Wound Healing and Repair
Wound Care Treatment & Management

http://emedicine.medscape.com/article/1298129-overview#aw2aab6b4

http://emedicine.medscape.com/article/194018-treatment

I. Inflammatory Phase

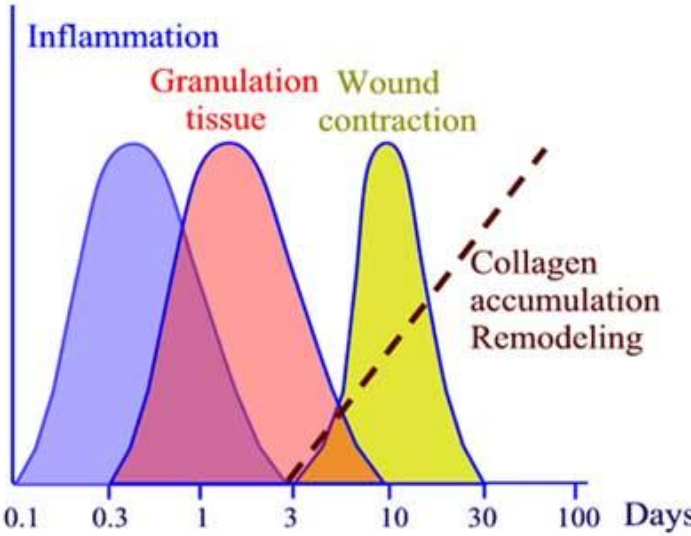
A) Immediate to 2-5 days

B) Hemostasis

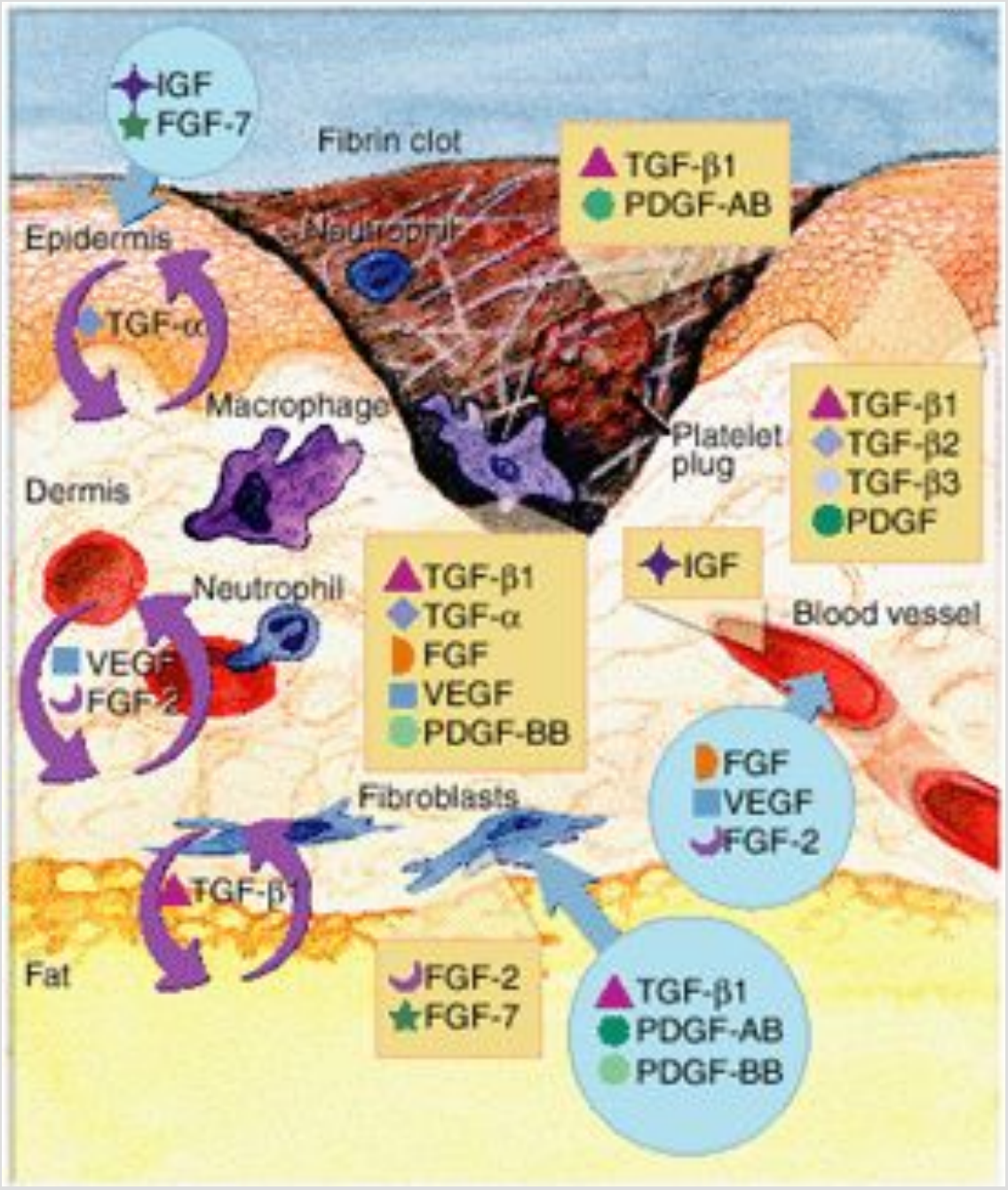
- Vasoconstriction
- Platelet aggregation
- Thromboplastin makes clot

