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A Review of Physical Therapy Intervention in the Healing of Wounds

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A REVIEW OF PHYSICAL THERAPY INTERVENTION IN THE HEALING OF WOUNDS

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This Independent Study, submitted by Stephanie Bertsch in partial fulfillment of the requirements for the Degree of Master of Physical Therapy from the University of North Dakota, has been read by the Faculty Preceptor, Advisor, and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Faculty Preceptor)

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ABSTRACT

Treatment of chronic wounds, such as pressure ulcers or arterial-insufficient ulcers, are commonly seen in health care today. Wound treatment is advancing and physical therapists are using modalities in the intervention to hasten wound healing. Electrical stimulation and ultrasound have been established through clinical studies as effective modalities for the treatment of wound healing. The purpose of this paper is to review and analyze current literature about physical therapy and wound care. This paper will discuss an overview of the anatomy of skin, physiology of wound healing, documentation of wounds, and physical therapy intervention with emphasis on electrical stimulation and ultrasound.

CHAPTER I

INTRODUCTION

Surveys show that pressure ulcers develop in 3% to 4.5% of general hospital patients and in 20% of all nursing home patients.[1] The estimated cost for treatment per ulcer is at $10-15,000. Traditionally, nurses have been caregivers of patients with wounds; however, wound treatment has evolved significantly in recent years.[2] The role of the physical therapists in wound care has been expanding through use of physical modalities as an adjunct with other interventions.[1] Controlled experimental studies support the efficacy of using physical therapy modalities for accelerating wound healing, thus decreasing costs and hastening recovery time.

The purpose of this paper is to review the current literature about physical therapy and wound care with the emphasis on the physical modalities, electrical stimulation (e-stim), and ultrasound (US). This paper will give an overview of the anatomy of the skin, physiology of wound healing, and documentation. These areas are essential for the physical therapist or health care professional to thus understand the wound healing process and to identify if the wound is healing properly. The research on e-stim and US will also be discussed to establish whether these two modalities are proven to enhance wound healing.

It is important to know whether the treatment choice has proven to help heal wounds not hinder the healing process. Also, it is essential to substantiate the clinical effectiveness of wound treatment for the purpose of reimbursement as well as to ensure physician and patient confidence in the care provided.

CHAPTER II

ANATOMY OF THE SKIN

All wounds, whether burns, decubitus ulcers, ischemic ulcers, or small abrasions, will alter the appearance and physical factors in the skin. A good background of the anatomy of the skin will help physical therapists and other medical professionals in treating wounds. This chapter will give a brief review of the anatomy of the skin.

The skin is the largest organ of the body and serves as a protective shield from the environment against external injury or infection; it also regulates body temperature, relays sensation, and helps maintain fluid balance.[1,3-6] The skin consists of two layers: the epidermis, which is the superficial layer, and the deep layer, termed the dermis. The basement membrane is a structure that divides the epidermis from the dermis.[5,7] This membrane is multilayered, non-rigid, and functions to hold the skin together. Beneath the dermis is the subcutaneous layer which is composed of the loose fat and connective tissue.[1,4] This subcutaneous layer provides the skin with cushion and is one more barrier between the muscle fascial layers and dermis.

The layers of the epidermis, in order of superficial to deep, are: 1) the stratum corneum or horny layer, 2) stratum lucidum or pars compacta, 3) stratum granulosum or granular layer, 4) stratum spinosum or prickle cell layer, and 5) stratum germinativum or basal cell layer.[3,5,7] The stratum corneum, responsible for the water characteristic of the skin and protection from infection, is the thin top layer of the epidermis. This layer consists of many dead epithelial cells which are horny or keratinized. It is thickest on the palms of the hands and plantar surface of the feet. Stratum lucidium is an optically clear layer, usually three to five layers thick, and found only on the palms of the hands and soles of the feet. The stratum granulosum layer is responsible for water retention and heat regulation. Stratum spinosum and germinativum layers are the most viable layers.[3] The basal cell or stratum germinativum layer, the deepest layer, has four different cell types which are keratinocytes, melanocytes, Langerhans cells, and Merkel's cells.[5] Keratinocytes are the main cell type in the basal layer; these cells are also found in the other layers of the epidermis as well as in the skin appendages, the hair, and nails.[5,7] The keratinocytes through cohesion help determine the strength of the epidermis. They may also produce immunological substance which can help in fighting common skin diseases. Melanocytes synthesize melanin which determines the color of the skin.[1,3] These cells also function in protecting the skin from ultraviolet radiation.[5] Langerhan's cells function is not clearly known. It is thought that perhaps these cells are involved I the immune response. Merkel's cells are in large number on the finger tips and face. The role of these cells is sensation, since they are found close to the nerve endings.

The dermis is composed of two layers and is 20 to 30 times thicker than the superficial epidermis.[4] The uppermost layer of the dermis is termed the papillary layer, while the deeper layer is called the reticular layer. Both layers are formed of connective tissue. However, the reticular layer contains more dense connective tissue.[3,5,7] The dermis layers contain collagen and elastic fibers, giving the skin its strength and elasticity. The three main cell types found in the dermis are fibroblasts, which produce collagen; macrophages, which are phagocytic; and mast cells, which synthesize, store, and release histamine which increases capillary permeability. The epidermal appendages which include nerve fibers, hair follicles, sebaceous and sweat glands are also found in the dermis.

The epidermis is avascular, whereas the skin's extensive blood supply is found in the dermis.[3,5,7] The network of blood supply is both deep and superficial in the dermis. Arteries supply the dermal area and form capillaries at the papillary layer. The venous supply is formed by vessels in the papillary area and the networks are similar to the arteries. There is direct communication through the arteriovenous shunts from the arteries to the veins in regulating body temperature. The lymphatic drainage system is a rich network in the papillary layer of the dermis. This system allows lymph vessels to go deeper and run to the local lymph nodes. The lymphatics assist the venous system by carrying fluid back from interstitial spaces back into the bloodstream.

