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Histologic Changes of Human Hair Follicles After Electrolysis: A Comparison of Two Methods

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The histologic changes induced by thermolysis of hairs of the scalp and legs were studied by light microscopy. Two techniques were compared on opposite sides: conventional thermolysis (erroneously termed electrolysis) using bare needles and a newly designed precision epilator using an insulated, bulbous-tipped probe.

Thermolysis generally did not immediately eliminate the papilla and hair matrix. Thermal injury provoked an inflammatory reaction which eventually destroyed the hair bulb. The insulated probe produced greater damage to the peribulbar tissue below and less necrosis of the perifollicular dermis above, enhancing the likelihood of permanent epilation and reducing the probability of scarring.

The infundibulum and associated sebaceous glands regenerated to near-normal architecture. The lower follicle was replaced by a fibrotic streamer—a scar.

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Electrolysis was introduced into therapeutics in 1875 when an ophthalmologist, C.E. Michel, of St. Louis, Missouri, achieved permanent epilation of "wild" ingrown eyelid hairs.[1] Three years later, a dermatologist of the same city, W. Hardaway, reported at a medical meeting that electrolysis could permanently remove unwanted facial hair.[2]

At that meeting,Carl Heitzman raised a criticism which applies to this day: he was discouraged by the large number of hairs that regrew. Dermatologists often see women with facial hirsutism who have undergone electrolysis for long periods, sometimes years, without great improvement in their appearance. A distinguished textbook of dermatology expresses general disenchantment with the method[3]: "It is not much employed by dermatologists in Great Britain, who remain somewhat skeptical of the high success rate claimed." Few American dermatologists are willing to rate electrologists highly; most have reservations regarding their general level of proficiency.

Most states, including Pennsylvania and New York, require no licensing or certification for electrologists. Hence, competence varies enormously among practitioners. Nonetheless, electrolysis remains the only way to secure permanent epilation.

The scientific literature does not contain a single paper describing the microscopic changes pro-

duced by electrolysis. Thus, the histopathologic effects of electrolysis are entirely conjectural.

Hinkel and Lind, in their textbook on electrolysis, note that electrologists "have relied on the theory that destruction of the papilla eliminates growth, but they have never been able to point to specific research on the subject."[4]

The recent publications of Inabe et al add new uncertainties. They suggest that hair may regrow even after the papilla is eliminated.[5] They observed regrowth of axillary hairs after removing the subcutaneous tissue, a procedure which they thought (incorrectly) removed all the hair bulbs and they concluded that regeneration occurred from the upper portion of the follicle. Subsequently, they electrocoagulated axillary hairs and claimed from microscopic evidence that new hairs originated from the isthmus, well above the germinative cells at the base of the follicle.[6,7]

This conclusion runs counter to all existing knowledge and the evidence presented in no way supports such a radical idea. These authors cite the work of Oliver who found that whisker hairs of the hooded rat could regenerate after surgical removal of the lower third of the follicle.[8] However, whisker hairs are complex neurovascular structures, not at all analogous to human hair follicles. Unlike in human tissue, surgical manipulations of hair do not result in scarring. The fallacy in Inabe et al's shaving experiments is that not all hair bulbs extend as far down as the subcutaneous fat. Some will have migrated to a higher position as a result of having entered the resting stage (telogen), hence some regrowth is inevitable.

All the evidence in humans is antithetic to regeneration of hairs from the upper follicle. Deep, split-thickness grafts of human scalps do not, when autotransplanted, grow hair, as every surgeon knows. When the bulbs of individual scalp hairs are cut off with scissors, the inevitable result is a scar and no regrowth (unpublished observations). Also, Van Scott and Reinertson demonstrated the impossibility of transplanting human hair bulbs.[9] These quickly degenerate with scarring. There is no evidence that the papilla and matrix can reform after being removed or destroyed. Together these structures control the growth of the hair. No one has demonstrated neogenesis of human terminal hair follicles.

Hinkel and Lind's explanation of hair regrowth after electrolysis is curiously similar to that of Inabe et al. They aver that "an entirely new follicle is regenerated after unsuccessful epilation and that its source is the outer root-sheath of the upper follicle."[4] No support is given for this notion.

These erroneous theories spurred us to carry out the present study, as did the development of a newly designed system, which promised greater efficacy.

The term "electrolysis" is inaccurate, although sanctioned by use. Modern devices do not use galvanic current which kills tissue by the electrolytic formation of sodium hydroxide. Instead, they employ high-frequency waves to generate heat which coagulates the tissue. The correct name for this modality is "thermolysis."

Materials and Method

Subjects—These were healthy, young adult, white men and women, volunteers, who gave their informed consent, and were paid for their participation.

