



Fourth Stage

General Surgery

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Lecture 2

wound healing is classically divided into 4 stages:

(A) hemostasis: is when blood vessels constrict to restrict the blood flow.

(B) inflammation: is the second stage of wound healing and begins right after the injury when the injured blood vessels leak transudate (made of water, salt, and protein) causing localized swelling. Inflammation both controls bleeding and prevents infection. The fluid engorgement allows healing and repair cells to move to the site of the wound. During the inflammatory phase, damaged cells, pathogens, and bacteria are removed from the wound area. These white blood cells, growth factors, nutrients and enzymes create the swelling, heat, pain and redness commonly seen during this stage of wound healing. Inflammation is a natural part of the wound healing process and only problematic if prolonged or excessive.

(C) proliferation: is when the wound is rebuilt with new tissue made up of collagen and extracellular matrix.

(D) remodeling: is when collagen is remodeled from type III to type I and the wound fully closes.

Each stage is characterized by key molecular and cellular events and is coordinated by a host of secreted factors that are recognized and released by the cells of the wounding response.

Wound Healing

The aim when trying to get a wound to heal is:

1- achieve anatomical integrity of the injured part

2- restore full function.

3- to produce a cosmetic result as possible. A sound knowledge of the principles of wound healing is necessary to achieve these aims and to allow appropriate planning of incisions and their closure. An understanding of the complications that can occur during wound healing is vital to try to avoid these or to treat them appropriately if they arise.

Classification of wound Healing

1- Primary intention

Where the edges are clean and held together with ligatures, there is little gap to bridge. Healing, when uncomplicated, occurs quickly with rapid ingrowth of wound healing cells (macrophages, fibroblasts, etc.) and restoration of the gap by a small amount of scar tissue. Such wounds are soundly united within 2 weeks and dense scar tissue is laid down within 1 month.

2- Secondary intention

Wound healing by secondary intention occurs when the wound edges are separated and the gap between them cannot be bridged directly. This occurs when there has been extensive loss of epithelium, severe wound contamination or significant subepithelial tissue damage.

Healing occurs slowly from the bottom of the wound towards the surface by the process of granulation. This larger defect results in a greater mass of scar tissue than healing by primary intention. In time, such scarring tends to shrink, resulting in wound contracture.

Normal sequence of wound Healing

Despite the differences in time taken and amount of scar tissue produced, the sequence of events in wound healing by primary and secondary intention is similar:

- Skin trauma results in damage to superficial blood vessels and hemorrhage. Blood clotting results in fibrin clot formation, and this is stabilized by a number of factors, including fibronectin.
- Within 24 h neutrophils have migrated to the area, and epidermal cells have extended out in a single layer from the wound edges in an attempt to cover the defect.
- Between days 1 to 3 the neutrophils are replaced by macrophages, which clear debris and play a role in producing the environment that stimulates local and recruited fibroblasts to produce collagen. This step, along with new blood vessel formation (neovascularization), constitutes 'granulation tissue'.
- Towards the end of the first week neovascularization is at its peak. In healing by primary intention at this stage the incised gap is bridged by collagen. The full thickness of epithelium is restored.
- During the second week there is increased fibroblast activity and collagen formation, with decreasing vascularity and cellularity in the wound. With primary intention by 1 month there is a cellular connective tissue scar with normal overlying epidermis.

By 2 months the wound has regained approximately 80% of its original strength. The redevelopment of strength in the wound involves remodeling and orientation of collagen fibers and continues for a number of months.

In healing by secondary intention there is more necrotic debris, exudate and fibrin, and a more intense inflammatory response result.

There is a larger defect, therefore, with more granulation tissue and a greater mass of scar tissue. Wound coverage takes longer and wound contraction occurs caused by myofibroblasts.

Regulation of the complex interactions involved in wound healing is achieved by a number of local and systemic factors. These are produced both at distant sites (e.g.growth factor) and locally by the cells involved in the healing process.

Many factors are involved, important examples including cytokines, platelet-derived growth factor and epidermal growth factor.

Factors affecting healing

Local Factors	Systemic Factors
1-Wound Sepsis	1-Nutritional Deficiencies
2-Poor Blood Supply	2-Systemic Disease
3-Wound Tension	3-Therapeutic Agents
4-Foreign Bodies	4-Age
5-Previous Irradiation	

Local factors

1- Wound sepsis

Removal of hair allows better visualization of the wound. It also facilitates application of adhesive dressings and suture removal. However, evidence has shown that shaving of skin at an early stage preoperatively increases bacterial counts in the area, and shaving more than 12 h before incision can significantly increase the rate of wound infection. Hair removal should therefore be performed where necessary just prior to surgery.

Preparing the skin with antiseptic wash prior to surgery is vitally important. Chlorhexidine and povidone-iodine have been shown to reduce the skin bacterial flora by up to 95%. Most surgeons perform a double scrub of the area, preparing the skin well wide of the area of surgery. Careful hand wash by the surgeon using these antiseptics is also very important in reducing wound sepsis.

2- Poor blood supply

As described above, bleeding and neovascularization play fundamental roles in wound healing. Areas with good vascularity, such as the scalp and face, heal well, whereas those with poor blood supply, such as pretibial skin, heal poorly. Surgical technique can also have a significant effect on the blood supply to the area. Care should be taken where possible to maintain the vascular supply to the incised area.