C) Inflammation

- Vasodilation
- Phagocytosis



Orderly phases of wound healing



platelet-derived growth factor (PDGF), platelet factor IV, and transforming growth factor beta (TGF-b),

II. Proliferative Phase

A) 2 days to 3 weeks

B) Granulation

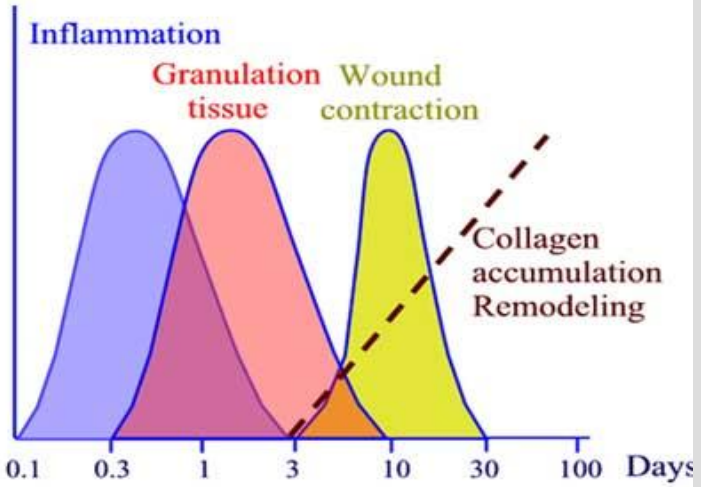
- Fibroblasts lay bed of collagen
- Fills defect and produces new capillaries

