Using cluster analysis to develop a healing typology in vascular ulcers

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A clinically meaningful typology of healing was developed to assist nurses in assessing patients' healing potential. A descriptive correlational design was used to determine similarities in healing characteristics of older people with venous, venous-arterial, and arterial leg ulcers (n = 156). Hierarchical clustering techniques dendrogram using Ward's method suggested that three clusters existed based on the ankle/brachial pressure index, liposclerosis (hardening and induration of the skin of the lower limb), edema, and wound characteristics; thus a healing typology was potentially formed. Nonhierarchical techniques such as analysis of variance examined cluster differences for the initial ulcer area ($p < 0.013$) and suggested that these groupings were reflective of differing ulcer areas. However, significant differences in the rate of healing (difference between ulcer surface area in week 4 and week 1) (measured by topographic mapping) group comparisons were not significant at the 0.05 level. Clinical differences in the healing rate were apparent, and three individual profiles of leg ulcer sufferers based on the three differing clusters of factors were outlined: rapid healers, slow healers, and nonhealers. Further research into the clustering of these factors and their application to longer healing times or time to complete healing may be significant and support the utility of this typology. (J Vasc Nurs 1997;15:45-9.)

Community nurses are major care providers for patients with chronic leg ulcers. Complete healing is the goal of most nursing care, but the presence of substantial venous or arterial disease, or both, may preclude that outcome. Diagnosis of the type of peripheral vascular disease is critical, although community nurses and physicians have limited access to high-technology diagnostic facilities. Many factors that explain healing in these patients are not interventions but measures of pathophysiologic change.[1] Interventions aimed at slowing the progression of these changes and enhancing healing potential are determined by the medical diagnosis. This study presents an alternate classification system for leg ulcer patients based on healing potential. This typology would form part of the community nurses' initial and ongoing assessment of leg ulcer clients.

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LITERATURE REVIEW

Leg ulcer etiology

A chronic leg ulcer is a manifestation of disease and not a disease itself; venous and arterial disease, rheumatoid disease, and diabetes mellitus may be present.[2] These conditions are not mutually exclusive; an increasing proportion of leg ulcer patients have venous and arterial disease.[2] Currently, the medical diagnosis of venous or arterial disease directs the nursing interventions.[3] Therapies for venous ulcers, such as limb compression and elevation, are contraindicated in the presence of arterial disease.[4] For clients with coexisting venous and arterial disease, this can result in clinicians feeling that they should do no harm, and consequently they may apply bandages at pressures unable to be beneficial,[5] or may simply attend to wound care without addressing other underlying factors that influence healing.

Factors influencing healing

Previous healing modeling, including physiologic, therapeutic, and psychosocial factors, highlighted the fact that increased pain when the patient is mobile, increased hours with limbs in horizontal positions, moderate and severe liposclerosis (hardening and induration of the skin of the lower limb), and necrotic and exudative or yellow necrotic wound characteristics were associated with poorer healing in venous ulcers (49% of the variance in the healing rate explained).[1] The presence of edema was also an important factor. Limb positioning was the only important therapeutic factor, even though ankle compression, dressing, and diuretic usage were examined. The inclusion of subjects with venous and arterial disease still allowed for 24% of the variance in the healing rate to be explained by liposclerosis, wound characteristics, pain when the patient is mobile, and to a lesser extent, horizontal limb positioning.[1] Consistent factors appeared in the venous and venous-arterial disease groups. As can be seen from these findings, wound characteristics, liposclerosis, and edema are common features assessed by clinical nurses before any intervention. Similarly, correct diagnosis as to the extent of arterial disease is critical.

