wound area depends on proper photographic technique, where the planes of the wound and camera lens are parallel. The improperly photographed wound area measured 13.1 cm^2. Actual wound area based on proper technique is 20.1 cm^2.



A low-resolution copy (approximately 300 Kb) is saved and uploaded to the WEMR. A higher-resolution copy (approximately 4 Mb) is also saved. File names include patient MRN, last and first name, general wound location (left lower extremity, trunk, etc), specific wound location (great toe, plantar foot, etc), and photograph date. Wound categories (diabetic foot ulcer, venous ulcer, ischemic ulcer, etc) are included elsewhere in the WEMR but not in the photograph file name, as further testing may alter the final diagnosis.

Measuring the Wound Area

Once saved, photographs are opened with WoundImager 2.0 (Med-Data Systems Inc, Cherry Hill, New Jersey) to determine the area, length, and width. To calibrate these measurements on each individual photograph, the user marks a known length on the ruler and then traces the wound edge around the area of ulceration with the computer mouse. The enclosed areas are filled automatically, and the program calculates the total wound area. Length and width are measured manually on the screen. The length of the wound is defined as the longest span in any direction, whereas the width is the longest span perpendicular to the length. For multiple ulcerations that are considered the same wound, individual areas are summed, and the length and width of the entire ulcerated area are measured (Figure 3C). All values are recorded in the WEMR.

Wound Documentation Entry Points: Outpatients

Outpatients are seen weekly, and a photograph of each individual wound is taken at each visit. When outpatient debridements are performed, a photograph is taken before and after the procedure. The initial photograph is used to document wound area changes from the preceding data point, whereas the postdebridement photograph and measurement provide a new baseline for future healing and comparisons.

Inpatients

A photograph of each individual wound is taken upon admission and repeated weekly and at discharge for inpatients. An additional photograph is taken within 3 days of sharp debridement to provide a baseline for future healing.