C) Contraction

- Wound edges pull together to reduce defect

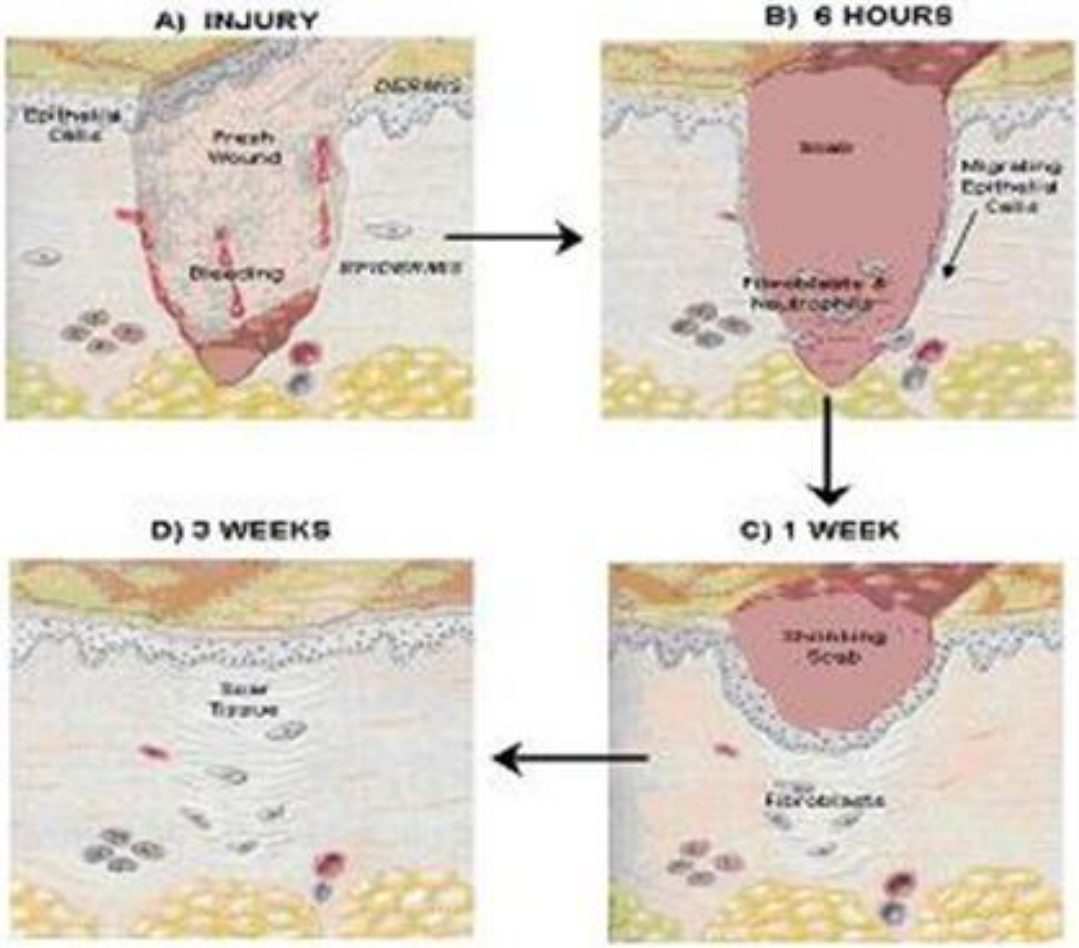
D) Epithelialization

- Crosses moist surface
- Cell travel about 3 cm from point of origin in all directions