Clustering techniques and proposed typology

The ability of clustering techniques to identify recurring patterns among individuals, the basis of diagnostic groupings, was identified some time ago.[6] Cluster analysis examines the similarities and dissimilarities between individual cases on a set of variables to demonstrate the likely classification.[7] Hierarchical and nonhierarchical techniques of cluster analysis are used in these analyses to construct typical healing pro-

A long-standing venous ulcer in patient with no documented coagulation abnormalities despite nine members of the family having a history of venous thrombosis. This patient had mesentric venous thrombosis and two subsequent deep venous thromboses while taking coumadin. Note the liposclerosis and hemosiderin deposits. (History and photo courtesy of Janice D. Nunnelee, RN, MSN, CS.)

files of clients with leg ulcers. Hierarchical clustering relates cases to other cases by graphic linkages such as a dendrogram. From this pictorial understanding a relatively arbitrary selection of cluster groupings can be made. The analysis then proceeds to force all cases into groups. Nonhierarchical techniques, such as analysis of variance, are then used to determine cluster differences on factors used for the classification, and more appropriately, some outcome measure.[7]

The proposed typology is derived from the principles of the pathologic processes of venous and arterial disease and the factors that influence healing in leg ulcers. Postphlebitic damage with resulting stenosis and occlusion of superficial or deep veins leads to venous hypertension, capillary dilatation and proliferation, and leg ulceration.[8] The overlying tissue becomes anoxic and ulcerates, lipodermatosclerosis occurs, redness and brown pigmentation (hemosiderin deposits) of the skin develop, and thickening and hardening of skin and subcutaneous tissue occur.[9] Failure to heal has been related to the degree of lipodermatosclerosis.[10] Varicose eczema may develop[11] but may be difficult to differentiate from the eczema that follows allergic responses to treatments. Hyperpermeability results in edema, a factor in poorer healing, although the exact mechanism remains unclear.[12] Venous skin changes such as hyperpigmentation, liposclerosis, and edema have been found to be present in 70% of leg-ulcer sufferers[13] and will be the factors included in this study.

Arterial ulcers are a result of partial or complete occlusion of the arteries supplying the lower limbs.[3] The presence or absence of peripheral pulses is not always an accurate indication of disease or the ability of an ulcer to heal.[4,14] Noninvasive procedures, such as Doppler ultrasonography, demonstrate the extent of arterial ischaemia by determining the distal systolic occluding pressure or the ratio of the highest ankle pressure to brachial pressure (ankle/brachial pressure index [ABpI]). An ABpI less than 0.80 has been associated with arterial disease.[15] Investigators suggest that an ischemic ulcer will heal if the ankle systolic blood pressure is more than 50 mm Hg or the ABpI is greater than 0.25.[16] Not only is this procedure an indicator of arterial ischemia, it is also an indicator of healing. ABpI will be considered as an element in this typology.

Wound characteristics—moderate exudate in the inflammatory phase; granulation tissue in the proliferative phase; marginal epithelial cell migration during the proliferative and maturation phases[17]—are features that guide dressing selec-

TABLE

HEALING POTENTIAL TYPOLOGY

	Characteristics					
Type	***ABpI****	***Liposclerosis***	***Edema***	***Wound***	***Ulcer size***	***Healing rate/mo***
Rapid healing	*1* 0.91	*0* No liposclerosis	*0* No edema	*2* Granulating	Small ulcer 320 mm^2	40% decrease in ulcer area
Slow healing	*2* 0.63	*0* No liposclerosis	*1* Mild edema	*3* Exudative	Moderate to large ulcer 773 mm^2	11% decrease in ulcer area
No healing	*3* 1.01	*3* Liposclerotic changes on lower third of the limb	*1* Mild edema	*3* Exudative	Moderate-to-large ulcer 741 mm^2	13% increase in ulcer area

*This sample did not include sufficient numbers of patients with severe arterial disease or very low ABpI.

tion and may reflect disease as well as cellular activity in both venous and arterial disease. Wound characteristics will also be included in this classification.

The first purpose of this study was to develop a healing typology for chronic leg ulcers on the basis of the factors that affect healing in venous and arterial disease: hyperpigmentation, liposclerosis, edema, ABpI, and wound characteristics. Second, to further validate this typology, hypotheses will be examined that explore (1) the differences in the developed clusters in terms of the initial ulcer area and (2) the rate of healing.

METHOD

A descriptive correlational design was used to cluster healing factors in participants with venous, venous-arterial, and arterial leg ulcers.