The nerve supply to the skin is through free nerve endings and three specific sensory receptors.[3] Nocioreceptors relay pain sensation; thermoreceptors relay temperature changes; mechanoreceptors respond to cutaneous and deep pressure, touch two-point discrimination, and vibration.

Cutaneous innervation of the skin is also supplied by neurofibrils of the autonomic nervous system and help to give sensation to the skin.[7]

It is important to keep in mind the appearance of the skin when first evaluating a patient. Appearance of the skin, such as temperature, moisture, and skin texture, can give important information in detecting a possible medical problem. Jaundice or yellow skin may be indicative of gall bladder disease.[3,6] Cyanosis or bluish skin can be associated with diminished or absent circulation. Occlusion of small arteries can cause oxygen deprivation, and the skin will appear shiny, hairless, and dry. This type of skin is more easily damaged and takes longer to heal.[3] Induration, fever, erythema, and edema (IFEE) are signs of infection. Pressure over a bony prominence can result in redness from blood rushing into the ischemic tissue.[1] Blanching occurs when pressure is applied to these areas and it turns white. This is a sign to monitor for the possibility of a wound developing from skin breakdown.

Since the emphasis of this paper is wound healing, the next few paragraphs will describe appearance of wounds. A wound's location is important. When a wound is over a bony prominence, such as scapula or hip, it may heal slower due to stretching of the skin.[8] If located on the coccyx and feet, healing may be slowed as a result of vascular insufficiency. Wounds can be characterized as simple or complex. A simple wound is one in which skin is intact, occurs with soft tissue trauma, and may exhibit partial thickness dermal loss. Complex wounds have full thickness dermal loss and tissue involvement of muscle, tendon, or bone.

There is also a way to classify pressure ulcers. A classification system, which is universally accepted, is by the National Pressure Ulcer Advisory Panel (NPUAP).[9] The pressure ulcers are classified objectively into different stages.[1,8,10]

Stage I: has intact skin that is reddened;
warm for longer than 15 to 30 minutes;
this stage is reversible with pressure relief.

Stage II: a partial thickness wound involving only the epidermis;
it is superficial and presents as a blister or abrasion.

Stage III: a full thickness wound down to the dermal layer;
it may be necrotic, infected, or draining.

Stage IV: a full thickness wound down to the deep tissues, pass the dermis and subcutaneous layer, such as tendon or bone;
may be infected or necrotic.

When a wound begins to heal, granulation tissue will be seen.[8] It is pink and glossy because it contains capillaries. Thick yellow or green exudate is a sign of infection in a wound. Necrotic tissue is black and a small necrotic wound may be more harmful than a large clean wound with granulated tissue.

The skin protects the body from the outside environment. Without it, the body would be more susceptible to infection and illnesses. Because wounds break down skin, it is important for physical therapists and other medical professionals to note wound characteristics and understand healing mechanisms to give appropriate care. The next chapter will discuss the physiology of wound healing.

CHAPTER III

PHYSIOLOGY OF WOUND HEALING

There are three phases of wound healing: the inflammatory phase, which involves inflammation and phagocytosis; the proliferative phase, which involves depositing collagen; and the maturation or matrix formation phase, which is accomplished by contraction and epithelialization.[1,4,9,11,12] These three phases tend to overlap each other. The time frame for the phases is usually three to five days for the inflammatory phase, up to 21 days for the proliferative phase, and the maturation phase can take anywhere from several months to years.[9,12]

The Inflammatory Phase

The inflammatory phase is characterized by the four cardinal signs of inflammation: rubor or redness, tumor or swelling, calor or heat, and dolor or pain.[4,9] Immediately following an injury, vasoconstriction occurs which lasts approximately five to ten minutes.[4,12] Vasodilation then occurs increasing blood flow to the area. This increase in blood flow to the injured area results in redness and heat.[1,4,11,12] The permeability of the blood vessels increases allowing the escape of cells and fluid from the vascular system and results in edema formation. This edema fluid contains a large number of leukocytes.

Neutrophils, a type of leukocyte, begin migrating to the site of injury and are the predominant cell in the early stages.[1,11,12] The neutrophils are phagocytic and rid the area of contaminating bacteria. Monocytes, another type of leukocyte, begin phagocytosis by releasing enzymes collagenase and proteoglycan degrading enzymes.[11] The monocytes act as macrophages and become dominate later in the inflammatory and are responsible for directing cells for macrophagic response. If these cells are eliminated as a result of minimal oxygen in the area, repair is inhibited. Therefore, the main purpose of the leukocytes is to rid the area of contamination and, once this has been done, cellular repair can begin.[1,4,9,11]

The Proliferative Phase

The next phase of wound healing is called the proliferative phase or the initial tissue repair phase. Epithelialization occurs following phagocytosis and marks the beginning of this phase.[1] Fibroblasts produce connective tissue by secreting collagen and ground substance made of a protein, polysaccharide, that result in scar tissue.[1,4] Collagen is deposited in random alignment and this will increase the tensile strength to the tissues.[4,11] As the fibroblasts are migrating and proliferating, granulation tissue is formed. Granulation tissue is the hallmark sign of healing and consists of fibroblasts, macrophage, and blood vessels.[4,9,11] When treating wounds during this stage, care must be taken not to traumatize the new granulation tissue.[3]

Wound contraction occurs during the proliferative phase. Contraction is the process in which wounds close by movement of the surrounding tissues.[1-4] After the loss of tissue occurs, the available tissue gradually moves toward the center of the wound. Contact inhibition, when the edges meet, will stop the process of contraction. If the edges of the wound cannot meet, the wound will have to heal through epithelialization and scarring.

