THE BASIC PRINCIPLES OF WOUND HEALING

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An understanding of the basic physiology of wound healing provides the clinician with the framework necessary to implement the basic principles of chronic wound care.

Introduction:

Wound healing is a complex and dynamic process with the wound environment changing with the changing health status of the individual. The knowledge of the physiology of the normal wound healing trajectory through the phases of hemostasis, inflammation, granulation and maturation provides a framework for an understanding of the basic principles of wound healing. Through this understanding the health care professional can develop the skills required to care for a wound and the body can be assisted in the complex task of tissue repair.

A chronic wound should prompt the health care professional to begin a search for unresolved underlying causes. Healing a chronic wound requires care that is patient centered, holistic, interdisciplinary, cost effective and evidence based. This is one of five articles made available by the Canadian Association of Wound Care to assist the wound care clinician develop an increased understanding of wound healing. This article explores:

- Why wounds happen.
- How wounds heal.
- When is a wound considered chronic?
- The nature of good chronic wound care

It is hoped that these basic principles will provide a framework for further study and exploration into the complex area of wound care. For more articles in this series see www.cawc.net

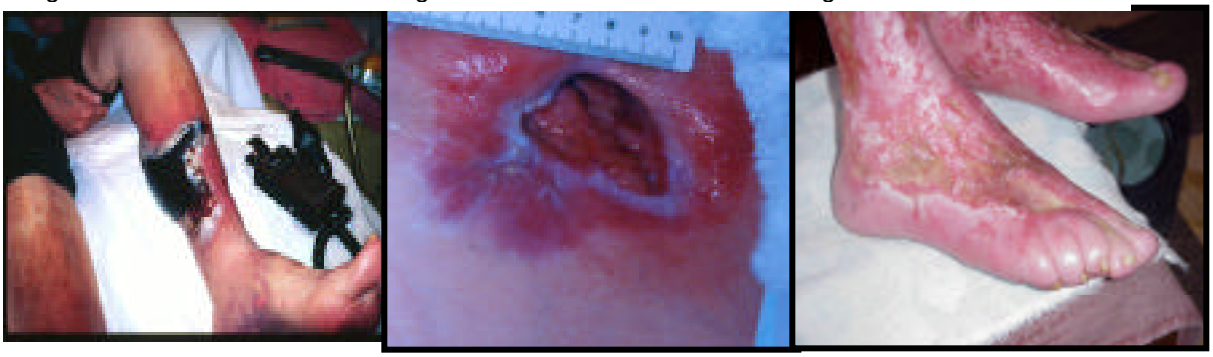
Why Do Wounds Happen?

In any natural disaster the damaging forces must be identified and stopped before repair work can begin. So too in wound care the basic underlying causes and factors that affect healing must be identified and controlled as best we can before wound healing will begin. Following are some of the common underlying causes or factors, which may interfere with wound healing:

- Trauma (initial or repetitive)
- Scalds and burns both physical and chemical
- Animal bites or insect stings
- Pressure
- Vascular compromise, arterial, venous or mixed
- Immunodeficiency
- Malignancy
- Connective tissue disorders
- Metabolic disease, including diabetes
- Nutritional deficiencies
- Psychosocial disorders
- Adverse effects of medications

In many cases the underlying causes and factors interfering with wound healing may be mutlifactorial.
Figure 1 illustrates an elderly patient who suffered trauma when she banged her leg on a coffee table. She is on coumadin which contributed to the injury becoming a large black hematoma of old blood. What is the safest way to heal this wound?
In figure 2 we see a young spinal cord injured patient with a chronic pressure ulcer surrounded by erythema. Is the erythema caused by infection, irritation of wound fluid, incontinence or continual pressure to the area?
In figure 3 we see chronic ulcers in a frail elderly woman that has lower leg edema related to decreased mobility. The ulcer drains copious amounts of chronic wound drainage causing irritation to the surrounding skin. The patient sits most of the day in a dependent position which worsens the leg edema. How can the wound fluid be controlled to enable healing?
The clinician working in wound care needs to be a good detective and needs to consider all possible factors influencing healing.

