Structural Changes in Aging Human Skin

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In both exposed and protected areas of progressively older people the underside of the epidermis becomes increasingly flattened out. This flattening is accompanied by a comparable rarefaction of the superficial blood vessels. In this article we review the architecture of the elastic fiber framework in the papillary dermis of skin protected from the sun; aging changes that occur are similar to, but less severe than, those in sun-exposed areas. Most cutaneous sensory end organs are little affected by aging; those in the external genitalia, however, and particularly those underneath the vaginal epithelium become smaller and some disappear.

Investigators who have attempted to characterize the gross histological alterations that occur in aging skin have found the effort singularly unrewarding. For example, the hallmarks of old skin, wrinkles, show nothing peculiar in histological preparations. In this brief review we focus attention on the underside of the epidermis, on the fine elastic fibers that traverse the upper papillary body on their way to the epidermal basal lamina, on the vessels of microcirculation, and on the terminal cutaneous nerves and nerve end organs. Details of age-related alterations in other cutaneous structures have been described in a previous article [1].

We stress that some aging alterations resemble those found here and there in young skin, and many are so subtle that they escape the notice of microscopists who are not completely familiar with the many morphological attributes of normal skin. Of greater consequence is the fact that most histological material is too poorly preserved and prepared to permit refined observations.

We have made the observations that follow (light microscopy and scanning electron microscopy) on many normal tissues collected over the years from cadavers of persons of graded ages collected a few hours after they had died accidentally. For split-skin preparations, tissues have been incubated in sodium bromide according to a well-known, but unfortunately not widely used, technique [2]. Split-skin preparations have been viewed with a light microscope under direct lighting and with a scanning electron microscope. For the preparations of elastic fibers, frozen and paraffin-embedded, 10% formalin-fixed tissues have been sectioned from 10 μm to 100 μm and stained with a modified acid-orcein Verhoeff technique [3]. Blood vessels have been studied in thick frozen sections prepared to demonstrate alkaline phosphatase [4] and nerves have been demonstrated, also in thick frozen sections treated with the technique of Winkelmann [5] and with a modified cholinesterase technique [6].

OBSERVATIONS

The Epidermis

One cannot appreciate the progressive transformations that occur with aging in nonexposed epidermis if one is not familiar with the undamaged skin of young adult persons. The underside of the epidermis in split-skin preparations of young skin is a bas-relief of contiguous, branching ridges, valleys, crevices, and craters with a depth and a complexity that are characteristic of the location; glabrous skin, and singularly the volar surfaces of the hand and foot, has an epidermal understructure much more elaborate than other skin. Because patterns of epidermal undersurface are peculiar to specific regions of the body, with practice one can identify the seat or origin of pieces of skin [7].

The patterns on the undersurface of the epidermis are clearly visible even with a light microscope (Fig. 1). With a scanning electron microscope (magnifications of 1,000 to 2,000), the lower surfaces of the basal epidermal cells in contact with the papillary dermis by way of the basal lamina are plainly differentiated into fine villous protrusions that give the surface a velvety appearance (Fig 2 and 3).

Changes attributable to age often occur in different periods in one's life, and the same areas in different individuals of the same age can show variable magnitudes of modulation. Alterations in such exposed skin as the forehead, face, neck, and backs of hands occur precipitously in the early 20's or even earlier, but in areas protected by clothing they occur gradually. Whatever the case, the deviations are similar and are charac-
terized by a progressive flattening out of the variably complex understructure. We already described [8,9] such modifications in the lower abdomen, nipples and areolae of the breasts, and genitalia of women; we have subsequently found similar changes everywhere else (Fig 4–7). In very old persons the underside of the epidermis is often completely flattened out. Wrinkles on the underside of split-epidermis preparations appear as elevations (they are actually depressions of the outer surface) (Fig 8 and 9). The finer aging alterations can be seen only with the scanning electron microscope at magnifications of 1,000 to 2,000 ×. At such enlargements the outlines of adjacent basal cells are slightly separated by dehydration. Although in young epidermis these cells have myriad basal microvilli (described earlier), their population in senile epidermis is either severely reduced or destroyed (Fig 10). The basal cells of the thinned epidermis of the deep wrinkles on the wrists and knuckles, gluteal folds, foreheads, and napes of old individuals have no villi.