Orderly phases of wound healing

PROCESS OF WOUND HEALING

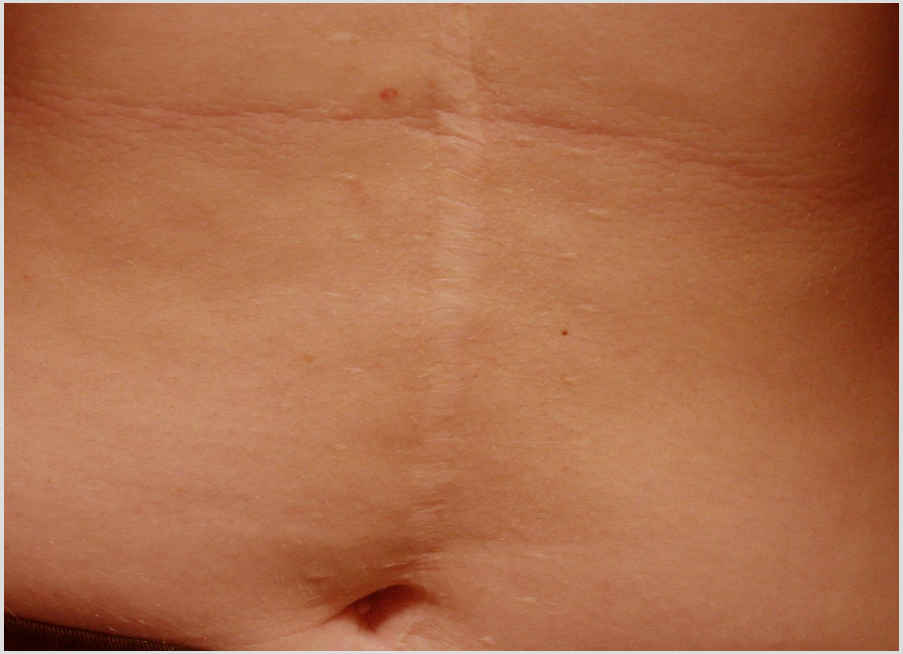


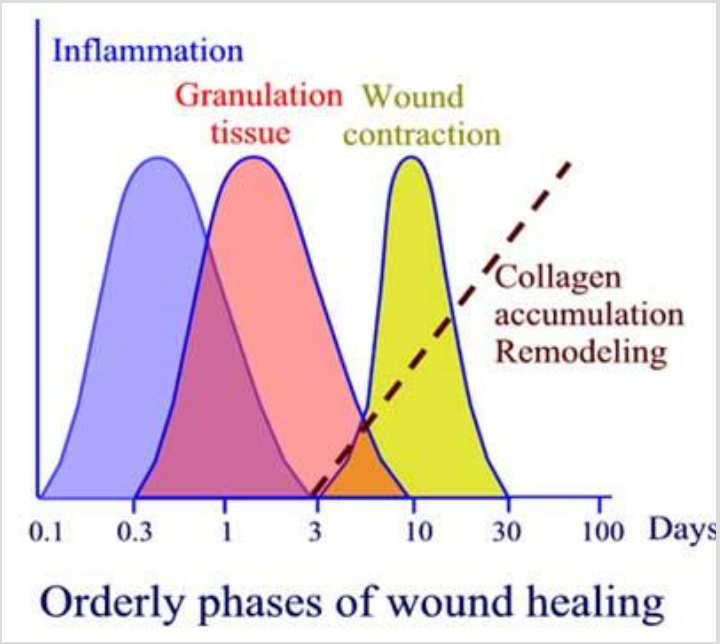
III. Remodeling Phase

A) 3 weeks to 2 years

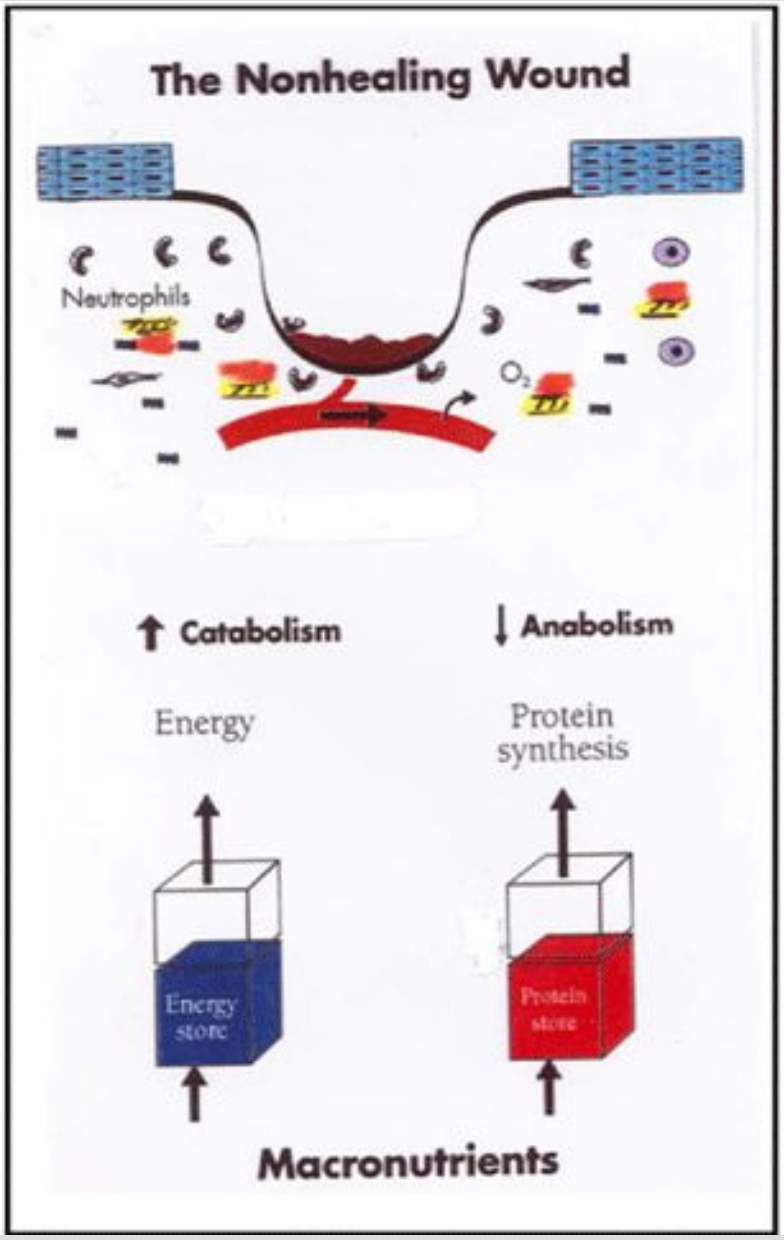
B) New collagen forms which increases tensile strength to wounds

