Title
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Journal
Nursing Clinics of North America, 25(1)

ISSN
0029-6465

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Publication Date
1990-03-01

DOI
10.1016/s0029-6465(22)00232-8

 0029-6465/90 $0.00 + .20

Optimizing Wound Healing

A Practice Within Nursing's Domain

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The 1980s could perhaps be referred to as the "era of the wound." During the past decade, owing in large part to the work of Winter and others,[15,16,43,44] who documented the fact that moisture was the optimal environment for epithelial cell replication, there has been a burgeoning of wound care products and a concurrent emphasis on educating health care professionals in the theoretical basis and use of these new modalities. The vast majority of instruction regarding healing and approaches to wound care has been undertaken by manufacturers, and although in some cases firmly grounded in theory, in others the content varies both in depth and quality. Increasingly, clinicians work at synthesizing basic science and the findings of bench research pertaining to wound healing. Some have reformulated the information available and shared their conclusions and suggestions in the literature, hoping to influence the quality of healing in humans. This latter process is only recently gaining momentum, however, and, not unlike the information provided by companies, varies in depth, quality, and practicality. Realistically, regardless of how well presented, many publications do not reach those who might best incorporate the information contained in them into their everyday practice with patients; nor in most circumstances have the authors addressed the issues of the appropriateness and degree of involvement of selected members of the health care team in the activities of caring for a patient with a wound.

Aware of the need for ongoing instruction and discussion in this important area of clinical practice, this article begins by focusing on the appropriateness of wound healing activities as one of nursing's legitimate practices. Some of the reasons why clarity regarding the healing process is essential to active participation in wound care in today's health care milieu are also addressed as well as examples of how to influence trends

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suggested. An overview of the process by which wounds heal is presented, at the same time as some of the factors known to affect the quality of healing are highlighted. Finally, because for clinicians knowledge is most useful when it influences practice, issues surrounding selected wound care treatments currently in vogue are raised. All this is done to create a backdrop against which the remaining articles in this symposium might be read.

HEALING ACTIVITIES: APPROPRIATENESS FOR NURSING

Recently a group of nurses was asked to suggest what they thought the most appropriate treatment for selected open wounds might be; several responded by saying that in doing so they felt as if they were "acting like physicians." It is doubtful that such a reaction is unique to the individuals in that particular sample. Despite being actively involved daily in tending wounds, for years many nurses have viewed wound care, particularly the act of suggesting or directing local wound care treatments, as being clearly the domain of medicine and, therefore, the sole prerogative of the doctor, not the nurse. This relegation of the *directional* aspects of wound care to a dependent function in nursing is interesting given the fact that nurses have long been viewed as the members of the health care team most closely involved in ministering to wounds. The images of nurses creatively organizing and initiating the care of wounded soldiers and the ill within the community reflect some of the ways in which nurses have effectively directed and implemented wound care. Yet, in other settings, the acute care hospital in particular, where over 80% of nurses currently practice with some of them tending increasingly complex wounds, the extent of the nurses involvement in the directional aspects of wound care remains poorly defined.

In spite of the belief held by some that all aspects of wound care are dependent nursing functions, the attitudes of many nurses and physicians regarding that care are changing. With increasing frequency some members of both professions collaborate not only about the status of a patient's wound but, more significantly, they deliberate about the most appropriate and physiologically sound interventions to treat wounds. Many might view the current expansion in nursing practice regarding wound care as coincidental to the overall increased collaboration between physicians and nurses. I submit that an alternative explanation is perhaps more accurate and deserves consideration.

In addition to the fact that healing activities have always formed the basis of nursing practice, it is likely that the current expansion by some nurses of their role in the care and treatment of patients' wounds lies in the fact that in general nurses are gaining increased clarity about which of the activities they perform with patients are clearly identifiable as *nursing*. As these individuals become clearer about the domain of nursing, they gravitate toward, study, and master selected aspects of patient care, reformulating them for nursing and ultimately increasing autonomy in those areas for the profession at large. Examples of patient care situations to which nurses have brought new perspective, scholarship,

and increased autonomy are pain management, attentive care of the terminally ill, the teaching of health care practices, active guidance during the birthing process, and, gradually, the organization of systematic and therapeutic approaches to skin and wound care. With regard to wound healing, however, the increasing involvement nurses have vis-à-vis adoption of some new products should not be mistakenly accepted as proof that clarity exists regarding the breadth of healing activities forever embedded in nursing practice.

