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Image Processing in the Study of Wound Healing

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Wound healing is an important field in dermatology. At least in European countries, dermatologists routinely treat chronic nonhealing wounds, including venous leg ulcers, pressure sores, vasculitis ulcers, diabetic ulcers, and ulcers caused by inoperable vascular diseases.[1] In general, treatment is focused on improving the patient's condition, treating the underlying disorder whenever possible, and wound care. Wound care has become a specialty in itself. In the last 15 years, an enormous amount of wound care materials have been introduced on the market. Many of these products have not been properly tested in randomized, double-blind, placebo-controlled clinical trials. Such trials are desperately needed to supply clinicians with information to guide them in their choice of wound care products. One of the problems in performing clinical trials on wound healing is the lack of objective evaluation methods. The evaluation method should be adapted to the wound type and the wound healing phase (debridement phase, granulation tissue formation, epithelialization phase, or remodeling phase). If a product is designed for use in the epithelialization phase, then the time required for complete wound healing, or the reduction in wound size within a certain time limit, can be used as a primary outcome parameter. If a product is designed for wound cleaning, the wound size is a useless parameter, because wound size can remain exactly the same or increase slightly during the debridement phase, while important qualitative changes occur: the yellow or greenish black layers of fibrin and necrosis are removed and gradually replaced by healthy red granulation tissue. This article describes a digital image analysis (DIA) system designed to measure the shift from black/yellow necrosis to red granulation tissue objectively.

Measuring Wound Surface

The simplest method is to trace the wound margins on a transparent sheet and to redraw the line with a computer pen on a digitizing tablet later. The advantage is that the clinician decides where the wound ends and epithelialization begins. The disadvantage is that on two occasions, errors may occur in tracing the ulcer outline. If the clinical observer and the computer operator are experienced, these errors are low (<2%). Another method is to obtain a digital image of the wound or a photograph of the wound (including a centimeter scale in two directions) and trace its outline directly on the screen, by using a mouse. In some wounds digital image analysis (see below) can be used to detect the wound margins automatically; however, the color differences between granulation tissue, surrounding skin, and the thin, partly transparent layer of the newly formed epithelium can be too small to allow automatic detection.

Wound contraction is not easy to quantify in human studies, because orientation marks are needed to measure the approximation of the wound edges. In animal studies, tattoos can be used.

Measuring Wound Volume

In deep wounds like decubitus ulcers one may want to measure how fast the wound fills up with granulation tissue. In this case, volume is an important parameter. Stereophotogrammetry can be used,[2] but it is less suitable if the wound has undermined borders. Calculating the volume by casting, or filling it up with water, is an alternative.[3–6] These volumetric methods may be painful and unreliable, as the volume of some wounds change considerably depending on the position of the patient.[7] Some promising new noninvasive volumetric techniques using ultrasonic imaging, laser profilometry, or color-coded structured light have been described.[8–10]

Measuring Wound Debridement

Wound cleaning (debridement) is an essential first phase in wound healing.[11] Wound debridement can be achieved by surgical methods, by the repeated application of moistened hydrophillic gauzes, or by the use of special products designed for debridement such as proteolytic enzymes, dextranomers, polysaccharide granulates, hydrocolloid dressings, and intracavity gels.[12–14] These products dissolve and absorb necrotic

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