VARIATIONS IN COMPLETENESS OF SKIN REPAIR IN POSTTRAUMATIC REGENERATION

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Healing of full-thickness skin wounds on the abdomen and back of hedgehogs was studied. Closure of the skin defect on the abdomen was found to take place mainly by contraction of the wound. New hair and sebaceous glands were formed in the small zone of regeneration arising in the center of the initial defect in some animals. Contraction of the wound was almost absent on the back and the defect was covered mainly by the formation of new tissues, so that in place of the wound extensive zones of regeneration were formed. The connective-tissue basis of the regenerating tissue on the abdomen and back resembled the intact dermis in the arrangement of its fibers.

KEY WORDS: *skin regeneration; hedgehogs; hairs and sebaceous glands.*

The healing of extensive full-thickness skin wounds in man is known to end with the formation of a connective-tissue scar. The scar tissues replace the characteristic structures of the area of skin studied: Papillae, sebaceous and sweat glands, hair follicles, and other structures disappear in the zone of the scar [4]. Mature scar tissue consists mainly of numerous coarse collagen fibers and thin, long fibrocytes, which like the fibers lie in the horizontal direction parallel to the wound surface. The collagen bundles are almost uniform in type and are linear in arrangement [1].

Healing of extensive full-thickness skin wounds on the back and side of rats and mice, just as in man, ends with the formation of a connective-tissue scar. In the overwhelming majority of investigations into the completeness of regeneration of skin, observations have been made on the regeneration of wounds on the back and, less frequently, on the side in rats and mice [5].

As a result, the view has become established that in all mammals the healing of full-thickness skin wounds always ends with the formation of a connective-tissue scar covered by epithelium. However, several workers have shown that in mammals zones of regeneration differing in structure from scars and resembling intact skin in certain morphological features can be formed at the site of a full-thickness skin wound. It has been shown, for instance, that in regenerating skin in piglets new sweat glands are formed [3], in regenerating skin on the concha auriculae of rabbits and the horns of stags hairs and sebaceous glands appear [2, 5, 8], and dermal papillae develop in regenerating skin on the sole of the foot in rats [5]. The connective-tissue basis of the regenerating tissue in some cases resembles intact dermis in the arrangement of its fibrous structures [3, 6]. It has been found that the completeness of regeneration of the skin depends primarily on the species of animal and the location of the wound defect. Since the course and outcome of regeneration have been studied in only a very small number of species of mammals, it is important to broaden the range of experimental animals used.

The object of this investigation was to study regeneration of the skin on the abdomen and back in hedgehogs.

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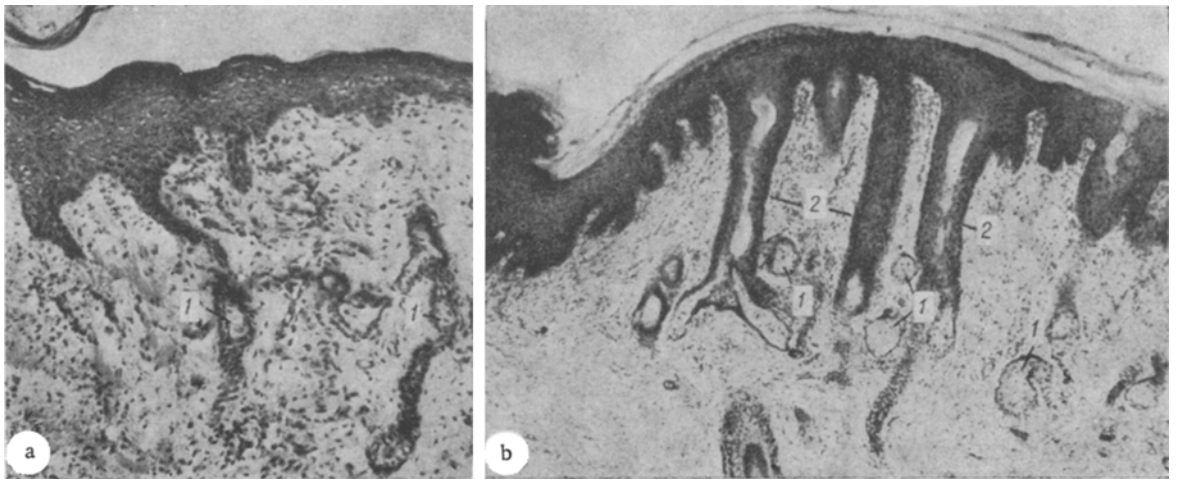

Fig. 1. New sebaceous glands (1) and hair follicles (2) in regenerating skin on hedgehog abdomen: a) 9 days; b) 13 days after operation. Hematoxylin–eosin, 120×.