It is Levine, a nurse theorist, who speaks most directly of the essential role of the nurse as the promoter of healing, of reintegration, of wholeness (i.e., hāl, Anglo-Saxon word for whole) within the human body.[25-32] Through her "conservation principles" Levine elucidates the duty the nurse has in protecting the patient's structural integrity. In addition, she points out that all nursing activities are directed toward conserving the patient's energy. Nurses select energy-conserving interventions, Levine suggests, in order that patients might channel all available energy toward the healing process at hand, be it the realignment of tissue, of self, or even the reintegration of oneself with family and community. Levine clarified the pivotal and pervasive nature of the healing role of the nurse most clearly when she wrote:

> Every healing process, regardless of its nature, occurs over a period of time. The success of the ultimate healing depends in large measure on what happens to the individual during that time. The nurse is the person on the health team who shares the most time with the patient, and thus no worker can influence the success of the healing process more than the nurse. Nursing processes of every kind are dedicated to the promotion of healing.[29]

This cementing by Levine of the influential and essential role nurses assume in regard to healing must be carefully understood and actively espoused by nurses if they are to fulfill their role definition. Healing behaviors, among them meticulous assessment of a patient's wound; coordination of a carefully orchestrated and scientifically based plan of wound care; active suggestion of modifications in wound care treatments as the need arises; anticipation of wound care problems (including the assessment of the potential for skin breakdown); practical, timely, and helpful teaching of wound care treatments to patient and family; and ongoing supportive assistance to the patient and family throughout the healing process all represent actions reflecting the breadth of healing activities undertaken by nurses. Thus, healing, including the directional and coordinating aspects of local wound care, is an appropriate activity and bedrock to nursing practice. In the years to come nurses will need to work with increased diligence at codifying and testing the activities they perform in assisting the patient to heal. As they do so, greater and greater responsibility for the total care of tissue wounds will fall to them.

NECESSITY FOR CLARITY REGARDING THE HEALING TRAJECTORY

In the case of tissue healing the strongest reason for understanding the physiology of the process is the fact that all activities that concern

patients must be theory based.[9,31] Only with a clear grasp of the intricacies of the healing trajectory are clinicians able to provide optimal, goal-directed wound care. It is necessary to emphasize the significance of understanding the healing process and the necessity of supporting wound care practices with research partly because of the fact that, other than focusing on the initial changes brought about in the patient as a result of the trauma that caused the wound, healing, for the most part, has been viewed by the majority of clinicians as a tranquil, inevitable, and "unimprovable" process.[20] Because of its universal nature, healing is so familiar as to be an expected event that will evolve successfully regardless of what anyone does.[30] Consequently, with few exceptions,[5,6,17-19,22,41] not enough has been done by clinicians to study the conditions and therapies affecting the healing wound in humans.

An age-old adage ascribed to Paré, a noted French surgeon, speaks to the attitude that healing is a passive process and states "I dressed the wound, God heals it." Although few present-day clinicians would agree with the passivity of Paré's dictum, many, seeing the majority of wounds heal in a nonproblematic manner, assume that healing is a given. And, although most wounds do heal without noticeable consequence, adoption of the belief that this is a universal will always be incorrect. Findings point up the fact that even in the case of apparently optimal healing, actions can be taken to support, perhaps even enhance, the quality of the process.[41] Nurses tending wounds, then, cannot approach them as inert phenomena. Rather, they must know precisely what it is they are assessing when they evaluate a patient with a wound, or the wound itself, before they can initiate or carry out actions directed at optimizing healing.

Looked at from another perspective, clarity regarding the healing trajectory assists clinicians in the selection of therapies aimed at restoring integrity with the least energy expenditure by the patient. Pragmatically, selection of appropriate therapies can result in earlier patient discharge from costly health care settings and reduce the emotional drain of protracted recovery placed on some patients and families.