Sampling and sampling procedures

A convenience sample of clients from home-nursing services in two major Australian cities fulfilling the following criteria were selected: (1) 60 years of age or older; (2) having a leg ulcer of more than 6 weeks' duration; (3) no history of sickle cell disease or thalassemia; (4) no oral steroid use; (5) able to understand English or having available interpreter assistance; and (6) cognitively able to give consent or having a significant other available to give consent. Fourteen subjects (8%) withdrew during the data collection period because of unexpected events. From the remaining participants (n = 156) the mean age was 78 years (median 79 years) with a standard deviation of 8 years (range 60 to 96 years); 58% were female, 42% male. Additional losses occurred at the follow-up visit (n = 16), leaving 140 subjects with complete data sets. Written consent to participate in this study was obtained from all participants or significant others. Ethical approval was obtained from both home nursing services and university ethics committees.

Instruments

The following instruments were used in the study:

- **ABpI.** Measured with the Medasonics ultrasound stethoscope, model BF5A (a pocket-pencil Doppler)
- **Hyperpigmentation and liposclerosis indices.** Range from 0 (absence) to 3 (severe, lower third of the limb affected)
- **Edema index.** Range from 0 for no evidence of swelling to 3 for severe swelling of the limb
- **Wound status index.** Pink (new tissue, reepithelialization) = 1, red (revascularization granulation tissue present) = 2, yellow (exudate/yellow necrosis) = 3, and black (necrosis) = 4; also has interval data characteristics
- **Healing or monthly changes in surface area.** Measured by a topographic mapping technique known as stereophotogrammetry

Healing rate per 28 days was calculated by subtracting the surface area at week 4 from the initial surface area at week 1 multiplied by 28, then divided by the initial surface area multiplied by the number of days between measurements. The relationship between short-term intervals of surface area change and the endpoint of healing has been supported.[18]

The healing rates ranged from -4 to 9, with ulcers that decreased in surface area (healing) during the study period having negative values. The reliability and validity of these instruments has been addressed elsewhere.[1,19]

Procedure

All data were collected during or after the normal home nursing visit. Clients were visited in their homes on two occasions, week 1 and week 4 or 5. First, Doppler sonograms were performed, and stereophotographs of the wound were taken. The scales to assess hyperpigmentation, liposclerosis, and edema were then completed. Only one ulcer was selected per participant. The Short Portable Mental Status Questionnaire[20] was also administered to ensure that subjects were

Veins that have been marked for surgery. Circular marks indicate perforator veins. (Photo courtesy of Janice D. Nunnelee, RN, MSN, CS.)

able to give informed consent. The only data included in this study from the second visit were the stereographs of the wound.

Data analysis

Hierarchical and nonhierarchical techniques of cluster analysis were used in these analyses to construct typical profiles of clients with leg ulcers.[8] A randomly selected subset of the total data set (n = 48) was used in the hierarchical techniques, and the entire sample was used in the nonhierarchical techniques (n = 150). All analyses were performed with the Statistical Package for the Social Sciences. The development followed a four-step procedure: (1) determining relationships between variables (correlation matrix), (2) graphic clustering using Ward's method (dendrogram) progressively aggregating clusters of similar cases. Validation was performed by retaining the clusters and examining differences in the mean initial ulcer and rate of healing for the defined clusters using nonhierarchical techniques such as analysis of variance.

RESULTS

Most subjects (n = 148, 95%) were found to have normal or mildly impaired cognition and had illnesses such as osteoarthritis (n = 86, 55%), arteriosclerosis (n = 39, 26%), leg clots (n = 34, 22%), rheumatoid arthritis (10%, n = 15), and diabetes mellitus (n = 21, 14%). The duration of chronic leg ulcers ranged from 2 to 384 months (median 12 months), and the initial ulcer area ranged from 3 to 5367 mm^2.