Figure 1 Figure 2 Figure 3



How Do Wounds Heal?

Research work on acute wounds in an animal model shows that wounds heal in four phases. It is believed that chronic wounds must also go through the same basic phases[1]. Some authors combine the first two phases.

The phases of wound healing are:

- ***Hemostasis***
- ***Inflammation***
- ***Proliferation or Granulation***
- ***Remodeling or Maturation***

Kane's analogy to the repair of a damaged house provides a wonderful framework to explore the basic physiology of wound repair[2] (See Table 1).

Hemostasis:

Once the source of damage to a house has been removed and before work can start, utility workers must come in and cap damaged gas or water lines. So too in wound healing damaged blood vessels must be sealed. In wound healing the ***platelet*** is the cell which acts as the utility worker sealing off the damaged blood vessels. The blood vessels themselves constrict in response to injury but this spasm ultimately relaxes. The platelets secrete vasoconstrictive substances to aid in this

process but their prime role is to form a stable clot sealing the damaged vessel. Under the influence of ADP (adenosine diphosphate) leaking from damaged tissues the platelets aggregate and adhere to the exposed collagen[3]. They also secrete factors which interact with and stimulate the intrinsic clotting cascade through the production of ***thrombin***, which in turn initiates the formation of ***fibrin*** from ***fibrinogen***. The fibrin mesh strengthens the platelet aggregate into a stable hemostatic plug. Finally platelets also secrete cytokines such as ***platelet-derived growth factor*** (PDGF), which is recognized as one of the first factors secreted in initiating subsequent steps. Hemostasis occurs within minutes of the initial injury unless there are underlying clotting disorders.

Inflammation Phase:

Clinically inflammation, the second stage of wound healing presents as erythema, swelling and warmth often associated with pain, the classic "rubor et tumor cum calore et dolore". This stage usually lasts up to 4 days post injury. In the wound healing analogy the first job to be done once the utilities are capped is to clean up the debris. This is a job for non-skilled laborers. These non-skilled laborers in a wound are the ***neutrophils or PMN's (polymorphonucleocytes).*** The inflammatory response causes the blood vessels to become leaky releasing plasma and PMN's into the surrounding tissue[4]. The neutrophils phagocytize debris and microorganisms and provide the first line of defense against infection. They are aided by local ***mast cells***. As fibrin is broken down as part of this clean-up the degradation products attract the next cell involved.

The task of rebuilding a house is complex and requires someone to direct this activity or a contractor. The cell which acts as "contractor" in wound healing is the ***macrophage***. Macrophages are able to phagocytize bacteria and provide a second line of defense. They also secrete a variety of chemotactic and growth factors such as ***fibroblast growth factor (FGF), epidermal growth factor (EGF), transforming growth factor beta (TGF-__*** and ***interleukin-1 (IL-1)*** which appears to direct the next stage[5].

Proliferative Phase (Proliferation, Granulation and Contraction):

The granulation stage starts approximately four days after wounding and usually lasts until day 21 in acute wounds depending on the size of the wound. It is characterized clinically by the presence of pebbled red tissue in the wound base and involves replacement of dermal tissues and sometimes subdermal tissues in deeper wounds as well as contraction of the wound. In the wound healing analogy once the site has been cleared of debris, under the direction of the contractor, the framers move in to build the framework of the new house. Sub-contractors can now install new plumbing and wiring on the framework and siders and roofers can finish the exterior of the house.

The "framer" cells are the ***fibroblasts*** which secrete the collagen framework on which further dermal regeneration occurs. Specialized fibroblasts are responsible for wound contraction. The "plumber" cells are the ***pericytes*** which regenerate the outer layers of capillaries and the ***endothelial cells*** which produce the lining. This process is called ***angiogenesis.*** The "roofer" and "sider" cells are the ***keratinocytes*** which are responsible for ***epithelialization***. In the final stage of epithelializtion, contracture

occurs as the keratinocytes differentiate to form the protective outer layer or stratum corneum.