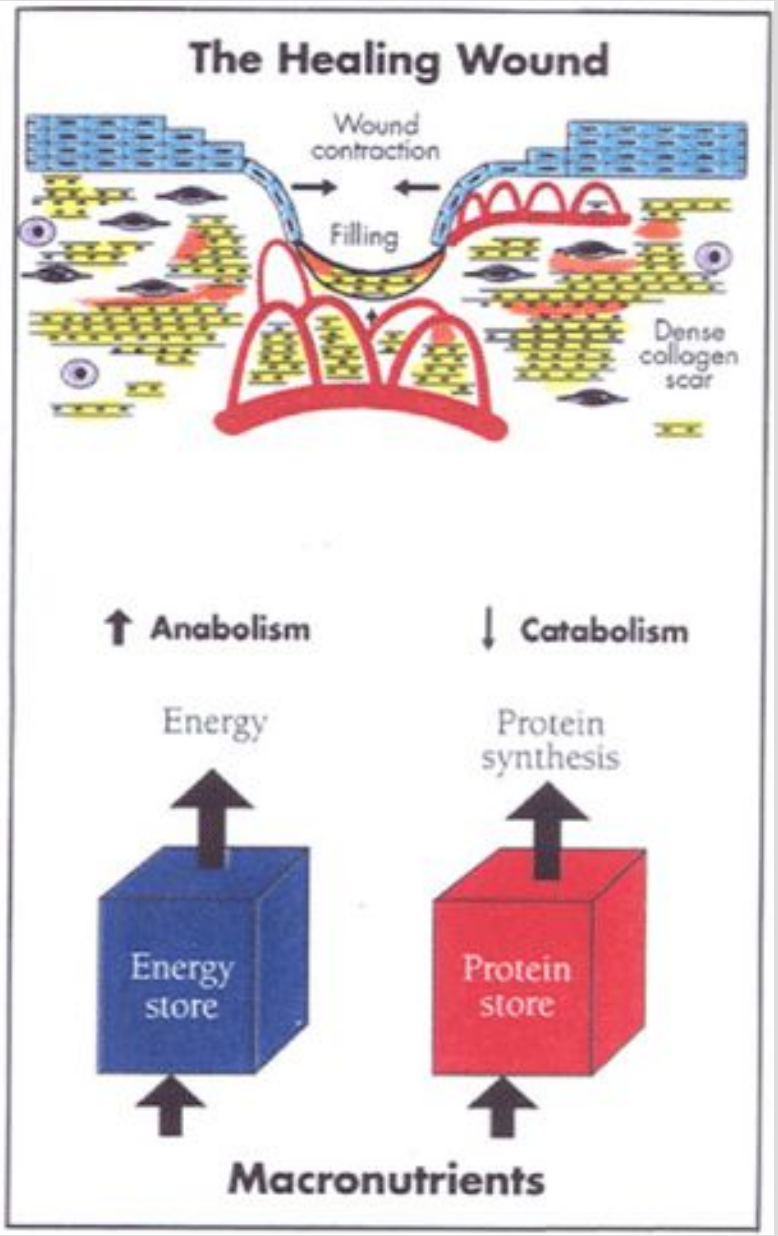
C) Scar tissue is only 80 percent as strong as original tissue





Orderly phases of wound healing


The Nonhealing Wound
Neutrophils
O_2
Catabolism
Anabolism
Energy
Protein synthesis
Energy store
Protein store
Macronutrients


The Healing Wound
Wound contraction
Filling
Dense collagen scar
Anabolism
Catabolism
Energy
Protein synthesis
Energy store
Protein store
Macronutrients

Future advances in wound healing

- Laser techniques, nonlaser techniques, and other modalities are being explored to enhance the proliferation of cells, the migration of cells, and the acceleration of the healing of wounds
- Human cell–conditioned media developed in embryologic like conditions
- Fetal tissue
- Hyperbaric oxygen
- Stem cells, in particular adipose-derived stem cells

General treatment of nonhealing wounds can be described as follows:

See Treatment of specific types of wounds.