The Elastic Fiber Framework

Human skin is unique in being rich in elastic fibers. In the reticularis dermis, we have observed that the coarse, branching fibers are entwined with the collagenous fiber bundles. From the deeper layers of the papillaris dermis, fibers rise up toward the epidermis, split repeatedly, and become finer. In some areas the fibers form palisades oriented roughly perpendicularly to the epidermis, and each fiber sprays out into a terminal pene-
cillate formation. Just under the epidermal cells, these terminal fine fibers, barely resolvable with the light microscope, have slight globose terminations that appear to end in the basal lamina.

The skin of a 5-mo-old fetus had only a few fine elastic fibers in the dermis. In that of an 8-mo-old fetus the fibers were numerous and robust in the reticular layer; some fine fibers rose to the papillary layer, but none seemed to have a definite architecture. The organization of the fibers in the skin of 6- and

Fig 2. Scanning electron micrograph of the undersurface of abdominal epidermis from a 17-yr-old woman. Compare with Fig 3 (× 650).

Fig 3. Scanning electron micrograph of fine villous protrusions on the lower surfaces of the basal epidermal cells from the elbow of a 19-yr-old man (× 2,600).

Fig 4. Light micrograph of the underside of the epidermis of the areola from a 23-yr-old woman. Compare this with the Fig 5 split-skin preparation (reduced from × 50).
Fig 5. Light micrograph of the undersurface of the epidermis of the areola of a 79-yr-old woman. The topography is relatively flat (reduced from × 50).

Fig 6. Scanning electron micrograph of the lower side of abdominal epidermis from a 17-yr-old woman. Note the uneven surface and compare with Fig 7 (× 50).

Fig 7. Scanning electron micrograph of the undersurface of abdominal epidermis of a 92-yr-old woman. Compare Fig 7; the understructure is largely flattened (× 45).

Fig 8. Light micrograph of the underside of a split-epidermis preparation, showing deep wrinkles, from the neck of a 51-yr-old man. The wrinkles appear as elevations, but are actually depressions of the outer surface (× 26).
33-mo-old infants in the papillary layer somewhat resembled that of adults. In specimens from 3- and 9-yr-old children the elastic fibers were sparse but similar to those in adult skin.

The abundance of the penicillate terminals of the elastic fibers follows the complexity of the undersurface of the epidermis. On the malar part of the face, for example (where the underside of the epidermis is flat), the penicillate endings are shallow and broad. In the scalp and finger pads (where the epidermis has an elaborate underside), elastic fibers are wound loosely around the superficial capillary loops, from whence they give off short and tight penicillate terminals to the basal lamina of the epidermis. Different configurations are present in each general area of the body.

In the cheeks, eyebrows, and chin, the elastic fibers in the papillary body are tightly woven around the blood vessels. Fibers are somewhat sparse in the glabrous portion of the lips even though the underside of the epidermis is very complex. Only a few elastic fibers are present under the outer surface of the eyelid, or under the conjunctiva. The palpebral border and the tarsal plate are rich in elastic fibers.

The scalp also abounds in elastic fibers. Numerous penicillate formations spring from fibers that originate from the base of the papillary body or from fibers entwined around the many capillary loops. Terminal penicillate fiber units also spring from hair follicles, arrector pili muscles, and directly from the reticularis dermis.

The papillary bodies in fingers, toes, palms, and soles have the densest fine fiber meshes found anywhere. Individual Meissner corpuscles are surrounded by fibers, as are the subepidermal capillary loops.

In the chest and breasts, thighs, axillae, mons pubis, gluteal areas, abdomen, and other general body areas, the coarse fibers in the reticularis dermis are parallel to the surface; in the chest, axillae, and mons pubis, some perpendicular fiber bundles from the reticularis dermis rise to the papillary layer, where they form arcades from which straight branches radiate toward the epidermis in penicillate patterns.

Changes in Sun-Exposed Areas

Changes inflicted by the sun have been studied in the neck [10] and in the pinnae of the ears [11]. There and elsewhere, the major elastic changes consist of a thickening of the fibers in the papillary body into curled and amorphous masses. In the face such alterations are present in children as young as 9 yr of age and are sometimes fully developed by 20 yr. The severity of the damage seems to depend on the amount of exposure, the individual, and the specific regions involved.

In skin samples from the same 20-yr-old individual, we found greater elastic alterations in the philtrum, cheeks, forehead, and nose than on the chin. In the hairy surface of the lips the thicker fibers in the papillary body were beginning to agglutinate; in the glabrous surface, however, the fibers showed only minor change, and the mucosa was normal. The scant alteration in elastic fibers in the glabrous portion of the lips is the result of the sparseness of the fiber population there [12].