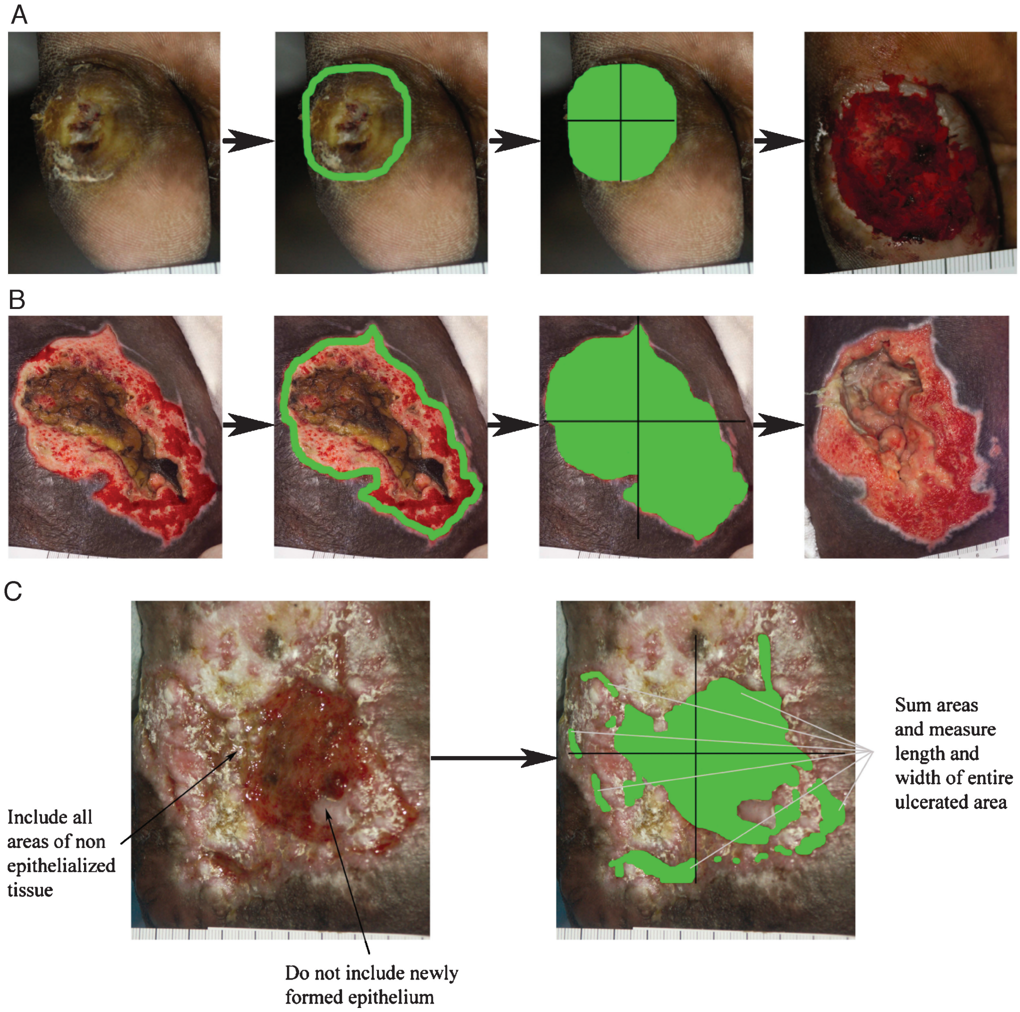
Wound Photography Training

Wound photography training specifically involves 2 days of instruction and practice to operate the camera and upload images into the WEMR. Before photographs of actual wounds are taken, the trainees take a photograph of mock-up wounds (ie, a simple piece of paper with different geometric patterns of different sizes) attached to different anatomical locations on a volunteer. A wound clinician then reviews the mock-up photographs for image sharpness and the trainees' ability to measure the area accurately as per the described protocol. After this initial period, every wound photograph taken by the technician is reviewed by the senior clinician for a period of 2

FIGURE 3.

TROUBLESHOOTING SPECIFIC ULCERS

A. Include callus in diabetic foot ulcer area calculations. Final photograph illustrates the wound area after debridement. B. Include eschar, slough, and/or necrotic tissue in pressure ulcer area calculations. Final photograph illustrates the wound area after debridement. C. Include all contiguous areas of nonepithelialized tissue in venous ulcer area calculations. Sum the areas for multiple ulcers of the same etiology separated by less than 2 cm. Calculate the length and width of the entire ulcerated area as described in the text.



weeks or until photographs and the wound area measurements are considered accurate and reliable, as determined by the senior physician and by comparisons to an experienced technician's documentation of identical wounds.

TROUBLESHOOTING FOR SPECIFIC ULCERS

Foot Ulcers on Patients with Diabetes

Foot ulcers on patients with diabetes often present as a callus with or without associated ulceration. Extensive debridement, including debridement of callus, accelerates healing[48]; therefore, the callus is included when calculating the wound length, width, and area (Figure 3A). The precise border between callus and healthy epithelium may be easier to palpate than to visualize. In this case, a marking pen is used by the examiner to delineate the border of the callus before taking a photograph of the wound. When a patient with diabetes presents with a foot ulcer, photographs of both feet are taken (capturing common ulcer locations, such as plantar, dorsal, etc) to document the presence or absence of additional ulcerations. This practice enables the clinician to document new ulcer formation. If an amputation occurs, the amputation site, if open, may be measured and tracked with the WEMR as if it were a new ulcer.

Venous Ulcers

Venous ulcers typically occur on the malleolar, shin, and calf areas and are often a collection of small breakdowns of the skin. Photographs should effectively demonstrate the topography of the wound as well as the condition of the surrounding skin. Many wounds form areas of hyperkeratosis, or crusting, around the border of the wound. This nonliving tissue is bluntly removed (ie, with gauze and saline) before photography to clarify whether the underlying tissue is normal skin or wound. Re-epithelialized tissue toward the wound edge is often lighter in color than normal skin and is not included in area measurement. All contiguous areas of nonepithelialized tissue in the same anatomical location are included in a single area measurement (Figure 3C).

Venous ulcers often exist in multiple planes or may be completely circumferential. To accurately track healing in these cases, the authors suggest measuring the longest possible length and width using flexible, disposable rulers laid flat against the wound and recording the area measurement (calculated as length multiplied by width). Circumferential ulcers are photographed from the same perspective each time to facilitate the evaluation of wound progression. Further study is needed to compare different methods of measurement.