Experimental Design—In three subjects, elliptical areas about 2 cm long were epilated on opposite parietooccipital areas of the scalp. In another four hairy individuals, the midlateral portions of the legs were epilated. The epilations were done by one electrologist (L. Peters). The sites epilated with the new system were shaved a week before so that current was applied only to growing (anagen) hairs. Following standard procedure, no preshaving was done when the conventional apparatus was used. Full-thickness excision biopsy specimens, one pair per subject, essentially removing the epilated areas, were taken at varying intervals: two, eight, and forty-nine days for the scalp, two, seven, fourteen, and thirty days for the legs.

The specimens were formalin-fixed, step-sectioned, and stained with hematoxylin and eosin.

Epilation Techniques—The first system utilized the Kree apparatus with a standard straight needle, which we called conventional electrolysis (CE). The second utilized the LPS 1118 epilator with an insulated bulbous tipped probe; we termed this the Integrated System™ (IS).

All commercially available conventional systems have various drawbacks in operation which cannot be detailed here. A noteworthy problem is that the current will bleed out along the uninsulated needle and produce the greatest tissue injury higher up in the follicle, which is the inverse of that theoretically required. There may be as much as a 90 percent loss by the time the current reaches the bulb. Additionally, timing and steadiness of output levels are not precisely controlled. The shortest time is relatively slow, about one-tenth of a second.

The standard needles have sharp cutting tips and can easily pierce the follicular wall. They are also inflexible and difficult to guide into follicles which are not straight. Extrafollicular insertion is futile and may result in visible scarring when repeated.

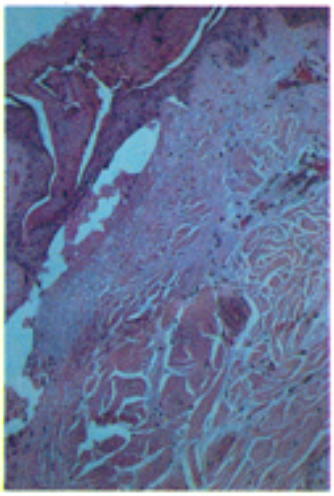

Figure 1. *Scalp, forty-eight hours after conventional electrolysis. There is a wide zone of perifollicular coagulation with considerable exudate in lumen. The infundibulum is necrotic.*

The circuitry of the IS system permits greater control of electrical properties, including fail-safe provisions. Effective timing of the high-output desiccating current is in milliseconds and highly repeatable, with feedback to the operator, through a single-impulse foot pedal.

Because of its greater flexibility the insulated, bulbous-tipped probe can be guided down with greater certainty, especially if the follicle is naturally curved as in spiraled kinky hairs or is distorted from previous injuries (inflammatory disease, repeated plucking, previous faulty electrolysis). Insulation concentrates current at the germinative hair bulb, with little bleeding into the perifollicular tissue above. The bulbous tip is less likely to penetrate the follicular wall and promotes accurate insertion; the probe will be deflected if it is not properly placed in the follicular ostium.

For CE, the machine was set at 85 to 100 percent of full power output with timing from one- to three-tenths of a second. Attempts to lower the current and shorten timing did not extract the hair. Multiple insertions were sometimes necessary.

The IS machine was set between 50 and 65 percent of available power, with timing from 45 to 50 milliseconds.

Results

Clinical Observations—Both methods were effective, although the sites were not rendered completely bald. Nongrowing telogen hairs were not treated with the IS system and would soon enter the growing phase. Experience indicates that to epilate resting follicles is generally futile. The subjects uniformly noted more pain and tenderness on the side treated with CE.

With IS the base of the extracted hairs was more desiccated and shriveled. With CE the external root sheath of extracted hairs was often intact, which never occurred with IS. With both systems, tiny wheals generally develop at the follicular openings. After CE, these sometimes become confluent and associated with increased pruritus. Follicular crusting was greater with CE at twenty-four hours. Vellus hairs were not epilated and so were unchanged.

Histologic Observations—The changes were the same for the legs and scalp and will be described together. The extent and configuration of the destructive changes wrought by the two techniques were distinctly different.

Two days after CE the follicular infundibulum was completely necrotic, surrounded by a wide zone of collagen degeneration (Figure 1). The lumen was filled with an exudate of serum and neutrophils. The sebaceous glands were variably necrotic, though some lobules seemed viable. The hair erector muscles were largely unaffected. The hair papillae were only moderately damaged and remained as a nest of pyknotic mesenchymal cells. The papilla was edematous and contained hemorrhages (Figure 2). The matrix cells of the bulb were variably altered but not completely necrotic and showed intra- and intercellular edema, dark shrunken nuclei, and variable staining. Free melanin granules were scattered over the papilla. The

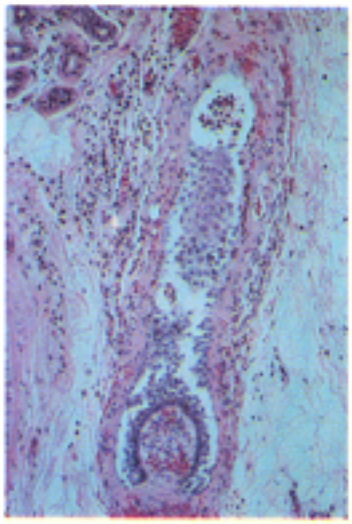

Figure 2. *Scalp, forty-eight hours after conventional electrolysis. Papilla is swollen and hemorrhagic. Matrix cells are necrobiotic and separating from each other. The peribulbar tissue damage is slight.*

periinfundibular tissue showed a mild infiltration by inflammatory cells, a mixture of neutrophils and lymphocytes. The relative sparing of the lower portion of the follicle was especially noticeable in the leg (Figure 3).