At present the marketplace is deluged with new products to treat wounds. In order to utilize the health care dollar judiciously, nurses need to assume an active role in the selection of effective products known to support healing. One approach to accomplishing this is for nurses, knowledgeable about the healing process, to place themselves strategically on committees where products are evaluated. Likewise, when new and effective treatment modalities appear, adoption of the cost-effective products is greatly increased if nurses bring them to the attention of the appropriate individuals. Being cognizant of products known to reduce healing time and patient discomfort is a necessary and appropriate nursing activity and is another reason why clarity regarding the healing trajectory is essential. There are products on the market reported to have proven healing properties, to increase patient rest time, and to reduce nonproductive nursing time.[2,35,36]

In addition to selecting effective products, nurses also need to challenge the manufacturers of poorly tested products to substantiate them with tightly controlled research findings. Adoption of untested "thera-

pies" only further entrenches wound care in the unscientific mode in which it has existed for far too long. Active involvement in the creation and testing of wound care products that optimize patients' healing, likewise, is an example of an indirect but potentially meritorius healing activity.

The continued exclusive use of traditional wound care materials throughout an institution because that is the way "it has always been done," or snap adoption of new but poorly tested products are equally negative circumstances and nurses must challenge them. Clarity regarding the healing trajectory leading to the formulation of sound protocols for wound care usually makes the situation described above nonexistent. Further, the effort put into establishing protocols elevates practitioners' vigilance regarding wound care, eventually reduces costs, and can form the basis for research regarding systematic and beneficial approaches to care.

Health care, whether provided in the hospital or the home, is expensive. Increasingly patients with complex wounds, who in the past would have remained in the acute care setting, are being transferred back to their homes with follow-up care provided by nurses in the community. This set of circumstances forces community health nurses to re-evaluate their knowledge of the physiology of healing and the interventions that support the process. The energy of dedicated professionals, intent on supporting healing, need not be drained by the provision of outmoded, unsubstantiated therapies. In addition to expanding their knowledge of tissue healing, nurses in the community also need to work closely with manufacturers to effect the creation of products that can be used easily in the home by family members, require infrequent application, and are not so costly as to be prohibitive.

Enhancing one's understanding of the healing process through knowledge of the alterations brought about as a consequence of various medical conditions also can assist the clinician to anticipate problems and proactively support healing. Being fully cognizant of the fact, for example, that the first moments of healing greatly influence the subsequent quality of the wound separates the informed nurse "healer" from the uninformed.

To summarize, then, increasing one's clarity regarding the healing trajectory can only serve to influence the way one approaches the patient with a wound. The growing clarity of the essential role the nurse has in wound tending, combined with an awareness of the pressures imposed upon the ill in today's health care environment, demand that nurses be intricately involved in all aspects of wound care and that they influence the direction it takes. Bearing that in mind, it seems appropriate to review the healing process.

THE HEALING PROCESS

Healing has been described variously as the "defense of wholeness,"[32] "a normal reaction to injury,"[20] and the "filling of a defect with connective tissue."[4] Some scholars maintain that healing "consists of a

chronological sequence of events"[39] that is "highly integrated and follows an orderly sequence."[24] Others, however, regard it as less than ordered, if not an "imperfect,"[12] "nonspecific,"[1] or "pathologic" process.[12] Regardless of the definition or degree of orderliness, wound healing is "a fundamental quality of living tissue,"[41] which, if absent, would quickly result in extinction of the human species.[38]

Not unlike a waterfall, healing is a cascading process composed of multiple small goal-directed events that combine and result in the creation of something more complex and energy rich than any one component considered by itself. It is a process as intricate as any of the other major functions in the human body and, for the sake of discussion, must be divided into stages.

Some writers separate the healing trajectory into three phases, others four or more depending on their perspective.[20,38,39] The terms used to describe the phases also differ from author to author, though the events described within each phase allow one to identify easily the stage being addressed. Using the three-phase approach, the healing trajectory can be divided into the *inflammatory phase*, the *proliferative phase*, and the *maturation phase*. Certainly scholars have written indepth analyses of the healing process and it is not my intent to describe it to the extent found elsewhere.[17–19] Rather, an overview of the process is provided, pointing up selected aspects of the trajectory that might have particular significance for the clinician.