The Maturation Phase

The third phase of wound healing is termed the maturation phase, or matrix formation and remodeling phase, or the second phase in tissue repair. Once a wound is covered with epithelium, it is considered to be healed, but remodeling of the scar can continue up to two years.[4] Collagen will continue to deposit and help strengthen the area, and the collagen synthesis continues in this phase. After the wound is completely healed, it will have 70% strength of normal intact skin.[11,12]

As the collagen remodels, during maturation, the ratio of collagen breakdown to production determines the type of scar formed.[4] The scar will be pale, flattened, and pliable if the breakdown equals the production of collagen.[4,11] A hypertrophic scar is red, raised, firm in texture, and stays within boundaries of the original wound and occurs when there is a greater production of collagen than breakdown. A keloid scar is a large firm scar that overflows the boundaries of the original wound. Both the keloid and hypertrophic scar can take longer to mature and can cause cosmetic and functional deformities.

Factors Affecting Healing

There are extrinsic and intrinsic factors that will affect wound healing. Extrinsic factors include the physical therapist or medical intervention and will be addressed in the fifth chapter. Some intrinsic factors that can affect healing include nutrition, age, radiation therapy, infection, emotional stress, nicotine, necrotic tissue, ischemia, and medications.[1,9,12] Nutritional deficiencies of protein and vitamins A and C are the most detrimental because collagen synthesis is impaired with malnutrition. Tissue friability is the primary concern when treating the elderly. With aging, the skin will undergo changes causing the elderly to have factors that may affect wound healing. Some factors include delayed wound contraction, decreased epithelization, delayed vascular function, and an increased rate of dehiscence. Radiation therapy will also reduce leukocyte production and affect the inflammatory phase.[1] Certain medications, such as corticosteroids, aspirin, heparin, coumadin, and nonsteroidal anti-inflammatory drugs, will affect different stages of healing.[1,9]

Certain disease processes may also alter wound healing. Diabetes is one common disease process that affects healing of wounds. There are approximately 10 to 12 million diabetics in the United States and diabetics are at a greater risk than nondiabetics for atherosclerotic disease of the lower extremity.[13] This population is at risk for vascular disease and neuropathy which are two major factors for ulcer formation.[14] Therefore, diabetics are more vulnerable to infection and thus at an increased risk for arterial disease resulting in decreased nutrition to the tissues from ischemia.[16] The neuropathies result in decreased sensation which may allow for the healing sites to be re-traumatized.[9]

Factors that will increase the risk of skin injury can usually be reduced or prevented. Some of these factors include: 1) pressure, which can be relieved by positioning or cushions, 2) inactivity, which can be reduced by having a turning schedule, 3) reducing shear and friction forces, 4) preventing poor nutrition, 5) emotional stress may be prevented by teaching relaxation techniques, 6) managing incontinence, and 7) using infection control techniques.[16]

Those factors which affect healing and factors that can reduced or prevented to help with skin injury have also been outlined. Assessment of these risk factors is needed when first evaluating a wound patient, since they can delay or alter healing. If a skin injury occurs, proper wound healing goes through the three stages discussed earlier. Appropriate documentation is also necessary for wound management and will be discussed in the next chapter.

CHAPTER IV

DOCUMENTATION

Documentation is important in the treatment of wounds, since it identifies wound healing and is essential for reimbursement of the services provided. A complete history will provide the information that is critical in developing a treatment plan. The demographic information, such as age, gender, and occupation as well as events leading up to the wound injury development or mechanism of injury, are part of the information gathered for the history.[9,11]

In addition to the obtaining a general history, there are important questions to be asked that can help identify whether there is a current disease process going on that may affect the wound pathogenesis.[9,11] These questions include asking the patient if she/he has diabetes and, if so, the onset since this may give insight to the extent or severity of vascular and neuropathic changes. A second question to ask is whether there is any history of peripheral vascular disease, hypertension, or congestive heart failure. These conditions can lead to venous or arterial insufficiency and can help to establish the insight of the wound. The current medications a patient is taking should be determined since, as noted in the previous chapter, certain medications can alter the healing process. Asking the patient if he/she is allergic to any medications or treatment agents can help identify whether the patient may have an adverse reaction to any agents used for treatment. Another question to ask is if the patient has ever been treated for this condition and, if so, what were the treatment results. This can help in treatment planning; if there was not success in the previous treatment, different options should be utilized. Finally, it is important to know whether the patient is a tobacco and/or alcohol user as well as obtain diet information on the patient. The significance of asking these questions is relevant since tobacco, alcohol, and inadequate nutrition will alter the healing process.

The subjective interview will also reveal the patient's current symptoms or complaints in a variety of situations.[9,11] The most common symptom is pain. Locating pain is important in order to identify whether it is within or around the wound or in other areas. Different body positions can affect the pain in wound patients. In patients with lower extremity ulcerations that are a result of venous insufficiency, pain is aggravated by the dependent position and relieved by elevation of the extremity since this deviation can assist in removing fluid from the leg and decrease pressure in the tissues. Arterial problems will worsen with elevation and activity as this increases the demands on the already compromised system.

Symptom behavior, as well as location, will help identify what type of wound the patient has. Ulcers have a characteristic location.[9,11] The typical location of a venous ulcer is the lower one-third of the leg around the medial malleolus. This area has high pressures in incompetent perforating veins and also there is a poor arterial supply to the area.[9] Arterial ulcers are usually located on the toes, feet, and lateral malleolus and usually present with punched-out lesions with a well demarcated border which are lacking in epithelium. Diabetic patients with insensitivity will have ulcers located over weight bearing areas on the plantar surface of the foot. Spinal cord injury population can also develop pressure ulcers, especially over the sacral area or feet from loss of sensation, inadequate pressure relief, and incontinence.