The correlation matrix performed on the factors demonstrated coefficients less than 0.50, except for hyperpigmentation, which was strongly correlated with liposclerosis (r = 0.56, p = 0.001) and subsequently removed from further analyses. The initial cluster analysis by Ward's method (minimizing within-cluster variation) on a subset of the data represented in the dendrogram suggested that there were three major groupings for the four factors (ABpI, liposclerosis, edema, and wound characteristics).

The final cluster centers for the factors in the three clusters were evenly distributed in the three clusters: cluster 1 representing 32% (48/150), cluster 2 representing 37%, and cluster 3 representing 31%. Further validation of the relationship of the groupings to the outcome of healing was confirmed with an analysis of variance finding significant differences in the initial ulcer area for the groups (cluster 1 mean [M] = 319.6 mm^2, cluster 2 M = 773.44 mm^2, cluster 3 M = 741.10 mm^2; F (2,147) = 4.507, p = 0.013).

Subsequent analysis of variance of the rate of healing for the three clusters was, however, not significant at the 0.05 level (cluster 1 M = – 0.39 [SD = 1.76]; cluster 2 M = – 0.11 [SD = 0.45]; cluster 3 M = 0.13 [SD = 1.03], F(2,136) = 2.159, p = 0.11).

DISCUSSION

Nursing interventions that promote healing currently rely on disease assessment, the utility of such diagnosis being limited in its use, particularly in the community. Another taxonomy, based on healing, has been explored. This study uses data from a study designed to identify factors that influence healing in leg ulcers[1] and the interactions of control and health beliefs in leg ulcer sufferers.[21] Three levels (or clusters) of healing were identified with four characteristics: ABpI, liposclerosis, edema, and wound status. Differences between the three clusters for the initial ulcer area were significant, supporting the first hypothesis. Unfortunately, these differences were not found at the 0.05 significance level for the healing rate; therefore the second hypothesis was not supported. Differences were, however, present at the 0.11 level, and clinically significant differences were apparent between cluster 1 (–M = 0.39, rapid healing rate), cluster 2 (M = –0.11, still healing but slower than 1), and cluster 3 (M = 0.13, an ulcer that is deteriorating or increasing in surface area over time). A larger sample size may result in significant findings. Another plausible explanation for this result may be that shorter time periods for change in the surface area result in quite different findings than do 3-month study periods or time to complete healing.

The clustering of healing factors has demonstrated differences in the initial ulcer area. The area would be related to

the duration of the ulcer and indirectly to the healing time. Because there were clinical differences in the healing rate and differences significant at the 0.11 level, profiles for persons within each cluster are presented on the basis of the characteristics of centroids of the cluster analysis and related to the mean initial ulcer area of the clusters also derived from the initial hierarchical analysis in the Table.

Implications for clinical practice

In practice, all patients would be assessed for their healing potential level on the related factors (ABpI, liposclerosis, edema, and wound status). For example, a patient with an ankle/brachial pressure of 0.92 (level 1), no liposclerotic changes (level 0), mild edema (level 1), and an exudative wound (level 3) is likely to have a healing potential of 2 or be a slow healer. This patient is likely to have an ulcer area that will decrease in surface area at 11% per month on the basis of these factors alone. By reducing the edema by adequate compression and elevation, and appropriate wound care for an exudative wound, the healing level may rise to 1, or 40% decrease in the month. This may occur because the edema is reduced (level 0) and the wound begins granulating (level 2) as a result of appropriate wound care. This system allows for areas of assessment to be related directly to the interventions and also encourages the clinician to assess regularly all of these factors to improve the healing potential.

Implications for research

The application of these clusters to another sample using discriminant function analysis would further develop and cross-validate this typology. This study has highlighted how clustering techniques can define groupings on the basis of specific characteristics and supported the importance of applying those clusterings to some meaningful clinical outcome.[7] The application of this typology, if further validated, also rests on clinicians making a concerted effort to alter their thinking to incorporate these new notions.[22]

The inclusion of cluster-analytic techniques in the development of a client typology and nursing diagnoses, and their application to meaningful clinical outcomes, is limited in the nursing literature. These techniques may provide new insights as we strive to define nursing's focus within health care.

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