SKIN: UNIQUE CHARACTERISTICS AND ANATOMY IN THE LOWER EXTREMITY

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Introduction

The skin is the largest and possibly the most complex organ in the human body. A thorough understanding of the structure and function of skin is a necessity to all surgeons, if one is to be prepared to deal with the peculiarities of skin and wound healing. The scientific and biologic basis for all surgical procedures are dependent on understanding the complex subject of the skin in the lower extremities.

Microscopic Anatomy

Skin is a compound organ consisting of two major layers, epidermis and dermis (Fig 1).

The epidermis (outer layer) can be divided into two layers; stratum malpighian or "living layer", which rests upon the dermis, and the outer desquamating layer or stratum corneum. The stratum malpighian consists of several distinct layers. From deep to superficial are the basal layer (stratum germinativum), the stratum spinosum (prickle cell layer) and the stratum granulosum. The stratum lucidum is more superfiscial and consists of a clear layer which is variable in size being directly proportional to the thickness of the skin. The plantar aspect of the foot demonstrates this layer very well. However, the stratum lucidium is almost absent on the dorsum of the foot.

All epidermal cells originate in the basalar layer or stratum germanativum and migrate superficially. It takes approximately 28 days for an epidermal cell to migrate from the stratum germinativum to the stratum corneum. Certain diseases such as psoriasis may greatly alter this time sequence.

Beneath the epidermis lies the dermis. It is composed of two layers. The superficial papillary layer is composed of widely separated delicate collagenous, elastic, and reticular fibers which are infiltrated with capillaries and ground substance. The deeper, reticular layer is formed by dense, coarse, branching, collagenous fibers. The dermis supplies blood and nutrients to the epidermis which has no blood supply of its own.

Beneath the skin lies the subcutaneous layer or superficial fascia. The superficial fascia may also be divided into two different layers: the outermost panniculus adiposus and the deeper panniculus carnosus. The panniculus adiposus contains the main arteries, veins, and nerves that serve the skin.

Gross Anatomy

Although the microscopic anatomy is fairly consistent, the gross anatomy of skin can differ significantly. The three primary factors which account for the variables seen are relative skin thickness, the orientation of skin tension, and the thickness of the subcutaneous tissue. Obviously the skin is thicker on the plantar aspect of the foot as well as other areas subjected to chronic irritation. The variable thickness of the subcutaneous is of importance to the surgeon, since this layer not only contains the blood supply to the skin but also acts as a buffer to bony prominances. Areas which contain a thin subcutaneous layer can easily be subjected to vascular compromise and lead to a partial or full necrosis of the skin.

Tension is an important factor in all healing wounds. The direction of tension determines the orientation of collagen, elastic, and reticular fibers. It was not until 1962 that Borges and Alexander published the concept of relaxed skin tension lines (RSTL). The RSTL are oriented parallel to the collagen, elastin, and reticular fibers within the dermis. Incisions made parallel to the RSTL produce a stronger scar due to more effective collagen repair and structural arrangement. Laner in 1861 made an earlier attempt at discussing these tension lines, however, clinical experience did not reinforce his findings. Crease lines which are lines of maximal tension are formed perpendicular to the direction of pull of muscles and tendons.

Wound Healing

Wound healing may occur via primary, secondary, or tertiary mechanisms. Primary wound healing (first intension) occurs after wound edges have been well coapted as in a surgical wound. Healing occurs from side to side. Secondary wound closure occurs when a wound is left "open" and healing occurs via granulation from deep

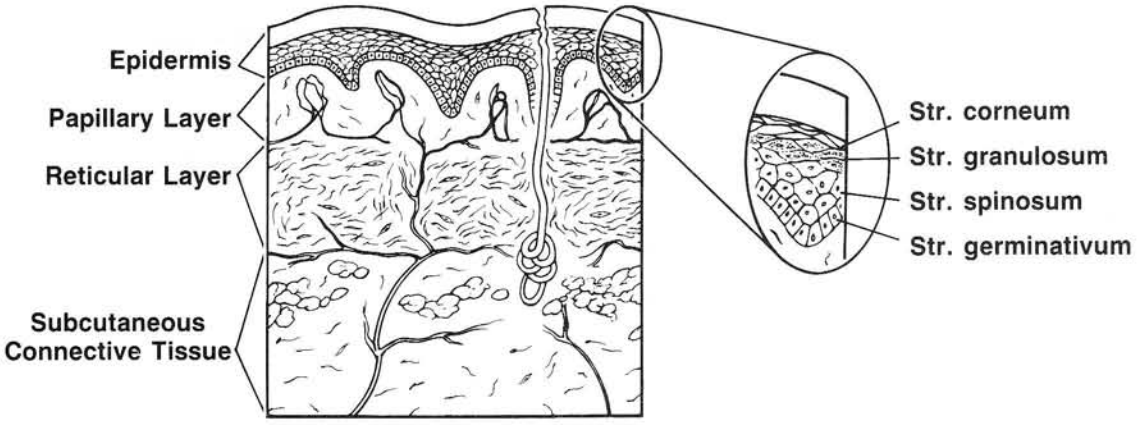

Fig. 1. Skin anatomy.

to superficial with subsequent wound contracture leaving a larger scar. Tertiary wound healing is seen when a wound which has been left open for a period of time is primarily closed.