Drainage from a wound should be assessed for color, odor, consistency, and amount.[9,11,17,18] An increase in exudate may slow wound healing and a foul odor is usually an indicator of an infection. The tissues around the wound should also be assessed for color, skin texture, temperature, and edema. Dramatic changes in skin temperature can be a sign of an infection. When edema is present, objective measurements of either girth or limb volume should be taken. The wound edges or if undermining is occurring will identify the severity and amount of tissue necrosis. The presence of necrotic tissue will retard wound healing. Slough or eschar represents different levels of necrotic tissue.[17] Slough is yellow, thin, stringy, or mucinous, whereas eschar is black, soft, or hard; this represents full tissue destruction. On the other hand, granulation tissue is the sign of healing. When examining a wound, the color and amount of granulation or necrotic tissue should be noted.

A physical therapy department may have a standard evaluation form to use when assessing a wound patient. An example of an evaluation form is the Pressure Sore Status Tool (PSST). It is a paper and pencil instrument that is proven to be valid and reliable and can be used to assess pressure ulcers.[17,18] The Pressure Sore Status Tool consists of 15 items which include the areas that have already been discussed, like exudate and necrotic or granulation tissue. Thirteen of the 15 items are scored on a scale of one to five, with one being best for the characteristic and five being the worst. Two items, location and shape, are not scored. The PSST allows for tracking of wound using the scoring system and allows for quantification of observations. See Appendix A.[19]

Determining the size and depth of the wound can be done in different ways. Common methods used are the ruler. which measures length and width; perimeter tracings of the wound using an acetate film; and photography.[18] The ruler method should measure the wound from the longest and widest aspect or from head to toe and side to side of the wound.[17] The ruler may be a disposable ruled transparent film or it can be a straight ruler with centimeters as the measurement.[18] The advantage of using the ruler is that it is easy to use, inexpensive, and does not require any other special equipment. One disadvantage of this method is that measurement conditions are difficult to standardize. Transparency tracings of the wound consists of using an acetate transparent film, placing it over the wound, and tracing the perimeter of the wound. The traced area can be measured by laying the transparency over the grid paper and counting the squares in the traced area. The traced area can also be measured by a ruler. Another way to measure the traced area is by using the planimeter or a digitizer which gives a digital reading of the area in square centimeters. The advantage of using the tracing method is that it is inexpensive, easy to use, provides a permanent record, and correlates with other standards of measure. Disadvantages are that it makes contact with the skin, computation with the grid system can be time consuming, and the digitizer or planimeter may not be available in some departments. Photographic measurements use a camera that contains a macro lens and takes a picture of the wound. Some cameras contain grid film and thus provide a way to measure the wound size directly from the wound. Advantages of this method are that contact with the wound is avoided, a permanent record is obtained, and the tissue and dimensions can be visualized. The disadvantages of this method are that it requires special equipment and it is necessary to get the same angle and distance each time a photograph is taken.

The depth of the wound can be measured by using a sterile cotton-tipped applicator that is placed inside the wound.[9,11] By using a tape measure, the depth may be assessed off the applicator after it is removed. Another method of measuring depth is filling a syringe with a known amount of water. With the wound positioned parallel to the floor, the water is injected into the wound. The amount of water left in the syringe is subtracted from the original amount which indicates the volume of the wound. Both of these methods are easily done and are inexpensive. The depth of tissue destruction can also be characterized by the stages of the wound classification I to IV, as outlined in Chapter II, seen with pressure ulcers.[17]

Griffin and colleagues[20] compared the reliability of measurement using the photographic and the transparency methods for determining wound size. The tracings and the photographs were digitized to determine the size of the wound. Twenty-two ulcers were measured in this study. The authors concluded that the photographic and transparency measures were equally reliable as the two methods gave equivalent measurements for wound size. Bohannon and Pfaller[21] evaluated the differences in surface area tracings which were performed by two different clinicians. The clinicians traced five different wounds and found the greatest source for error when using the transparency method was in the tracing itself and not in the calculation of the area traced. Majeske[22] measured the size of 31 ulcers using the transparency method. The wound area from the transparency was calculated four different ways which included the ruler method, counting the squares on graph paper, using a planimeter, and a digitizer. Majeske found good reliability of all these methods of measurement. Majeske suggested using the graph paper technique to clinicians who do not have the access to a planimeter.

In documenting wounds, it is essential to be consistent in the measurements utilized for establishing wound size to increase accuracy with determination of wound healing. Not only should a therapist be consistent with each patient, but a department should be consistent to ensure accuracy between therapists. Documenting the characteristics of the wound is a continuous process and helps to determine treatment goals and progression. It should be done periodically to assess if the wound is healing properly and, if not, physical therapy modalities such as electrical stimulation and ultrasound could be used to enhance healing. These will be discussed in the next chapter.

CHAPTER V

PHYSICAL THERAPY INTERVENTION

When treating wounds, there may be a collaborative effort between different professions to ensure the patient gets efficient treatment. The team approach can consist of a nurse, doctor, and a physical therapist. Physical therapists can offer different options in treating patients with wounds. Some choices may include sharp debridement, dressings, topical agents, whirlpool, pulse lavage, ultrasound, and electrical stimulation.

Whirlpool is one of the most common modalities used for cleansing of wounds.[23] This modality will not be discussed in detail, but there are some important aspects of this modality that should be mentioned. Whirlpool should be used at a neutral temperature of 92° to 96° for wound management.[23] The treatment should be discontinued when the wound is considered clean. Excessive pressure from the turbine traumatizes newly formed granulation tissue.[2] Precautions should be taken with patients with pulmonary disease, coronary heart failure, acute phlebitis, high fever, and upper respiratory infection. Also, patients with venous ulcers should not be treated with their legs in the dependent position.[23]

Utilization of ultrasound and electrical stimulation physical therapy modalities as treatment choice for the wound healing has increased.[2] Since it would be impossible to cover all the areas of wound treatment, this chapter will focus on physical therapy using electrical stimulation (e-stim) and ultrasound (US) as an adjunct to wound healing.