Where large-scale changes in the elastic fibers in the papillaris dermis occur, usually in skin from persons in their late 20's and 30's, the integrity of the elastic fibers is lost. The fibers form a thick amorphous layer, with no visible fine fibers. Between the epidermis and the matted elastic fibers in the base of the papillary body remains a clear, so-called Grenz zone, which either contains damaged terminal fine segments of elastic fibers or lacks such segments altogether. In progressively older specimens there are increasing masses of very thick and curled fibers, with an irregular fibrillar structure (cf. Banfield and Brindley [13]), containing densely stained droplets and granules.

Aging Changes

To avoid confusing aging changes with actinic damage, we have studied the skin of the axillae, breasts, and genitalia of
women; all of these regions are normally shielded from the sun. There are pronounced individual differences in the amount of change that occurs with aging in the elastic fiber architecture. Although some alterations in the fibers of the papillary body occur even in young people, profound changes occur only in individuals 50 yr of age or older, in which the terminal elastic fiber arcades have become progressively, but irregularly, thicker. Eventually the entire elastic fiber structure in the papillary dermis shrinks and sags, and the distal branches do not reach the epidermis; some are broken off from the main structures and remain attached to the epidermis (Fig 11-13). In general, the changes are similar to, but less severe than, those brought about by sun exposure.

The Superficial Blood Vessels

The architecture and abundance of superficial capillary loops and tufts in the papillary body, just beneath the epidermis, paralleled the intricacy of the underside of the epidermis. It follows, then, that the richest population of vessels of the microcirculation occurs in skin that is truly glabrous. Ellis [14] first showed the rarefaction and near disappearance of these vessels in the scalp with advancing age in bald and nonbald areas. We verified (a) that the epidermis in the area of frankly bald scalp retains hardly any undersurface structures and (b) that there is an accompanying decimation of superficial capillaries. To a lesser, but still observable, degree, such alterations occur in old scalp still covered with good populations of terminal hairs. These changes, then, are attributable to age, and only the degree of alteration can be correlated with pilary protection. To avoid confusing this phenomenon with the effects of sun exposure, we have looked at the blood vessels of the nipples of women (which are rarely exposed) and the mucocutaneous areas of the labia, vulva, and vagina of women of different ages. Striking changes occur in these areas (Fig 14 and 15); there is collapse, disorganization, and even total disappearance of the

Fig 11. Histological section, showing the architecture of the fine elastic fibers, of a nipple from a 14-yr-old girl (× 400).

Fig 12. Terminal elastic fiber arcade in the papillary dermis of a nipple from a 46-yr-old woman. Compare with Fig 11 (× 400).

Fig 13. Elastotic changes in a nipple of a 72-yr-old woman. Compare with Figs 11 and 12 (× 400).
vessels of the microcirculation. Similar, if less conspicuous, changes occur in all other areas of the skin.

**Peripheral Nerves**

We have studied nerves nearly everywhere in the skin of aged people. Unlike superficial blood vessels, in which some destruction commonly occurs, cutaneous nerves are usually little affected by age. The number of Meissner corpuscles seems to remain unchanged, albeit enlarged and distorted [15]. All extant hair follicles are still equipped with apparently intact sensory end organs. In the bald scalp of very old people, where follicles have degenerated, the sensory mechanism is set free and resembles a mucocutaneous end organ, as was observed by Giacometti [16]. The nerves around eccrine sweat glands and axillary apocrine glands are similarly unaffected by age. All the nerves around the lactiferous glands remain seemingly intact even when the ducts have become atrophied [17]. In the eyelids of old people varying degrees of degeneration of accessory lacrimal glands and meibomian glands occur. In the latter, degeneration occurs at the proximal part of the glands, but the nerves remain apparently intact [17]. In the genital mucous membranes, the genital corpuscles become smaller and many disappear. Much of the superficial nerve net underneath the epithelium and the vagina disappears in old women.

**COMMENTS**

It is evident from these findings that tissue alterations occur with aging whether or not the skin is protected by clothing. Alterations are precocious and precipitous in sun-exposed areas, and slow to appear in protected skin; nonetheless, changes brought about by actinic damage and by aging do not differ in quality, only in quantity. Some changes similar to those caused by aging can be seen in nearly every area of the skin of a young adult body; similarly, even the skin of very aged people, which shows generalized alterations, may have here and there areas whose structural integrity has remained undamaged. These observations point again to the shortsightedness of observations made with techniques whose limitations are unknown. Even a well-prepared histological section stained with any of the routine dyes shows none of the profound changes described here.

**REFERENCES**


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