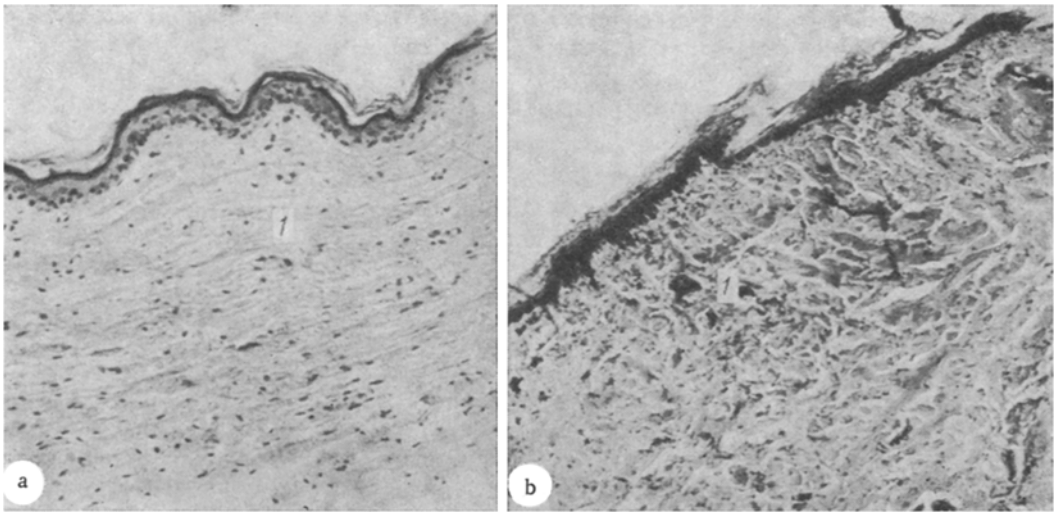

Fig. 2. Area of regenerating skin on hedgehog abdomen 105 days after operation (a) and on back 75 days after operation (b): 1) connective-tissue basis of regenerating skin. Hematoxylin–eosin, 70×.

EXPERIMENTAL METHOD

Nine common hedgehogs (*Erinaceus europaeus*) weighing 550-740 g (2 females and 7 males) were used.

A full-thickness square wound (2.25 cm^2) down to the cutaneous muscle was inflicted on both sides of the linea alba and at a distance of 1.5 cm from it on the abdomen of all the animals. The edges of the wound were marked with ink. The wound defects were measured immediately after the operation and on the 9th, 13th, 22nd, 60th, and 105th days after wounding. At these times pieces of tissue were taken from the region of the wound and adjacent areas of intact skin for histological analysis. One month after the last biopsy was taken from the region of the wound defect on the abdomen, another full-thickness square wound (1 cm^2) was inflicted on the back of all the hedgehogs. The areas of the wound were measured immediately after the operation and on the 9th, 22nd, 30th, and 75th days after wounding. Pieces of tissue were taken from the region of the wound for histological analysis. The pieces were taken through celloidin and embedded in paraffin wax. Sections 7-9 μ thick were stained with hematoxylin–eosin.

EXPERIMENTAL RESULTS

Healing of the wound on the abdomen of the hedgehogs took place under a thin scab. The initial area of the wound averaged 2.8 cm^2. On the 9th day after the operation the wound was much reduced in size and its mean area was 1.2 cm^2. After 13 days the area of the wound was 0.72 cm^2, and its scab-covered surface now projected above the surface of the surrounding skin. By the 22nd day after the operation the epithelized surface of the defect measured on average only 0.34 cm^2, and no further reduction in area took place. The defect was longer in a direction perpendicular to the long axis of the animal's trunk. In four animals the epithelized surface was covered with infrequent hairs.