Electrical Stimulation

There are several different rationales for using e-stim in wound healing which have been established through clinical and laboratory studies.[24,25] These studies show e-stim can enhance healing by: 1) improving blood flow,[26] 2) increasing cutaneous oxygen transport,[27] 3) helping reduce edema,[28] 4) improving wound tensile strength,[29] 5) increase wound contraction rate and fibroblast response,[30] and 6) produce better collagen matrix formation.[31]

Electrical stimulation may also enhance wound healing by augmenting the body's endogenous bioelectrical system.[24] The surface of intact human skin carries a negative charge compared to the deeper layers of the skin.[32] The average value for the electronegative charge on intact skin is -23.4 mV. When a wound is present, the deeper cells of the wound are positively charged. Combining the negative charge of the intact skin and the positive charge inside the wound creates the skin battery potential.24,33 Electricity conducts with low resistance through a moist environment and the positive bioelectric current will attract negatively charged cells. Neutrophils, macrophages, and epidermal cells migrate toward the positive charge of a moist wound environment. Treating wounds with e-stim should be considered if the clinical signs of healing are not seen in 14 days.[14] The use of e-stim may reestablish the body's bioelectric system, by augmenting or mimicking the endogenous electrical system, to help accelerate healing.

Both low intensity direct current and high voltage pulsed current (HVPC) have been used in wound healing studies. However, HVPC has been the most consistently used.[31] Monophasic, twin peaked HVPC allows for selection of polarity and variation of pulse rates. As can be seen with direct current, HVPC does not cause burns under the electrodes which allows for HVPC both comfort and safety for clients and especially for patients with decreased sensation.[25] Although there have been studies on different waveforms, this paper will focus on HVPC since it seems to be the waveform of choice.

In 1994, the use of e-stim for wound healing was backed by the Agency for Health Care Policy and Research (AHCPR). The panel issued the Treatment of Pressure Ulcers, Clinical Practice Guideline, Number 15. The guidelines state ". . . consider a course in treatment with electrotherapy for Stage III and IV pressure ulcers that have proved unresponsive to conventional therapy. Electrical stimulation may also be useful for recalcitrant Stage II ulcers."[2(p36),31(p1)] Besides pressure ulcers, HVPC may be considered for other types of wounds, such as diabetic wounds, venous ulcers, traumatic wounds, surgical wounds, ischemic ulcers, vasculitic ulcers, and burn wounds.[31]

There have been several clinical studies done on e-stim for enhancement of wound healing. In 1988, Kloth and Feedar[34] did a study on 16 patients with Stage IV decubitus ulcers. The patients were assigned randomly to a treatment group (n = 9) and control group (n = 7). A high voltage pulsed current was used at 105 pulses per second (pps) with the anode initially placed over the wound. The treatment group was stimulated five days a week for 45 minutes each day. The cathode was placed over the wound after a plateau was met in healing. The average rate of wound healing was 44.8% per week with an average period of 7.3 weeks. There was a 100% healing rate in the treatment group. The control group had an increase in size of 11.5% over a period of 7.42 weeks.

Akers and Gabrielson[35] studied the rate of decubitus wound healing with treatment of whirlpool only, whirlpool and HVPC, and HVPC only. Fourteen patients with decubitus ulcers who had a spinal cord injury or partial denervation were assigned to one of the three treatment groups. Each group received treatment of either the whirlpool bath once a day, HVPC and whirlpool twice a day, or HVPC twice a day. The patients who received HVPC only had the largest change in wound size and the greatest healing response; the whirlpool only group experienced the least change. Specific protocols were not reported.

Griffin and colleagues[36] assessed the efficacy of HVPC on healing of pressure ulcers in patients with a spinal cord injury. Seventeen patients were assigned to either the HVPC group or the placebo group. Patients received treatment for one hour a day for 20 consecutive days with the stimulator set at 100 pps with an intensity of 200 volts. The negative electrode was placed over the wound and the negative polarity was used for the entire 20 days. The results of this study demonstrated that the ulcers treated with HVPC had a significant decrease in size compared to the placebo group.

Unger, Eddy, and Raimastry[37] study consisted of 17 patients with pressure ulcers who were again randomly assigned to the HVPC group or placebo group. The HVPC protocol used the negative polarity initially and settings of 50 pps, 150 volts of intensity, ad 750 milliamps of current. At day six, the protocol was changed to positive polarities of 80 pps, 100 volts, and 500 milliamps. The patients received the treatment for 30 minutes twice a day. The average healing time was 51.2 days with HVPC. The patients receiving HVPC healed at a rate of 2.4 times faster than the placebo group.

Feeder, Kloth, and Gentzkow[38] did a study in 1991 on 47 patients with Stage II, III, or IV chronic ulcers. The patients were randomly assigned to a treatment group or control group. The protocol consisted of HVPC for 30-minute sessions seven days a week. Initially, a negative polarity was used with 128 pps. The polarity was changed to positive on the third day and then every three days the polarity changed if there was no sign of necrotic tissue. When the wound progressed to a Stage II classification, the polarity was changed every other day and 64 pps was used. The healing rates were 14% per week for the treatment group and 8.25% for the control group. The authors concluded that HVPC has a beneficial effect on healing of chronic dermal ulcers when using this protocol.