The Inflammatory Phase

Immediately after injury, regardless of the source, changes in the severed vessels occur in an attempt to wall the wound off from the external environment. Platelets, activated as a result of vessel wall injury, aggregate; blood coagulation is initiated; and in larger vessels, smooth muscle tissue contraction occurs, resulting in reduction in the diameter of the vessel lumen. These brief but important compensatory mechanisms serve to protect the entire organism from excessive blood loss and increased exposure to bacterial contamination.

The complement system, another key component of this initial phase of healing, is also activated. This system, composed of a group of proteins, plays a "central role in the inflammatory response."[10] Normally the proteins making up the complement system lie dormant in the blood, the interstitial fluid, and on the mucosal surfaces. When activated by microbes or antigen-antibody complexes, however, three key activities of the system come into play, namely: vasodilation of capillaries, chemotaxis (i.e., unidirectional migration) of phagocytic leukocytes into the contaminated region, and opsonization (i.e., coating) of the microbes for effective phagocytosis.[11] The chemotactic aspect of the complement system occurs as the result of the production of C3a and C5a, powerful and "critical" chemoattractants for neutrophils and monocytes.[10]

The efflux of phagocytic cells out of the vessels in which they normally reside is facilitated also by the action of kinins released early on by the platelets, so that 10 to 30 minutes after injury the vessels in and around the wound dilate and remain dilated for some time. External, macroscopic manifestations of vessel dilation and the subsequent efflux

of intravascular fluid can be observed by noting the classical indices of tissue injury—namely, heat, redness, and swelling in the wounded area. The combined result of vessel dilation and the production of C3a and C5a is the movement of cells through actual gaps in the capillary walls (i.e., diapedesis) caused by reversible opening of the junctions between the endothelial cells. Thus, cells normally contained within the intact microvasculature move into the area immediately adjacent to the wound causing large numbers of white blood cells to be present there.

Once there, given the right environment, the white blood cells actively ingest bacteria, secreting proteolytic enzymes as they do so. The presence of these enzymes ultimately stimulates the influx of still other cell types necessary for healing. In the meantime the initial phagocytic cell in the wound area is the polymorphonuclear neutrophil (PMN). These multilobular nucleated leukocytes ingest bacteria and debris by drawing them into the cell eventually exposing them to lysosomal enzymes. Although short lived (i.e., half-life in circulation of 6 hours) PMNs are quite effective in clearing the wound of contamination if the numbers of bacteria are not excessive (i.e., greater than 10^5 per gram of tissue).[34]

Approximately 24 hours after injury another larger and less selective phagocytic cell enters the wound area and remains there for an extended period. This cell, arising from the blood monocyte, is activated by lymphokines secreted by lymphocytes and once in the extravascular space is referred to as a histiocyte or fixed tissue macrophage. In addition to its role in phagocytosis, particularly of dead tissue, the macrophage is now considered to be the essential cell in the healing process primarily because of its role in the secretion of an angiogenesis factor (AGF).[3,14] The secretion of AGF by the macrophage is the stimulus for the formation of endothelial buds at the end of injured vessels. The intact microcirculatory network that results from vessel reanastomosis sustains the healing process and the wound itself throughout its life. So significant is the macrophage and the secretion of AGF that it is this cell that is now considered to be essential to the healing process; healing would be severely compromised, if not thwarted altogether, if one did not possess adequate numbers of properly functioning macrophages.

An additional factor that can influence the effectiveness of the macrophage and other cells in the early moments of healing is the degree of oxygen present in the wound area. Although both macrophages and neutrophils can accomplish phagocytosis in a relatively anoxic environment, the total absence of oxygen greatly reduces the "efficiency of intracellular digestion [of bacteria]" by both these cells.[38] Macrophages, for example, have been shown to be inactivated at a pO_2 level of less than 30 mm Hg. Thus, it has been said that there is a linear relationship between oxygen availability and the efficiency of healing. Logically one can project what might happen to the quality of healing in a wound in which oxygen was reduced greatly and bacteria were allowed to flourish.