Pressure Ulcers

The most common areas for pressure ulcers are the sacrum, greater trochanter, ischium, and heel. Except for heel ulcers, the majority of these wounds will be confined to 1 plane and will have well-defined wound edges. Upon initial presentation, pressure ulcers may be covered with necrotic tissue, eschar, or slough. This tissue requires debridement and is included within the area of the wound (Figure 3B). Depth and undermining are measured with a cotton swab and recorded during all pressure ulcer visits. For undermining, both the distance and location (using a clock-hour integer scale) are recorded. In cases where ulcers are in multiple planes, the same protocol described for circumferential venous ulcers is used. Bed-bound or contracted patients require coordinated teamwork to safely position the patient for optimal ulcer documentation. When the wound is surrounded by soft adipose tissue, such as the buttock, the tissue is pulled back to maximally expose the ulcer. To minimize distortion of wound size and shape, the patient is positioned the same as at the time photography is recorded (ie, left lateral decubitus, supine, etc) and previous photographs are reviewed immediately before subsequent documentation points to reproduce the precise wound and camera orientation. Stage I ulcers are photographed using the same protocol, and the area of nonblanchable erythema is measured and tracked. If a Stage II or higher-grade ulcer forms at the location of a Stage I pressure ulcer, a new area graph is started that tracks only the area of epidermal breakdown. The common pressure ulcer sites listed above are photographed during the initial visit to document the presence or absence of ulceration and facilitate the early identification of new ulcers.

Cellulitis

Cellulitis is an infection of subcutaneous tissue that manifests as a swollen, tender, and erythematous area of skin. It is difficult to track the progression of cellulitis associated with chronic wounds. One method is to trace the affected area with a marking pen and label the outline by date. When an ulcer is present, cellulitis is not included in wound area measurements. When cellulitis is present without ulceration, the cellulitis area is tracked through time. If a break in the skin occurs at the location of a previously documented cellulitis infection, a new area graph that tracks only the area of skin breakdown is started. For circumferential cellulitis, the protocol detailed for circumferential venous ulcers is used. When photographing cellulitis, healthy skin is captured for comparison, which may require zooming out or including the contralateral limb in the photograph.

RESULTS

For 3 years, a specific WEMR has been used that is approved by the local forms committee and has institutional review board (IRB) approval for research purposes (protocol IRB-AAAB4531). This WEMR has been used to capture 14,195 photographs of 1067 individual patients with 3063 wounds to date. The distribution of wound type is as follows: 45%, venous ulcers; 18%, diabetic foot ulcers; 17%, pressure ulcers; 11%, ischemic ulcers; and 9%, others (sickle cell, burn, infection, etc).

This system has been fully integrated into both an outpatient and inpatient service. One full-time technician is responsible for photographing outpatients before being seen by the wound physician, as well as collecting and entering all relevant clinical and laboratory data into the WEMR. A data sheet with an updated photograph and a summary of recent wound-healing and clinical trends are available to the clinician in real time.

WEMR has been successfully implemented into an inpatient service with an average census of 10 patients. Color data sheets for all patients are printed before rounds and are a key resource of patient information for the clinical team. Photographs are obtained by a technician as per the described protocol during morning rounds.

CONCLUSIONS

Digital wound photography is integral to most effectively treat chronic wounds using the WEMR. The guidelines for wound documentation presented in this article provide a standardized method to record wound information over time.●