Assess the entire patient

Successful treatment of difficult wounds requires assessment of the entire patient and not just the wound. Systemic problems often impair wound healing; conversely, nonhealing wounds may herald systemic pathology.

Consider the negative effects of endocrine diseases (eg, diabetes, hypothyroidism), hematologic conditions (eg, anemia, polycythemia, myeloproliferative disorders), cardiopulmonary problems (eg, chronic obstructive pulmonary disease, congestive heart failure), GI problems that cause malnutrition and vitamin deficiencies, obesity, and peripheral vascular pathology (eg, atherosclerotic disease, chronic venous insufficiency, lymphedema).

Characterize the wound

Assess the following: (1) size and depth of involvement and the extent of undermining; (2) the appearance of the wound surface, that is, necrotic or viable; (3) amount and characteristics of wound exudate; and (4) status of the periwound tissues (eg, pigmented, scarred, atrophic, cellulitic).[23]

Ensure adequate oxygenation

The usual reason for inadequate tissue oxygenation is local vasoconstriction as a result of sympathetic overactivity. This may occur because of blood volume deficit, unrelieved pain, or hypothermia, especially involving the distal extent of the extremities.

Ensure adequate nutrition

Adequate nutrition is an often-overlooked requirement for normal wound healing.[24] Address protein-calorie malnutrition and deficiencies of vitamins and minerals.

Inadequate protein-calorie nutrition, even after just a few days of starvation, can impair normal wound-healing mechanisms. For healthy adults, daily nutritional requirements are approximately 1.25-1.5 g of protein per kilogram of body weight and 30-35 calories/kg. Increase these requirements for those with sizable wounds.

Suspect malnutrition in patients with chronic illnesses, inadequate societal support, multisystemic trauma, or GI or neurologic problems that may impair oral intake. Protein deficiency occurs in approximately 25% of all hospitalized patients.

Chronic malnutrition can be diagnosed by using anthropometric data to compare actual and ideal body weights and by observing low serum albumin levels. Serum prealbumin is sensitive for relatively acute malnutrition because its half-life is 2-3 days (vs 21 d for albumin). A serum prealbumin level of less than 7 g/dL suggests severe protein-calorie malnutrition.

Vitamin and mineral deficiencies also require correction. Vitamin A deficiency reduces fibronectin on the wound surface, reducing cell chemotaxis, adhesion, and tissue repair. Vitamin C is required for the hydroxylation of proline and subsequent collagen synthesis.

Vitamin E, a fat-soluble antioxidant, accumulates in cell membranes, where it protects polyunsaturated fatty acids from oxidation by free radicals, stabilizes lysosomes, and inhibits collagen synthesis. Vitamin E inhibits prostaglandin synthesis by interfering with phospholipase-A2 activity and is therefore anti-inflammatory. Vitamin E supplementation may decrease scar formation.

Zinc is a component of approximately 200 enzymes in the human body, including DNA polymerase, which is required for cell proliferation, and superoxide dismutase, which scavenges superoxide radicals produced by leukocytes during debridement.

Treat infection

Issues to consider are wound infection versus colonization and osteomyelitis.[25]

A positive wound culture does not confirm a wound infection. Opportunistic microorganisms may colonize any wound. Wound exudate, which is naturally bactericidal, inhibits the spread of surface contamination from becoming a deep wound infection. However, when wound ischemia or systemic immune compromise supervenes, pathogenic microorganisms propagate until an excessive concentration of bacteria in the wound precludes healing. This heralds a true wound infection. Multidrug resistant organisms are becoming increasingly common.

Foul-smelling drainage, a spontaneously bleeding wound bed, flimsy friable tissue, increased levels of wound exudate, increasing pain, surrounding cellulitis, crepitus, necrosis, fasciitis, and regional lymphadenopathy characterize the infected wound. Fever, chills, malaise, leukocytosis, and an elevated erythrocyte sedimentation rate are common systemic manifestations of wound infection.

Remove foreign bodies

Be attentive to the possibility of foreign bodies, which may prevent healing of traumatic wounds, including road debris and retained fragments of dressing materials or suture material.