The significant place the inflammatory response plays in the quality of healing has caused one group of physicians to write: "No inflammation, no repair."[7] It is not difficult to understand, then, why this initial phase of healing could be affected by anything that deterred the mustering of inflammation. Patients on chronic low-dose steroids represent a

category of individuals particularly at risk for altered healing.[20] Because of the suppressive effect steroids have on the ability of the body to initiate an inflammatory response, healing can be prolonged and in some cases seriously compromised in patients required to be on them. Similarly, patients experiencing extended periods of reduced tissue oxygenation could manifest compromised healing. And, although the neutrophil is no longer considered to be the cell most essential to healing, an inadequate number of mature PMNs could result in incomplete debridement of the wound, infection, and protracted healing. Thus, anything that alters the maturation of neutrophils likewise could influence the quality of healing.

For the clinician, then, the significant aspect of this first phase of healing, lasting from the moment of injury to day three or four post trauma, is to gain an appreciation of the necessity of supporting the adequacy of a patient's inflammatory response. Most importantly, the practitioner needs to realize that preventing suppression of inflammation and fostering oxygenation of healing tissue in the first moments and days of the wound's existence helps determine the quality of healing that will ensue weeks, months, if not years post injury. During this first phase of healing, then, in addition to closely monitoring the appearance of the would site itself, the nurse should carefully and thoroughly assess the physiologic status of the patient through laboratory values, medication regimens, and the presence or absence of medical conditions that might affect the reserves the patient brings to the healing experience.

The Proliferative Phase

The second phase of healing, referred to as the *proliferative phase,* extends from approximately day three to day 21 post injury. The key cell in this phase of healing, the fibroblast, rapidly synthesizes collagen. This collagen synthesis forms the basis for referring to this phase as proliferative. Recalling the cascading pattern demonstrated by the healing process, it is now known that during the inflammatory phase the same macrophages that secrete AGF also secrete a fibroblast-stimulating factor. The presence of this factor, combined with a growth factor released by dead platelets in the first moments post injury, results in the influx of fibroblasts into the wound approximately 24 hours post injury. And, although fibroblasts are found in the wound environment as early as one day post wounding, the vast majority of their "work" does not become evident until approximately day five post injury.

In addition to synthesizing collagen, fibroblasts also synthesize proteoglycans, or ground substance. These two substances have been said to form the "scaffolding" on which ultimate repair is effected.[38] The production of tropocollagen (i.e., a preliminary soluble form of collagen) is a complex process involving the hydroxylation of proline and lysine, processes dependent on the presence of iron, ascorbic acid, and oxygen. Ultimately tropocollagen is converted into insoluble collagen which, along with angiogenesis and ground substance, comprise the connective tissue that fills in the wound.

One result of collagen production is a gradual increase in the strength of the wound (i.e., tensile strength) between day 5 and day 15.

Prior to day 5 the tensile strength (or the ability of the wound to withstand external forces and not be disrupted) and, therefore, the collagen content of the wound are low. In normal healing, though, the greatest amount of new tissue synthesis occurs after day five. As a consequence, tensile strength within the wound increases rapidly even though the collagen that is laid down is poorly organized when compared to that in intact tissue. In an open wound, or one not sutured closed and instead left open to heal by secondary intention, one is able to observe the presence of this newly synthesized collagen, ground substance, and vessel formation by the appearance of bright red tissue filling in the wound cavity. This velvety tissue fills in the open defect left by the wound and over time and with contraction, causes the wound to close, ultimately restoring structural integrity.

In the wound sutured at the time of surgery one is able to determine the presence of newly synthesized collagen by the appearance to the touch of what is known as a "healing ridge" just under the intact suture line.[20] Absence of this ridge at the suture line five to seven days post injury would cause the clinician to treat the wound with greater care and to be concerned about the possibility of wound dehiscence and/or evisceration. Both of these sequelae of altered healing are most likely to occur during this second phase of healing and occur precisely because of alterations in collagen synthesis. If dehiscence or evisceration were to occur, they are more likely to present between day 5 and day 12 post surgery.