Remodeling or Maturation Phase:

Once the basic structure of the house is completed interior finishing may begin. So too in wound repair the healing process involves remodeling the dermal tissues to produce greater tensile strength. The principle cell involved in this process is the ***fibroblast.*** Remodeling can take up to 2 years after wounding and explains why apparently healed wounds can break down so dramatically and quickly if attention is not paid to the initial causative factors.

Table 1 Phases of Healing

Phase of Healing	Days post injury	Cells involved in phase	Analogy to House Building
Hemostasis	Immediate	Platelets	Capping off conduits
Inflammation	Day 1 - 4	Neutrophils	Unskilled laborers to clean up the site
Proliferation	Day 4 - 21	Macrophages	Supervisor Cell
Granulation		Lymphocytes	Specific laborers at the site:
		Angiocytes	Plumber
		Neurocytes	Electrician
Contracture		Fibroblasts	Framers
		Keratinocytes	Roofers and Siders
Remodeling	Day 21 – 2 yrs	Fibrocytes	Remodelers

When Does a Wound Become Chronic?

In healthy individuals with no underlying factors an acute wound should heal within three weeks with remodeling occurring over the next year or so. If a wound does not follow the normal trajectory it may become stuck in one of the stages and the wound becomes chronic. Chronic wounds are thus defined as wounds, which have "failed to proceed through an orderly and timely process to produce anatomic and functional integrity, or proceeded through the repair process without establishing a sustained anatomic and functional result."[6] Once a wound is considered chronic it should trigger the wound care clinician to search for underlying causes, which may not have been addressed. Better yet, an understanding of the causative factors should lead us to be proactive in addressing these factors in at risk populations so that chronic wounds are prevented.

Basic Principles of Wound Care

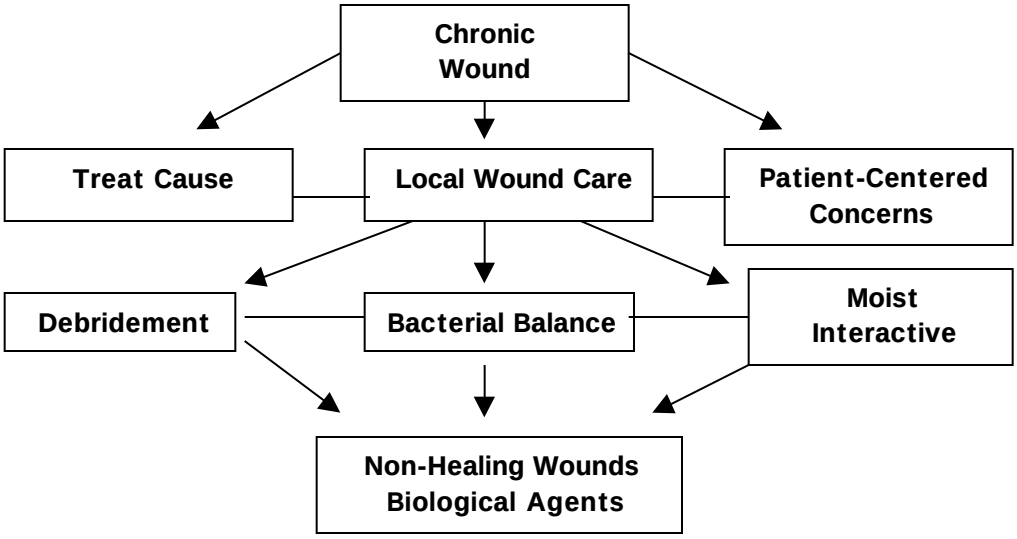
There are three basic principles which underlie wound healing.

1. ***Identify and control as best as possible the underlying causes.***
2. ***Support patient centered concerns***
3. ***Optimize local wound care.***

The CAWC Best Practice Recommendations for wound care (wound bed prep, venous ulcer management, pressure ulcer management and diabetic ulcer management) extensively covers all three principles (www.cawc.net). Figure 4,

excerpted from Wound Bed Preparation, outlines an algorithm that provides a framework for chronic wound management.