For example, creation of a distally based skin flap is likely to disrupt the vessels to the skin of the flap, and impair wound healing. Appropriate planning of incisions minimizes vascular damage.

3- Wound tension

Tension across a healing wound serves to separate the wound edges, impairs the blood supply to the area and predisposes to complications of wound healing. Care should be taken, therefore, when planning incisions to avoid creating tension if possible.

Where the gap between the wound edges is large, primary apposition of the edges might not be appropriate or even possible. Bridging of such a gap can be achieved by a number of plastic surgery techniques, including skin grafting or tissue flaps.

Better cosmetic results from surgery tend to be achieved if incisions are made along the lines of the collagen bundles of the skin (Langer's lines). These follow the natural skin creases on the face, transversely at the joints and longitudinally on the long parts of the limbs.

4- Foreign bodies

The presence of extraneous material within the wound predisposes to infection. It also results in a larger and more prolonged inflammatory reaction, which can predispose to excess scar tissue formation. Foreign material can enter a traumatic wound at the time of injury and should be removed at the onset of treatment with adequate debridement.

With surgical wounds, however, complications can result from endogenous material being inappropriately present within the wound, such as devascularized pieces of fat, necrotic tissue resulting from excess use of the diathermy, or the patient's hair. Thorough wound cleaning before closure helps to remove these materials.

5- Previous irradiation

Areas that have undergone preoperative radiotherapy suffer from a patchy vasculitis, impairing their blood supply and hence healing potential. Radiation also damages skin stem cells, resulting in poor re-epithelialisation.

Systemic factors

1- Nutritional deficiencies

Vitamins important in the process of wound healing include A and C. Vitamin A is involved in epithelialization and collagen production; vitamin C has an important role in the production and modification of collagen. This has been recognized for centuries by virtue of the disease scurvy caused by vitamin C deficiency. Certain minerals are also essential in wound healing. Zinc acts as an enzyme cofactor and has a role in cell proliferation. It accelerates wound healing in experimental models.

Deficiency may be encountered in patients on long-term total parenteral nutrition. Protein is the main building block in wound healing. A malnourished, hypoproteinaemic patient has impaired inflammatory and immune responses, vital for normal wound healing and prevention of wound infection. Protein amino acids are essential for collagen production, which is itself a protein.

2- Systemic diseases

Several diseases are known to impair wound healing via a number of mechanisms. Important examples include diabetes, uremia and jaundice.

3- Therapeutic agents

Immunosuppressive drugs dampen the inflammatory and immune responses, hence impairing wound healing. These include chemotherapeutic agents for malignancy and immunosuppressive and anti-prostaglandin drugs used for inflammatory conditions such as rheumatoid disease. Probably the most important and widely used example is corticosteroid therapy. Steroids have the additional effect of increasing the fragility of small blood vessels.

4- Age

Prior to puberty, the rate of wound healing is increased compared to post-puberty.

Complications of wound healing

1-Infection

Wound infection is dealt with further in the next lecture

2- Dehiscence

Total breakdown of all the layers of the surgical repair of a wound is called 'dehiscence'. The mortality of abdominal wound dehiscence is between 10 and 35%. Dehiscence can be caused by a number of factors, including those that generally impair wound healing

Factors causing wound dehiscence

- a- Suture breakage
- b- Knot slippage
- c- 'Cutting out' of sutures
- d- Excess tension on the suture line

3- Incisional hernia

Dehiscence of the deeper layers of a wound in which the skin layer remains intact will result in incisional hernia formation with protrusion of underlying structures through the deeper defect. This is of particular importance for abdominal wounds, where viscera such as small intestine can herniate.

4- Hypertrophic scarring

Hypertrophic scarring is essentially excess collagen scar tissue formation – almost an over healing of a wound. It is non-progressive after 6 months and does not extend beyond the edges of the wound. It occurs most frequently in specific areas, particularly around joints and where Langer's lines of tension are crossed by the incision.

Poor skin suturing technique frequently results in hypertrophic scar formation, especially where the edges of the skin are overlapping instead of being accurately apposed.

Treatment is difficult and further surgery should not be attempted for at least 6 months. Excision of the scar and re-suturing often has disappointing results, resulting in the same over-healing. Radiotherapy used to be used but has now been abandoned. Some improvement can be achieved with local injection of corticosteroids directly into the scar, a process that might need repeating several times.

5- Keloid scarring

Keloid scars are due to abnormal collagen metabolism. The excess scar tissue extends out beyond the wound edges and might continue to enlarge after 6 months.

Prevalence is higher in patients with dark skin, especially those of African origin, in younger patients and in those with burn wounds.

Areas prone to this type of scarring are the face, dorsal surfaces of the body, sternum and deltopectoral region.

Excision generally results in a larger recurrence, although excision followed by compression bandaging can have slightly better results. Corticosteroid injections can give some improvement.

6- Contractures

Wound Contractures can occur with any wounds but are more commonly associated with wounds that experience delayed healing (including infection), burns and those in which the incision crosses Langer's lines.

Contracture of a scar across a joint can result in marked limitation of movement. It is therefore essential to avoid vertical incisions across a joint if possible. At a joint, Langer's lines tend to run horizontally.

Surgical treatment of a scar contracture might be the only treatment available and can include skin grafting, local flaps or wound Z-plasty.