Surgical incisions heal primarily and exhibit minimal epithelialization and wound contracture. This is as opposed to secondary wound healing which relies primarily on the processes of wound contracture and epithelialization for closure.

There are three main phases of wound healing; inflammatory, fibroblastic, and remodeling. The inflammatory phase occurs immediately following a penetration of the skin until four days later. This initial reaction is characterized by an intense vasoconstriction followed by vasodilation. Subsequently, there is an influx of neutrophilic granulocytes, macrophages, and monocytes into the wound. These events act to cleanse the wound and prepare it for the next phase.

The fibroblastic phase begins at approximately day four of wound healing and may continue for up to two to four weeks. Mesenchymal cells in the area of the injury differentiate into fibroblasts. The fibroblasts appear to use the fibrin and fibronectin, byproducts of hemostasis, as a scaffold for collagen synthesis. Epithelial cells migrating in the area control the amount of collagen content in the wound, being produced by the fibroblasts, by the liberation of collagenase. Eventually the rate of collagen synthesis balances with the rate of degradation. Maturation of the scar will follow.

The maturation phase can continue for a year and consists of wound remodeling, resorption, and the differentiation of cells.

The processes of epithelialization and contraction occur throughout the early phases of wound healing. Once epithelial cells have covered the wound the final step is differentiation of the cells with restoration of function (i.e. keratin production). Contraction is the process by which the size of a full thickness wound is reduced. Unlike epithelialization, the entire dermis moves in contracture, not just the epidermis. This process is of prime importance when the epidermis and dermis cannot be coapted with primary closure.

Various chemicals and drugs have been shown to alter the typical process of wound healing. Cortisone inhibits wound repair by decreasing the rate of production of granulation tissue. A decreased fibroplasia and mesenchymal proliferation have also been observed secondary to the presence of cortisone and ACTH. The utilization of anabolic steroids has been shown to accelerate sound healing by increasing protein synthesis. However, the long term side effects are unknown at this time.

Wound healing is associated with an increased metabolic rate leading to a greater nutritional demand. Decreased protein availability will prolong the initial phase of wound healing and prevent the onset of the fibroblastic phase. However, the use of high protein diet has not been found to accelerate wound healing. Oxygen is required for the synthesis of proteins such as collagen. Anything interfering with the delivery of oxygen to the wound will alter healing. Examples would include peripheral vascular disease or excessive edema.

The role of vitamins and minerals in wound healing are well known. Vitamin deficiencies, such as vitamin C in scurvey, can cause improper healing of the wound. Vitamin A used topically or systemically can increase granulation tissue and epithelialization. However, excessive amounts of vitamin A can cause gross inflammation so caution must be observed. Vitamins are necessary for protein, fat, and carbohydrate metabolism utilized at the cellular level. Trace minerals (zinc, iron, copper, etc) are also important. Supplementation of vitamins and minerals to patients with adequate stores has not been

shown to have any significant beneficial effects to this date.

Recently zinc has been given much attention in its role in wound healing. Soon after the skin is penetrated, a decrease in zinc has been found at the incision site and in the blood levels. Zinc is necessary in the process of DNA transcription, epithelial and fibroblast proliferation, stabilization of lysomes and cell membranes, and enzyme function (co-enzyme). Patients who exhibit zinc deficiencies have been shown to have impaired wound healing. When given supplemental zinc, wound healing returns to normal. A good diet with proper nutrition is important to ensure proper wound healing. Patients who have inadequate nutrient stores or deficiencies should receive supplementation to maximize healing potential.

Disorders of Wound Healing

Failure can occur at any increment of wound healing. Four major areas of concern include:

1. coagulation and hemostasis
2. inflammation and phagocytic function
3. neovascularization, and
4. fibroblast and collagen synthesis.

Coagulation and hemostasis are necessary for the initial phase of wound healing. Disorders of the inflammatory process and phagocytic function (i.e. secondary to chemotherapy) disrupt the entire initiation of wound healing. This could result in non-healing, possibly infected wound. The need for an adequate blood supply is obvious. Evaluation of blood flow must always be performed to ensure proper wound healing.

Fibroblastic function and collagen synthesis can be affected by drugs (steroids) as previously discussed. Disease such as diabetes mellitus, malnutrition, infection, synthesis/lysis imbalance (keloids and hypertrophic scars) and collagen fiber defects (Ehler's, Danlos, Marfan's, cutis laxa) can also interfere with fibroblastic function. This can lead to delayed healing or the production of a weak fragile scar.

Miscellaneous

An integral aspect of wound healing is the management of the wound itself. Some technical factors to consider are antisepsis, debridement, dressings, immobilization, and closure. These factors will be discussed by other authors.

Summary

Skin and its unique properties are important considerations to all surgeons. Before any incision is considered, a thorough understanding of these basic principles of skin structure and wound healing must be obtained to ensure proper results. One must remember that the lower extremity skin possesses its own peculiarities. A fine surgical correction can be tainted by the sight of a large gapping wound or painful scar.

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