REFERENCES

1. Lazarus GS, Cooper DM, Knighton DR, et al. Definitions and guidelines for assessment of wounds and evaluation of healing. Arch Dermatol 1994;130:489-93.
2. Mostow EN. Diagnosis and classification of chronic wounds. Clin Dermatol 1994;12:3-9.
3. Stojadinovic O, Brem H, Vouthounis C, et al. Molecular pathogenesis of chronic wounds: the role of beta-catenin and C-myc in the inhibition of epithelialization and wound healing. Am J Pathol 2005;167:59-69.
4. Medicare Coverage Advisory Committee: Usual Care of Chronic Wounds. Baltimore, MD: Centers for Medicare and Medicaid Services [cited 10/15/2007]. http://www.cms.hhs.gov/FACA/downloads/id28a.pdf?origin=globalsearch&page=/mcd/viewmcac.asp&mid=28&where=index. Last accessed November 2, 2008.
5. Bergan JJ, Schmid-Schönbein GW, Smith PD, et al. Chronic venous disease. N Engl J Med 2006;355:488-98.
6. Margolis DJ, Bilker W, Santanna J, et al. Venous leg ulcer: incidence and prevalence in the elderly. J Am Acad Dermatol 2002;46:381-6.
7. Hareendran A, Bradbury A, Budd J, et al. Measuring the impact of venous leg ulcers on quality of life. J Wound Care 2005;14:53-7.
8. van Gent WB, Hop WC, van Praag MC, et al. Conservative versus surgical treatment of venous leg ulcers: a prospective, randomized, multicenter trial. J Vasc Surg 2006;44:563-71.
9. Centers for Disease Control and Prevention. History of foot ulcer among persons with diabetes: United States 2000-2002. MMWR Morb Mort Wkly Rep. 2003;52:1098.
10. Cho CH, Sung HK, Kim KT, et al. COMP-angiopoietin-1 promotes wound healing through enhanced angiogenesis, lymphangiogenesis, and blood flow in a diabetic mouse model. Proc Natl Acad Sci U S A 2006;103:4946-51.
11. Gibran NS, Jang YC, Isik FF, et al. Diminished neuropeptide levels contribute to the impaired cutaneous healing response associated with diabetes mellitus. J Surg Res 2002;108:122-8.
12. Maruyama K, Asai J, Ii M, et al. Decreased macrophage number and activation lead to reduced lymphatic vessel formation and contribute to impaired diabetic wound healing. Am J Pathol 2007;170:1178-91.
13. Grayson ML. Diabetic foot infections. Antimicrobial therapy. Infect Dis Clin North Am 1995;9:143-61.
14. Yönem A, Cakir B, Guler S, et al. Effects of granulocyte-colony stimulating factor in the treatment of diabetic foot infection. Diabetes Obes Metab 2001;3:332-7.
15. Lavery LA, Armstrong DG, Wunderlich RP, et al. Risk factors for foot infections in individuals with diabetes. Diabetes Care 2006;29:1288-93.
16. Diabetes and Cardiovascular Disease: Time to Act. Brussels: International Diabetes Federation [cited 10/12/2007]. http://www.idf.org/webdata/docs/Diabetes%20and%20CVD.pdf. Accessed November 2, 2008.
17. Gawlitta D, Li W, Oomens CW, et al. The relative contributions of compression and hypoxia to development of muscle tissue damage: an in vitro study. Ann Biomed Eng 2007;35:273-84.
18. Tsuji S, Ichioka S, Sekiya N, et al. Analysis of ischemia-reperfusion injury in a microcirculatory model of pressure ulcers. Wound Repair Regen 2005;13:209-15.
19. Groeneveld A, Anderson M, Allen S, et al. The prevalence of pressure ulcers in a tertiary care pediatric and adult hospital. J Wound Ostomy Continence Nurs 2004;31:108-20.
20. Pressure ulcers in America: prevalence, incidence, and implications for the future. An executive summary of the National Pressure Ulcer Advisory Panel monograph. Adv Skin Wound Care 2001;14:208-15.
21. Russo CA, Elixhauser A. Hospitalizations related to pressure sores, 2003. HCUP Statistical Brief #3. Rockville, MD: Agency for Healthcare Research and Quality [cited 2006 8/31/2006]. http://www.hcup-us.ahrq.gov/reports/statbriefs/sb3.pdf. Accessed November 2, 2008.
22. Landi F, Onder G, Russo A, et al. Pressure ulcer and mortality in frail elderly people living in community. Arch Gerontol Geriatr 2007;44 Suppl 1:217-23.
23. Redelings MD, Lee NE, Sorvillo F. Pressure ulcers: more lethal than we thought? Adv Skin Wound Care 2005;18:367-72.