Dehiscence, the interruption of a previously intact suture line, is frequently heralded by the appearance of sero-sanguinous drainage on a previously dry wound dressing or intact suture line. Often, just prior to this event, the patient will cough or experience a sharp pain somewhere along the suture line. Where a suture line dehisces that portion of the wound must be treated with the same care and attention as was the initial postoperative wound because, for all intents and purposes, a new wound exists. Evisceration, or the opening of the wound to expose the internal contents of a body cavity, is obviously a more serious set of circumstances, and, in addition to comforting the patient and carefully protecting the involved organs through sterile technique and maintenance of a moist environment, usually the nurse must prepare the patient to return to the operating room for wound closure. Once there, the wound can be assessed properly and appropriate action taken, be it resuturing the wound or leaving it open to close by secondary intention.

The clinician can support the activities of the proliferative phase by ensuring adequate nutrition including vitamins and minerals and assessing that the oxygen supply to the wound is adequate. Situations that place strain on the suture line should be avoided, among them straining at stool, persistent coughing, and unsupported suture lines, especially in the obese.

The Maturation Phase

The third phase of healing, referred to as the *maturation phase*, begins about day 21 after wounding and can extend to a year or two postinjury. Obviously it is the longest phase in the healing process, al-

though not necessarily the most significant. Although no particular cell has been identified as specific to this period, the fibroblast continues to synthesize collagen well into the maturation phase. In some respect the activities occurring during the last phase of healing determine the ultimate strength and mobility of the scar tissue laid down during the proliferative phase.

Normally, in uninjured tissue, collagen fibers lie in parallel arrangement and because of this the tissue is able to withstand a great deal of stress. Injury alters the symmetry of the healthy tissue and when new collagen is layed down the pattern is random and disordered. To reduce the accumulation of great amounts of collagen and to prevent us from becoming "frozen" in our own healing, enzymes referred to as collagenases are secreted. These enzymes lyse (i.e., break down) some of the newly synthesized collagen making it more malleable and less bulky (i.e., remodeled). At the same time the fibers making up collagen become cross-linked, ultimately causing this newly formed tissue to lie in a more organized fashion and thereby provide greater strength overall. Obviously, if alterations occur in the remodeling and crosslinking of collagen during this period of healing, sequelae such as contractures or adhesions and even obstruction of tubelike organs (e.g., the bowel, ureters) can occur. It also should be pointed out that regardless of how well collagen realigns itself, the tissue within the wound will never fully regain the degree of strength or intactness inherent in uninjured tissue (i.e., uninjured tissue tensile strength equals 100%, whereas injured tissue maximal tensile strength equals 80%). Additionally, the scar along the suture line is usually less elastic than uninterrupted tissue. For these and other reasons nurses, in addition to monitoring the patient's surgical wounds, need to guard every patient's integument vigilantly, reducing the possibility of the skin becoming interrupted.

With the trend toward earlier discharge (oftentimes prior to or early in the proliferative phase), clinicians must be actively involved in teaching patients what it is they can and cannot do following discharge; in this way optimal healing is more likely to be supported. Both the patient and their significant others need to understand sound reactivation programs as well as what observations to make about their healing wound.

Nurses and physicians alike can greatly reduce patients' anxiety during the maturation phase by describing to them the fact that as healing progresses the suture line will become more blanched and, therefore, less obvious, and contract down in size assuming the contour of the area over which it lies. These facts may seem obvious and less than necessary to the individual who has never had his or her structural integrity altered by a scar, but they are of great importance to those whose previously uninterrupted tissue and body image have been altered as the result of surgery or trauma. Consider the significance allotted a mere paper cut on one's finger and the fact that only after a bit of time and reassurance is the "damaged" finger reintegrated into the hand and body.[30] Then ponder the impact of a highly visible scar, particularly if that scar reminds the patient that it was created as a consequence of some serious or life-threatening disease. If clinicians, nurses in particular, are concerned with reducing unnecessary energy expenditure, how vital it is that the

patient be instructed either prior to discharge or in the community about what to expect as the wound evolves. Enormous amounts of energy have been known to be expended by patients with incisions or scars as they seek reassurance that healing is progressing optimally.