Figure 4



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Optimize Local Wound Care

In 1962 George Winter described improved wound healing under moist conditions[7]. Despite that seminal work it is only in the last decade that the advantages of moist interactive wound healing have become more widely recognized and applied in clinical practice. Some of the advantages include the following:

- ***Decreased dehydration and cell death.*** As described earlier, the task of wound repair requires the activity of a host of cells from neutrophils and macrophages to fibroblasts and pericytes. These cells cannot function in a dry environment.
- ***Increased angiogenesis.*** Not only do the cells required for angiogenesis require a moist environment but also angiogenesis occurs towards regions of low oxygen tension such that occlusive dressings may act as a stimulus in the process[8].
- ***Enhanced autolytic debridement.*** By maintaining a moist environment neutrophil cell life is enhanced and proteolytic enzymes are carried to the wound bed allowing for painless debridement[9]. Further as discussed earlier these fibrin degradation products are a factor in stimulating macrophages to release growth factors into the wound bed.
- ***Increased re-epithelialization.*** In larger, deeper wounds epidermal cells must spread over the wound surface from the edges. They must have a supply of blood and nutrients. Dry crusted wounds reduced this supply and provide a barrier to migration thus slowing rates of epithelialization[10].
- ***Bacterial barrier and decreased infection rates.*** Occlusive dressings with good edge seals can provide a barrier to migration of microorganisms into the wound. Bacteria have been shown to pass through 64 layers of moist gauze[11]. Wounds covered with occlusive dressings have been

shown to have lower rates of infection than those with conventional gauze dressings[12].

- ***Decreased pain.*** It is believed that the moist wound bed insulates and protects the nerve endings thereby reducing pain. Furthermore occlusive dressings often require fewer dressing changes, which may be uncomfortable for patients.
- ***Decreased costs.*** While occlusive dressings have a higher per unit cost than conventional gauze, the reduced frequency of dressing changes and increased healing rates may proved to be cost effective in the long term.

While moist wound healing has clear advantages, debate continues on how moist is moist. Dressings should retain enough moisture to stimulate good healing and yet should not cause maceration or irritation to the surrounding tissues.

The Ideal Dressing

So how do we provide for good moist interactive wound healing? In 1979 Turner described the ideal dressing as having the following characteristics[13]:

- Removes excess exudate and toxins
- High humidity at the dressing wound interface
- Allows for gaseous exchange
- Provides thermal insulation
- Protects against secondary infection
- Free from particulate and toxic components
- No trauma with removal

Over the past 15 years an ever-expanding list of dressing products has come onto the market in an attempt to meet these conditions. Among these are the transparent film dressings, hydrogels, hydrophilic foams, alginates, hydrocolloids and the new antibacterials and biologic dressings or devices. There is however no magic "one-size-fits-all" dressing. The clinician needs to become familiar with the characteristics of the different classes of dressings and to tailor the dressing used to the phase of healing, characteristics of the wound, the needs (and risk factors) of the patient and the availability and skill of the caregiver.

Summary

In summary ***wound healing requires an approach that is:***

- **Patient centered:** It is always wise to remember that we are dealing with a person who happens to have a chronic wound. We can develop a wonderful management plan but if we do not have patient buy-in the plan is doomed to failure.
- **Holistic:** Best practice requires the assessment of the whole patient, not just the "hole in the patient". All possible contributing factors must be explored.
- **Interdisciplinary:** Wound care is a complex business requiring the skills of many disciplines. Skilled nurses, physiotherapists, occupational therapists, dietitians and physicians both generalists and specialists (dermatologists, plastic surgeons and vascular surgeons depending on need) are central

members of the team. In addition in some settings social work involvement may be important.

- **Evidence based:** In today's healthcare environment treatment must be based on best available evidence and be cost effective.

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