Wounds of the hedgehog's back healed under a thick scab. The initial area of the wound averaged 2.6 cm^2 as a result of the pulling out of its edges. Later, the wound virtually did not contract and the area of the regenerating skin formed 30 and 75 days after the operation averaged 2.3 cm^2. In other words, contraction of the wound on the back hardly took place at all and the wound defect was covered mainly by the formation of new tissues. This is evidently connected with the property of hedgehogs of curling into a ball, for the muscles responsible for this curling act opposite to the forces of contraction, thereby widening the wound. Consequently, wounds on the hedgehog's back provide an excellent model for wound healing without contraction. The epithelized surface of the regenerating skin was covered with whitish flakes arising as a result of desquamation of the stratum corneum of the regenerating epithelium, a characteristic feature of the stratum corneum of the intact epithelium also.

A histological study of the material showed that on the 9th day after infliction of the abdominal wound the defect was filled with young loose connective tissue, consisting chiefly of cells and thin fibers. Epithelium covered three-quarters of the surface of the defect and formed invaginations into the underlying young connective tissue. In the peripheral part of the newly formed regenerating zones, the formation of sebaceous glands from invaginations of the epithelium was observed in four animals (Fig. 1a). All the surface of the wound defect was epithelized 13 days after the operation. The defect was filled with young connective tissue. There were fewer cells than at the previous time. The epithelium covering the young connective tissue was thickened (mean thickness 84 μ, thickness of intact epithelium 32 μ). Just as at the previous time, the regenerating epithelium formed invaginations into the young connective tissue. In four animals new hair follicles and sebaceous glands were formed in the regenerating zone (Fig. 1b).

The young connective tissue filling the wound defect was more compact 22 days after the operation. The fibrous structures were mainly oriented parallel to the surface of the defect although they did form crossovers. The epithelium covering the wound was still thickened (64 μ). Just as at the previous time the epithelium formed short invaginations into the underlying young connective tissue. Later (60 and 105 days after the operation) the connective-tissue basis of the regenerating skin consisted mainly of fibrous structures which interwove with one another (Fig. 2a). However, individual areas of fibrous tissue in which the fibers did not interweave but were oriented parallel to the surface of the defect were found in the connective-tissue basis of the regenerating skin. The thickness of the regenerating epithelium was similar to that of intact epithelium: Its mean thickness 60 days after the operation was 44 μ, decreasing to 42 μ 105 days after the operation (thickness of intact epithelium 34 μ). The regenerating epithelium at these times no longer formed invaginations into the underlying young connective tissue.

The connective-tissue basis of the regenerating skin on the hedgehog's back 30 and 75 days after the operation consisted mainly of a network of thick fibers. Large melanocytes were found in the top layers of the connective-tissue basis of the regenerating skin. By the arrangement of its fibrous structures and the presence of melanocytes, the connective-tissue basis of the regenerating skin resembled intact dermis (Fig. 2b) [7]. The epithelium covering the young connective tissue was thickened: Its thickness 30 days after the operation averaged 56 μ and 75 days after the operation 48 μ (thickness of intact epithelium 28 μ). In the basal layer of the regenerating epithelium many melanocytes — typical cells of the basal layer of the intact dorsal epithelium — were found. No spines were found in the regenerating tissues. Areas of fibrous tissues were seen in the connective-tissue basis of the regenerating skin. As a result of healing of full-thickness skin wounds on the abdomen of the hedgehog, zones of regeneration resembling in several morphological features the structure of intact skin were thus formed: New hairs and new sebaceous glands developed in them. The connective-tissue basis of the regenerating skin resembled intact dermis in the arrangement of its fibrous structures.

The connective-tissue basis of the regenerating skin formed on the hedgehog's back also resembled intact dermis in the arrangements of its fibrous structures.

However, no new spines were formed in the regenerating skin.

Consequently, there are considerable species variations in the ability of the skin to be restored during posttraumatic regeneration. In particular, regeneration of skin with close to the typical structure can take place in hedgehogs.

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