SOME FACTORS KNOWN TO AFFECT HEALING

Multiple factors affect the quality of healing including, no doubt, many not yet identified. Certainly the presence of specific medical conditions (e.g., diabetes, cardiovascular disease), the age of the patient, and the status of an individual's immune system all impact healing. Body build, stress levels, the length of time an individual has been hospitalized before wounding also are factors known to influence healing outcomes. The presence or absence of other injuries at the time a wound is sustained as well as whether or not the wound resulted from a surgical procedure or trauma need also be considered. When caring for healing patients none of these factors should go unassessed and, if present, should be evaluated thoroughly for their potential impact on the quality of healing. In a more direct fashion the nutritional status of the individual at the time of surgery should be assessed as well as the individual's volume/oxygen status in the periwound area. The presence or absence of acute illness prior to the time of surgery is another factor recently documented as potentially significant. More and more is being identified about the factors influencing healing with a new appreciation of the extent of their impact on the quality of healing. To substantiate this statement, two examples of research documenting the effect of factors on healing are presented in greater detail.

Animal studies have long revealed the essential role oxygen plays in wound healing; without it ischemia results and newly forming tissue is compromised. Silver and Niinikoski[37,41] have both suggested that the majority of postsurgical patients are probably underoxygenated. These findings were reinforced in 1983 when Chang et al,[8] studying the tissue-wound oxygenation and perfusion levels of surgical patients, found that the patients' wounds were hypoxic; and that this was most significant in patients having undergone radical mastectomy, abdominal surgery, and cardiac and vascular surgery. The investigators implicated hypovolemia as the cause when, after increasing the patient's volume, elevations in the tissue oxygen levels occurred in all subjects studied. These findings are particularly noteworthy for clinicians caring for surgical patients given the fact that the investigators pointed out that commonly used indicators of adequate tissue perfusion, namely cardiac output, right ventricular end-diastolic pressure, and urinary output have proved not to be valid or reliable indices of adequate perfusion at the wound site. In fact, with the exception of the implantation of a silastic catheter (the method employed in the study to measure tissue perfusion), the authors stated that "there are no quantitative measures of tissue perfusion available." The findings of the Chang et al study strongly suggest that clinicians caring for surgical patients increase their vigilance in monitoring the volume/oxygen status of postoperative patients and consider supplying these patients with "adequate" volume and oxygen during the initial postoperative period.

Another study of certain interest to clinicians caring for surgical patients substantiates a belief held intuitively for years by many that the presence of preoperative illness could affect the course of healing. Goodson et al[13] evaluated the accumulation of hydroxyproline (an indice of collagen synthesis and, thus by inference, a measure of healing) in patients having undergone appendectomy or cholecystectomy. Appendectomy patients, taken to the operating room immediately after diagnosis were found to accumulate 20% less hydroxyproline at 7 days postoperatively than the cholecystectomy patients studied ($p < 0.02$). The investigators concluded that the latter group, whose cholecystitis was treated medically prior to surgery, fared better than the appendectomy patients precisely because of the fact that they were not operated on during the acute or emergency period of their illness. In other words, depression of hydroxyproline in the appendectomy patients postoperatively was significantly ($p < 0.008$) related to the fact that these patients were experiencing an acute illness preoperatively, whereas the cholecystectomy patients were not. This finding is of interest given the fact that hydroxyproline levels were reduced in the postoperative period in the patients undergoing appendectomy despite the fact that the source of the illness (i.e., the inflamed appendix) had been removed. The researchers concluded that "even a brief preoperative illness has a more prolonged influence on postoperative healing than usually anticipated." The findings of the study by Goodson et al certainly encourage clinicians to pay careful attention to the surgical patients' immediate preoperative history.

The factors that influence healing cited in the preceding paragraphs are but highlights of the many known to influence the quality of healing. It is hoped that these examples point up the importance of keeping abreast of the increasing body of clinical research studying the many factors influencing healing. Certainly research regarding the physiologic and psychological events occurring to the healing patient that might impact the healing outcomes must be ongoing. In the meantime, nurses are capable of being creative in postulating situations that might influence healing and over which they have some control; for example, reducing the patient's stress level could decrease the outpouring of catecholamines and might result in reduction of the vasoconstrictive activity these substances are known to have on microcirculation. If a patient feels safe, is not in pain, has his or her loved ones nearby, and is not cold, the environment for healing might be more optimal. Nurses need to continue to identify both the scientific and the scientifically based artful practices they bring to the bedside that are supportive of healing. Once logged, studied, and found to influence healing positively, these practices could then be used on a broad basis by clinicians and no doubt influence the quality of healing for many patients.