These studies all had positive results using e-stim for healing of wounds. The results show evidence that e-stim is a good modality choice to use as an adjunct for wound healing. The determination of what polarity to use, duration, current intensity, and voltage vary from one study to another.[23] The duration ranges from 30 to 60 minutes, frequency from five to seven days per week, once or twice a day, pulse rate from 30 pps to 128 pps. Polarity is usually negative to begin with if the tissue is necrotic or infected, positive if there is no sign of infection, or alternated every three days or daily. Although the authors of these studies concur that e-stim enhances wound healing, it seems more research should be done on the parameters for e-stim and wound healing in order for a consensus to be met.

Sussman[31] gives protocols to use according to the phase of healing in which the wound is, but basis for these protocols is not stated. They are as follows:

Proliferation:

Polarity - negative

Pulse rate - 30 pps

Intensity - 100 to 150 volts

Duration - 60 minutes

Frequency - 5 to 7 times per week, once daily

Epithelization:

Polarity - alternate every 3 days, 3 days negative followed by 3 days positive

Pulse rate - 100 to 128 pps

Intensity - 100 to 150 volts

Duration - 60 minutes

Frequency - 5 to 7 times per week, once daily

Remodeling:

Polarity - alternate daily

Pulse rate - 60 to 64 pps

Intensity - 100 to 150 volts

Duration - 60 minutes

Frequency - 5 to 7 times per week, once daily

There are some contraindications to consider when using e-stim. These contraindications include osteomyelitis, in presence of neoplastic cells, cardiac pacemaker, and placement of electrodes over laryngeal musculature, carotid sinus, and topical substances containing metal ions, unless thoroughly cleaned.[24,30]

Ultrasound

Ultrasound is another physical therapy modality that can be used to promote wound healing. Ultrasound uses a mechanical vibration that has a frequency above the limit of human hearing.[9,39] It has both thermal and nonthermal effects. Thermal US has a deep penetrating heat and utilizes one megahertz sound waves to penetrate deep within the tissues, up to five centimeters depth.[24] Thermal effects of ultrasound include an increase in collagen elasticity, decrease in joint and muscle stiffness, decreased muscle spasm, and enhanced tissue healing. Thermal levels of US are best when used in the later stages of wound healing when collagen remodeling occurs.[40]

Nonthermal effects of US can be achieved by pulsed sound waves while using a higher frequency of 3 MHZ with low intensity. Dyson[41] suggests that nonthermal intensities of US have the greatest effect on promoting wound healing. Cavitation and acoustical streaming are two nonthermal effects by which US can promote wound healing.[2] Cavitation is a process by which pressure waves of small proportions cause fluid to move across the cell membranes.[25] Acoustical streaming is the circulatory flow of fluid resulting in changes in diffusion rate of cell membrane permeability and this causes acceleration of collagen synthesis.

Dyson[41] describes therapeutic US and how it affects the stages of wound healing. Ultrasound accelerates the inflammation process, but does not act as an anti-inflammatory. In the proliferative phase, US stimulates fibroblasts and endothelial cells. Stimulation of fibroblasts produces more collagen which influences tensile strength and stimulation of the endothelial cells will cause formation of new capillaries and, in ischemic tissue, perfusion is restored.

In 1976, Dyson, Franks, and Suckling[42] applied US adjacent to chronic varicose ulcers. The ulcers were treated three times a week for four weeks. A frequency of 3 MHZ and an intensity of 1.0 W/cm^2, with 2 ms pulses delivered to the tissues once every 10 ms for up to ten minutes was utilized. At the end of four weeks, the control group was then given US with the same treatment regimen. Both groups, after being treated with US three times a week for four weeks, showed a significant decrease in the wound size.

Roche and West[43] applied US to the periphery of venous ulcers. The experimental group received US three times a week for four weeks at a frequency of 3 MHZ, intensity of 1 W/cm^2, and 2 ms pulses every 10 ms. The experimental group had a consistent decrease in the area of the wound, while the control group showed a variable response. Since the larger wounds healed more rapidly, the authors felt that there was a relationship between the size of the wound and the rate of healing.

McDiarmid, Burns, Lewith, et al[44] studied US and the progress of pressure sores, where some sores were infected. A frequency of 3 MHZ at .8 W/cm^2, and 2 ms pulses every 10 ms was used three times per week to each pressure sore. The results of this study showed that US affected the healing of both the infected and clean wounds; however, the infected wounds responded more significantly to US.

A study by Reit, Kessels, and Knipschild[45] assessed the effects of US in the treatment of pressure ulcers. The subjects were randomly assigned and the US group received treatment once daily, five times per week, using a frequency of 3.28 MHZ, an intensity of .1W/cm^2, and a pulse duration of 2 ms. The results showed that after 12 weeks, 40% of the ulcers in the treatment group and 44% of the ulcers in the control group were healed. The authors felt that the data did not support US as a means of accelerating the healing of pressure ulcers.

In general, US at a frequency of 3 MHZ is best for affecting the structures at the dermis level.[11] However, a majority of the ultrasonic generators marketed in the U.S. have 1 MHZ frequency. Dyson[41] showed that US at 1 MHZ with < .5 W/cm^2 intensity, pulsed at 2 ms on and 8 ms off, can be effective in increasing calcium uptake at the fibroblasts. Using the lowest intensity to produce the desired effect is recommended. However, the reason that Reit and colleagues may not have noticed a significant increase in the healing of the ulcers is because the intensity was set at .1 W/m^2, which is lower compared to the other studies.

As seen with e-stim, there are also contraindications to using US. These contraindications include: never use over pregnant uterus, malignancy, eye cranium, heart, venous thrombosis, or over an acute infection, and discontinue if pain during treatment.[9,24]

Both e-stim and US have proven to enhance healing of wounds. There are several modalities that can be used with wound care. As physical therapists, it is beneficial to know US and e-stim have research to show their efficacy in wound healing. It is essential that any treatment performed by physical therapists or health care professionals show reliability and have research to establish efficacy.