24. Bakken S, Cimino JJ, Hripcsak G. Promoting patient safety and enabling evidence-based practice through informatics. Med Care 2004;42:II49-56.
25. Dorr D, Bonner LM, Cohen AN, et al. Informatics systems to promote improved care for chronic illness: a literature review. J Am Med Inform Assoc 2007;14:156-63.
26. Coerper S, Wicke C, Pfeffer F, et al. Documentation of 7051 chronic wounds using a new computerized system within a network of wound care centers. Arch Surg 2004;139:251-8.
27. Frias Soriano L, Lage Vázquez MA, Maristany CP, et al. The effectiveness of oral nutritional supplementation in the healing of pressure ulcers. J Wound Care 2004;13:319-22.
28. Subbanna PK, Margaret Shanti FX, George J, et al. Topical phenytoin solution for treating pressure ulcers: a prospective, randomized, double-blind clinical trial. Spinal Cord 2007;45:739-43.
29. Whitney JD, Salvadalena G, Higa L, Mich M. Treatment of pressure ulcers with noncontact normothermic wound therapy: healing and warming effects. J Wound Ostomy Continence Nurs 2001;28(5):244-52.
30. Thomas DR, Rodeheaver GT, Bartolucci AA, et al. Pressure Ulcer Scale for Healing: derivation and validation of the PUSH tool. The PUSH Task Force. Adv Wound Care 1997;10:96-101.
31. Schubert V, Zander M. Analysis of the measurement of four wound variables in elderly patients with pressure ulcers. Adv Wound Care 1996;9:29-36.
32. Gorin DR, Cordts PR, LaMorte WW, et al. The influence of wound geometry on the measurement of wound healing rates in clinical trials. J Vasc Surg 1996;23:524-8.
33. Jessup RL. What is the best method for assessing the rate of wound healing? A comparison of 3 mathematical formulas. Adv Skin Wound Care 2006;19:138-47.
34. Cukjati D, Rebersek S, Miklavcic D. A reliable method of determining wound healing rate. Med Biol Eng Comput 2001;39:263-71.
35. Stotts NA, Rodeheaver GT, Thomas DR, et al. An instrument to measure healing in pressure ulcers: development and validation of the Pressure Ulcer Scale for Healing (PUSH). J Gerontol A Biol Sci Med Sci 2001;56:M795-9.
36. Berlowitz DR, Ratliff C, Cuddigan J, et al. The PUSH tool: a survey to determine its perceived usefulness. Adv Skin Wound Care 2005;18:480-3.
37. Brem H, Kirsner RS, Falanga V. Protocol for the successful treatment of venous ulcers. Am J Surg 2004;188:1-8.
38. Brem H, Lyder C. Protocol for the successful treatment of pressure ulcers. Am J Surg 2004;188:9-17.
39. Robson MC, Cooper DM, Aslam R, et al. Guidelines for the treatment of venous ulcers. Wound Repair Regen 2006;14:649-62.
40. Steed DL, Attinger C, Colaizzi T, et al. Guidelines for the treatment of diabetic ulcers. Wound Repair Regen 2006;14:680-92.
41. Brem H, Sheehan P, Rosenberg HJ, et al. Evidence-based protocol for diabetic foot ulcers. Plast Reconstr Surg 2006;117:193S-209S; discussion 10S-11S.
42. Whitney J, Phillips L, Aslam R, et al. Guidelines for the treatment of pressure ulcers. Wound Repair Regen 2006;14:663-79.
43. Samad A, Hayes S, French L, et al. Digital imaging versus conventional contact tracing for the objective measurement of venous leg ulcers. J Wound Care 2002;11:137-40.
44. Rajbhandari SM, Harris ND, Sutton M, et al. Digital imaging: an accurate and easy method of measuring foot ulcers. Diabet Med 1999;16:339-42.
45. Houghton PE, Kincaid CB, Campbell KE, et al. Photographic assessment of the appearance of chronic pressure and leg ulcers. Ostomy Wound Manage 2000;46:20-6, 28-30.
46. Brem H, Jacobs T, Vileikyte L, et al. Wound-healing protocols for diabetic foot and pressure ulcers. Surg Technol Int 2003;11:85-92.
47. Peres M. Close-up photography and photomacrography. In: Paul VJ, ed. Biomedical Photography. Boston, MA: Butterworth-Heinemann 1992:171-99.
48. Saap LJ, Falanga V. Debridement performance index and its correlation with complete closure of diabetic foot ulcers. Wound Repair Regen 2002;10:354-9.