CURRENT TREATMENT MODALITIES

Myriad substances have been placed in wounds in the name of healing. Rudolph,[40] in a chapter entitled "Nostrums and Hokems," logged

pages of substances utilized at one time or another to treat wounds, each of them surely touted by their advocates as salubrious. Recalling the statement ascribed to Paré cited earlier, "I dressed the wound, God heals it," one can see how, armed with the conviction that God was "on one's side," made placing any and everything in a wound safe, for, despite what was placed there, the wound would go on to heal. Obviously now, logic would lead us to the conclusion that this could not be true, and, yet, even to this day substances are placed in wounds with little evidence, other than tradition, to support their use. In fact, on the contrary, some of the therapies currently in use have been described as detrimental, if not injurious to healing tissue, especially newly forming tissue.

Wounds, particularly open wounds, have long been treated with the emphasis incorrectly placed on ridding the wound of bacteria rather than focusing on the delicate nature of the newly forming cells and tissues. Certainly the necessity of protecting the patient from exposure to bacteria can be understood in times gone by when antibiotics were unavailable, and many wounds were sustained on battlefields at great distance from medical and nursing care. The curious fact, though, is that although so many other areas of health care have advanced, including the discovery of antibiotics, the local care and treatment of wounds has not kept up with the pace.

Research supports the deleterious effects of treatments such as full-strength povidone-iodine (Betadine)[4,45–47] and wet-to-dry dressings on healing tissue.[20] Further, the use of bulb and irrigating syringes as a mechanism of cleansing wounds also has been shown to be ineffective,[42] and heat lamps negate the findings that epithelial cells migrate best in a moist environment.[43] Yet each of these approaches to wound care continues to be used by bright and caring clinicians in the name of healing.

Certainly more needs to be written about the mechanisms by which many of the substances placed in wounds do or do not support healing. This is a task that those interested in healing must work at with increased determination and all due haste, but it seems to this writer that if the physiology of wound healing were understood more fully, clinicians could begin to determine on their own which interventions optimize healing and which do not. Perhaps no member of the health care team stands in a better position to influence the manner in which wounds are cared for than the nurse. Thus is the extreme importance of nurses' understanding fully the treatments they suggest and the ongoing value of establishing and testing wound care protocols rooted in the physiology of wound healing.

Practicing clinicians, however, cannot bear the full responsibility for bringing wound care into the modern era. Greater responsibility for teaching nursing students researched-based approaches to wound care must be accepted by faculty teaching those students. As in so many other areas of nursing, instructors can no longer teach students what it is they once learned. In most cases, teaching students what was once practiced in the name of excellent wound tending is no longer correct. In fact, in most cases, the passing on of such knowledge would not only be inaccurate, it would not be supportive of the role of the nurse as healer and energy conserver. Nursing students, both in their student role and even-

tually as professional nurses, have the potential of being "movers" in changing the way wound care is approached. Student nurses, graduate nurses, and faculty involved in caring for patient's wounds need to expend a world of effort establishing and testing protocols for wound management, and monitoring the activities they perform that support the healing process.

SUMMARY

Clinicians could be overwhelmed with all that needs to be done to advance the clinical care of tissue wounds. This is not the time to be discouraged, however. Perhaps there has been no period in the history of health care when the possibility of influencing future trends in wound care was greater. Generally speaking, nurses are increasing their understanding of their place in healing activities and are involved in tending wounds that demand greater direct care. Simultaneously, some manufacturers of wound care products seek the input of clinicians as they attempt to produce sound and usable products. Articles appear that delimit scientifically based approaches to wound care and debunk those based solely on tradition. Levine[29] reminded us that "perhaps no worker can influence the success of the healing process more than the nurse." I encourage the readers of this article to take Levine's statement to heart, to latch onto the current momentum, and to force the next decade in health care to be referred to not as the "era of the wound" but rather as the "era of healing."

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