CHAPTER VI

CONCLUSION

When treating patients with wounds, it is important to know the anatomy and physiology of the skin, physiology of wound healing, and how to document wound progression accurately. These will give insight to the treatment of wounds. Studies proved both electrical stimulation and ultrasound enhance wound healing and this substantiates the use of these modalities by physical therapists for the promotion of wound healing.

Electrical stimulation is recommended by the Agency for Health Care Policy and Research for the treatment of Stage II, III, and IV ulcers. High volt pulsed current is the waveform of e-stim used the most for wound healing. The studies show that this form of e-stim enhances wound healing; however, the parameters and protocols are not consistent from study to study. Further studies are necessary to establish parameters, such as what polarity to use, intensity, duration, and voltage settings.

Ultrasound is also proven to be beneficial for the promotion of wound healing. The evidence shows that it decreases wound size as long as it is used safely and with optimal efficiency. Ultrasound as well as electrical stimulation should be used as an adjunct to wound management when conservative treatment is not promoting healing. The use of these modalities allows the role of physical therapists in wound management to be more diverse and also allows for other alternatives to treatment of wounds.

APPENDIX A

Pressure Sore Status Tool

General Guidelines:
Fill out the attached rating sheet to assess a pressure sore's status after reading the definitions and methods of assessment described below. Evaluate once a week and whenever a change occurs in the wound. Rate according to each item by picking the response that best describes the wound and entering that score in the item score column for the appropriate date. When you have rated the pressure sore on all items, determine the total score by adding together the 13-item scores. The HIGHER the total score, the more severe the pressure sore status. Plot total score on the Pressure Sore Status Continuum to determine progression of the wound.

Specific Instructions:

1. Size: Use ruler to measure the longest an widest aspect of the wound surface in centimeters; multiply length x width.

2. Depth: Pick the depth, thickness, most appropriate to the wound using these additional descriptions:
   - 1 = tissues damaged but no break in skin surface
   - 2 = superficial, abrasion, blister or shallow crater. Even with, &/or elevated above skin surface (e.g. hyperplasia).
   - 3 = deep crater with or without undermining of adjacent tissue.
   - 4 = visualization of tissue layers not possible due to necrosis.
   - 5 = supporting structures include tendon, joint capsule.

3. Edges: Use this guide:

Indistinct, diffuse	=	unable to clearly distinguish wound outline.
Attached	=	even or flush with wound base, no sides or walls present; flat.
Not attached	=	sides or walls are present; floor or base of wound is deeper than edge.
Rolled under, thickened	=	soft to firm and flexible to touch.
Hyperkeratosis	=	callous-like tissue formation around wound & at edges.
Fibrotic, scarred	=	hard, rigid to touch.

4. Undermining: Assess by inserting a cotton tipped applicator under the wound edge; advance it as far as it will go without using undue force; raise the tip of the applicator so it may be seen or felt on the surface of the skin; mark the surface with a pen; measure the distance from the mark on the skin to the edge of the wound. Continue process around the wound. Then use a transparent metric measuring guide with concentric circles divided into 4 (25%) pie-shaped quadrants to help determine percent of wound involved.

5. Necrotic Tissue Type: Pick the type of necrotic tissue that is predominant in the wound according to color, consistency and adherence using this guide.

White/grey non-viable tissue	=	may appear prior to wound opening; skin surface is white or grey.
Non-adherent, yellow slough	=	thin, mucinous substance; scattered throughout wound bed; easily separated from wound tissue.
Loosely adherent, yellow slough	=	thick, stringy, clumps of debris; attached to wound tissue.
Adherent, soft, black eschar	=	soggy tissue; strongly attached to tissue in center or base of wound.
Firmly adherent, hard, black eschar	=	firm, crusty tissue; strongly attached to wound base and edges (like a hard scab).

6. Necrotic Tissue Amount: Use a transparent metric measuring guide with concentric circles divided into 4 (25%) pie-shaped quadrants to help determine percent of wound involved.

7. Exudate Type: Some dressings interact with wound drainage to produce a gel or trap liquid. Before assessing exudate type, gently cleanse wound with normal saline or water. Pick the exudate type that is predominant in the wound according to color and consistency, using this guide:

Bloody	=	thin, bright red
Serosanguineous	=	thin, watery pale red to pink
Serous	=	thin, watery, clear
Purulent	=	thin or thick, opaque tan to yellow
Foul purulent	=	thick, opaque yellow to green with offensive odor

8. Exudate Amount: Use a transparent metric measuring guide with concentric circles divided into 4 (25%) pie-shaped quadrants to determine percent of dressing involved with exudate. Use this guide:

None	=	wound tissue dry.
Scant	=	wound tissues moist; no measurable exudate.
Small	=	wound tissues wet; moisture evenly distributed in wound; drainage involves ≤ 25% dressing.
Moderate	=	wound tissues saturated; drainage involves > 25% to ≤ 75% dressing.
Large	=	wound tissues bathed in fluid; drainage freely expressed; may or may not be evenly distributed in wound; drainage involves > 75% of dressing.

9. Skin Color Surrounding Wound: Assess tissues within 4 cm of wound edge. Dark-skinned persons show the colors "bright red" and "dark red" as a deepening of normal ethnic skin color or a purple hue. As healing occurs in dark-skinned persons, the new skin is pink and may never darken.

10. Peripheral Tissue Edema: Assess tissues within 4 cm of wound edge. Non-pitting edema appears as skin that is shiny and taut. Identify pitting edema by firmly pressing a finger down into the tissues and waiting for 5 seconds, on release of pressure, tissues fail to resume previous position and an indentation appears. Crepitus is accumulation of air or gas in tissues. Use a transparent metric measuring guide to determine how far edema extends beyond wound.