Irrigate

Gently irrigate the wound with a physiologic saline solution. If cost is a major consideration, the patient can prepare a saline solution at home by using 1 gallon of distilled water and 8 teaspoons of table salt. The solution is boiled and then cooled to room temperature before use.

If surface exudate is present, consider irrigation under pressure. An irrigation pressure of approximately 8 psi can be achieved with saline forced through a 19-gauge angiocatheter with a 35-mL syringe. Pat the wound surface with soft moist gauze; do not disrupt viable granulation tissue.

Whirlpool treatment is reserved for large and infected wounds.

Provide a moist (not wet) wound bed

After debridement, apply a moist saline dressing, an isotonic sodium chloride gel (eg, Normlgel [Scott Health Care], IntraSite gel), or a hydroactive paste (eg, DuoDerm [ConvaTec]). Optimal wound coverage requires wet-to-damp dressings, which support autolytic debridement, absorb exudate, and protect surrounding normal skin.

http://www.kci1.com/KCI1/vactherapysystemfactsheet

Consider other topical agents

Topically applied platelet-derived growth factors have a modestly beneficial effect in promoting wound healing. Becaplermin gel 0.01% (Regranex), recombinant human platelet-derived growth factor (PDGF) that is produced through genetic engineering, is approved by the US Food and Drug Administration (FDA) to promote healing of diabetic foot ulcers. Regranex is contraindicated in persons with known skin cancers at the site of application. Freeze-dried, platelet-rich plasma showed promise in an animal study.[32]

Collagen comprises a significant fraction of the necrotic soft tissues in chronic wounds. The enzyme collagenase, which is derived form fermentation of *Clostridium histolyticum*, helps remove nonviable tissue from the surface of wounds. However, collagenase is not a substitute for an initial surgical excision of a grossly necrotic wound.

Other topical agents that have been used for wound treatment are sugar, antacids, and vitamin A&D ointment.

Avoid cytotoxic agents, such as hydrogen peroxide, povidone iodine, acetic acid, and Dakin solution (sodium hypochlorite).

Consider compression therapy

Consider the advisability of compression therapy. Compression is appropriate for ulcers caused or exacerbated by extremity edema. Compression may have to be avoided entirely in the presence of significant arterial inflow compromise.

Use support hose or elastic wraps with approximately 40-60 mm Hg of pressure in the absence of arterial disease and 20-30 mm Hg in the presence or suspicion of mild arterial insufficiency.

Manage pain

Manage wound pain by moistening dressings before removal. Consider using 2% topical lidocaine gel during wound care. (Anecdotal reports describe the use of topical morphine and diamorphine-infused gel for palliation of pressure ulcer pain in patients who are terminally ill,[33] but this use is not FDA approved.)

Complications

Complications of nonhealing wounds include the following:

- Amyloidosis - See Amyloidosis, Macular.
- Bacteremia - See Shock, Septic.
- Cellulitis
- Endocarditis
- Heterotopic bone formation
- Maggot infestation
- Meningitis
- Osteomyelitis
- Perineal-urethral fistula
- Pseudoaneurysm - See Peripheral Vascular Injuries.
- Septic arthritis
- Sinus tract or abscess

Surgical Therapy

Methods are available to expedite healing of the clean wound. After a wound is in a steady clean state, a decision must be made about allowing it to heal by natural processes or expediting healing with a surgical procedure. Clinical experience and observation of the healing progress in the individual case dictate the appropriate treatment. Surgical options include skin grafting, application of bioengineered skin substitutes, and use of flap closures.[58]

- Skin grafting: Autologous skin grafting is the criterion standard for viable coverage of partial-thickness wounds. The graft can be harvested with the patient under local anesthesia in an outpatient procedure. Meshing the graft allows wider coverage and promotes drainage of serum and blood.
- Cadaveric allografting: A cadaveric skin allograft is a useful covering for relatively deep wounds after surgical excision when the wound bed does not appear appropriate for application of an autologous skin graft. The allograft is only a temporary solution.
- Application of bioengineered skin substitutes[52, 59, 60]

- Use of flap closures: Delayed primary closure of a chronic wound, as shown below, requires well-vascularized clean tissues and tension-free apposition. This usually requires undermining and mobilization of adjacent tissue planes by creating skin flaps or myocutaneous flaps.[62]