11. Peripheral Tissue Induration: Assess tissues within 4 cm of wound edge. Induration is abnormal firmness of tissues with margins. Assess by gently pinching the tissues. Induration results in an inability to pinch the tissues. Use a transparent metric measuring guide with concentric circles divided into 4 (25%) pie-shaped quadrants to determine percent of wound and area involved.

12. Granulation Tissue: Granulation tissue is the growth of small blood vessels and connective tissue to fill in full thickness wounds. Tissue is healthy when bright, beefy red, shiny and granular with a velvety appearance. Poor vascular supply appears as pale pink or balanced to dull, dusky red color.

13. Epithelialization: Epithelialization is the process of epidermal resurfacing and appears as pink or red skin. In partial thickness wounds it can occur throughout the wound bed as well as from he wound edges. In full thickness wounds it occurs from the edges only. Use a transparent metric measuring guide with concentric circles divided into 4 (25%) pie-shaped quadrants to help determine percent of wound involved and to measure the distance the epithelial tissue extends into the wound.

Pressure Sore Status Tool Name________________________

Complete the rating sheet to assess pressure sore status. Evaluate each item by picking the response that best describes the wound and entering the score in the item score column for the appropriate date.

Location: Anatomic site. Circle, identify right (R) or left (L) and use "X" to mark site on body diagrams:

____ Sacrum & coccyx ____ Lateral ankle
____ Trochanter ____ Medial ankle
____ Ischial tuberosity ____ Heel Other Site ____

Shape: Overall wound pattern; assess by observing perimeter and depth.
Circle and date appropriate description:

____ Irregular ____ Linear or elongated
____ Round/oval ____ Bowl/boat
____ Square/rectangle ____ Butterfly Other Shape ____

Item	Assessment	Date	Date	Date
		Score	Score	Score
1. Size	1 = Length x width < 4 sq cm 2 = Length x width 4 - 16 sq cm 3 = Length x width 16.1 - 36 sq cm 4 = Length x width 36.1 - 80 sq cm 5 = Length x width > 80 sq cm			
2. Depth	1 = Non-blanchable erythema on intact skin 2 = Partial thickness skin loss involving epidermis &/or dermis 3 = Full thickness skin loss involving damage or necrosis through subcutaneous tissue; may extend down to but not through underlying fascia; &/or mixed partial & full thickness &/or tissue layers obscured by granulation tissue 4 = Obscured by necrosis 5 = Full thickness skin loss with extensive destruction, tissue necrosis or damage to muscle, bone or supporting structures			
3. Edges	1 = Indistinct, diffuse, none clearly visible 2 = Distinct, outline clearly visible, attached, even with wound base 3 = Well-defined, not attached to wound base 4 = Well-defined, not attached to base, rolled under, thickened 5 = Well-defined, fibrotic, scarred or hyperkeratotic			
4. Under-mining	1 = Undermining < 2 cm in any area 2 = Undermining 2 -4 cm involving < 50% wound margins 3 = Undermining 2 -4 cm involving > 50% wound margins 4 = Undermining >4 cm in any area 5 = Tunneling &/or sinus tract formation			
5. Necrotic Tissue Amount	1 = None visible 2 = White/grey non-viable tissue &/or non-adherent yellow slough 3 = Loosely adherent yellow slough 4 = Adherent, soft, black eschar 5 = Firmly adherent, hard, black eschar			

Item	Assessment	Date	Date	Date
		Score	Score	Score
6. Necrotic Tissue Amount	1 = None visible 2 = < 25% of wound bed covered 3 = 25% to 50% of wound covered 4 = > 50% and <75% of wound covered 5 = 75% to 100% of wound covered			
7. Exudate Type	1 = None or bloody 2 = Serosanguineous: thin, watery, pale red/pink 3 = Serous: thin, watery, clear 4 = Purulent: thin or thick, opaque, tan/yellow 5 = Foul purulent: thick, opaque, yellow/green with order			
8. Exudate Amount	1 = None 2 = Scant 3 = Small 4 = Moderate 5 = Large			
9. Skin color Sur-rounding Wound	1 = Pink or normal for ethnic group 2 = Bright red &/or blanches to touch 3 = White or grey pallor or hypopigmented 4 = Dark red or purple &/or non-blanchable 5 = Black or hyperpigmented			
10. Peripheral Tissue Edema	1 = Minimal swelling around wound 2 = Non-pitting edema extends <4 cm around wound 3 = Non-pitting edema extends ≥4 cm around wound 4 = Pitting edema extends < 4 cm around wound 5 = Crepitus &/or pitting edema extends ≥ 4 cm			
11. Peripheral Tissue Induration	1 = Minimal firmness around wound 2 = Induration < 2 cm around wound 3 = Induration 2 -4 extending < 50% around wound 4 = Induration 2 -4 cm extending ≥ 50% around wound 5 = Induration > 4 cm in any area			
12. Gran-ulation Tissue	1 = Skin intact or partial thickness wound 2 = Bright, beefy red; 75% to 100% of wound filled &/or tissue overgrowth 3 = Bright, beefy red; <75% & > 25% of wound filled 4 = Pink, &/or dull, dusky red &/or fills ≤ of wound 5 = No granulation tissue present			
13. Epithe-lilization	1 = 100% wound covered, surface intact 2 = 75% to < 100% wound covered &/or epithelial tissue extends >0.5 cm into wound bed 3 = 50% to <75% wound covered &/or epithelial tissue extends to <0.5 cm into wound bed 4 = 25% to < 50% wound covered 5 = < 25% wound covered			
TOTAL SCORE				
SIGNATURE				

Pressure Sore Status Continuum

0 10 13 15 20 25 30 35 40 50 55 60 65

Tissue Health — Wound Regeneration — Wound Degeneration

Plot the total score on the Pressure Sore Status Continuum by putting an "X" on the line and the date beneath the line. Plot multiple scores with their dates to see-at-a-glance regeneration or degeneration of the wound.

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