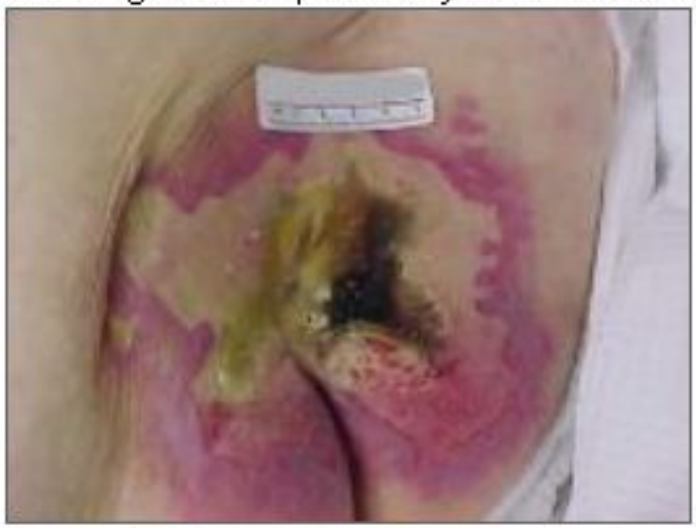
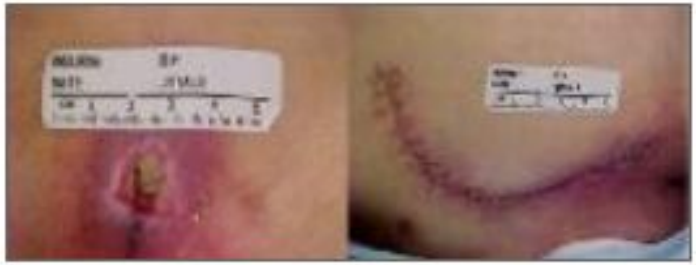


Image of advanced sacral pressure ulcer shows the effects of pressure, shearing, and moisture.



Sacral pressure ulcer before and after flap closure.

Future and Controversies

The aging of the population and continued advances in biotechnology drive the wound care industry, estimated at $10 billion globally. Besides the always-improving synthetic dressing materials, newer technologies in wound treatment include the xenogeneic tissue scaffold, bilayered human dermal substitutes, recombinant growth factors, endoscopic subfascial ligation of venous perforators, and endovascular arterial repair techniques. The use of hyperbaric oxygen therapy and electrical stimulation remain controversial.

Table 1. Characteristics and Uses of Wound-Dressing Materials

Category	Examples	Description	Applications
Alginate	AlgiSite, Comfeel, Curasorb, Kaltogel, Kaltostat, Sorbsan, Tegagel	Alginate dressings are made of seaweed extract contains guluronic and mannuronic acids that provide tensile strength and calcium and sodium alginates, which confer an absorptive capacity. Some can leave fibers in the wound if they are not thoroughly irrigated. These dressings are secured with secondary coverage.	These dressings are highly absorbent and useful for wounds have copious exudate. Alginate rope is particularly useful to pack exudative wound cavities or sinus tracts.
Hydrofiber	Aquacel, Aquacel-Ag, Versiva	An absorptive textile fiber pad, hydrofiber is also available as a ribbon for packing of deep wounds. This material is covered with a secondary dressing. The hydrofiber combines with wound exudate to produce a hydrophilic gel. Aquacel-Ag contains 1.2% ionic silver that has strong antimicrobial properties against many organisms, including methicillin-resistant *Staphylococcus aureus* and vancomycin-resistant enterococci.	Hydrofiber absorbent dressings used for exudative wounds.
Debriding agents	Hypergel (hypertonic saline gel), Santyl (collagenase), Accuzyme (papain urea)	Various products provide some chemical or enzymatic debridement.	Debriding agents are useful for necrotic wounds as an adjunct to surgical debridement.
Foam	LYOfoam, Spyrosorb, Allevyn	Polyurethane foam has absorptive capacity.	These dressings are useful for cleaning granulating wounds with minimal exudate.
Hydrocolloid	CombiDERM, Comfeel, DuoDerm CGF Extra	Hydrocolloid dressings are made of microgranular suspension of natural or synthetic polymers, such as gelatin or pectin, in an	Hydrocolloid dressings are useful for dry necrotic wounds, wounds with minimal