With IS, the injury to the infundibulum was considerably less, with a narrow zone of perifollicular degeneration of collagen as a consequence of coagulation and a slight serous exudate with few neutrophils in the lumen (Figure 4). A larger portion of the sebaceous glands seemed unaffected, although not consistently.

With IS, the papilla showed greater damage although it was still not completely necrotic. It was variably edematous, hemorrhagic, with weakly stained fibroblasts. Also, there was far greater in-

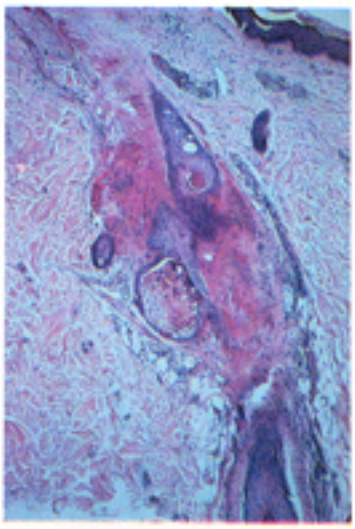

Figure 3. *Leg, forty-eight hours after conventional electrolysis. There is massive destruction of the upper follicle with broad dermal coagulation. By contrast, the lowermost bulbar region is only slightly damaged.*

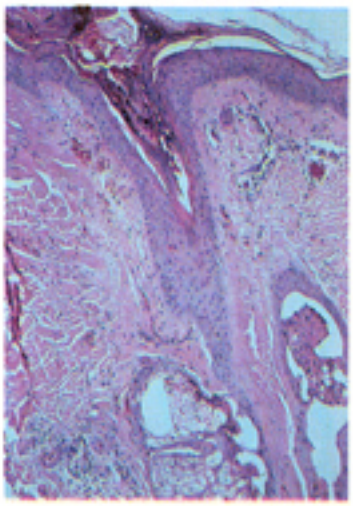

Figure 4. *Scalp, forty-eight hours after epilation with the Integrated System. There is limited damage to the follicular epithelium above and a modest exudate within the canal. Perifollicular dermal destruction is slight. Below, the sebaceous glands are mostly necrotic; a few lobules have survived.*

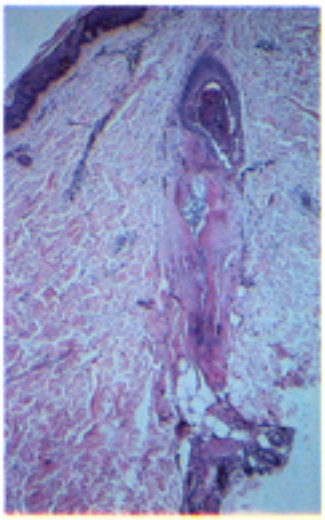

Figure 5. *Leg, forty-eight hours after Integrated System. The lower follicle is destroyed down to the subcutis, including papilla. Above, dermal necrosis is confined to a narrow zone. The upper follicular wall persists with an exudate within the lumen.*

jury to the cells of the matrix; many were dead,, swollen, and separated with loss of nuclei cellular detail. Nonetheless, seemingly viable clusters of matrix cells survived. Occasionally, the whole lower end of the follicle was coagulated; this was never observed with CE. The limited damage to the periinfundibular zone above and the greater destruction of the base of the follicle extending down to the subcutaneous fat was especially evident in the leg (Figure 5).

One week after CE there was a marked inflammatory cell infiltrate around the infundibulum,

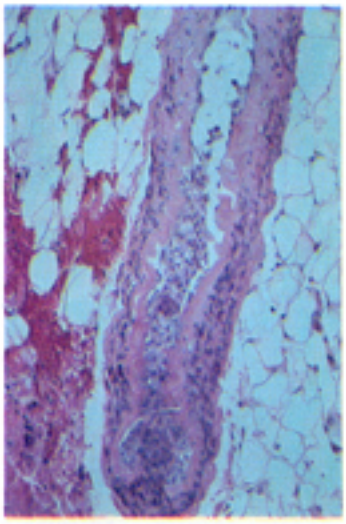

Figure 6. *Scalp, seven days after conventional electrolysis. This is a caricature of catagen showing a cord of partially separated undifferentiated epithelial cells terminating just above a readily identifiable, though abnormal, papilla. The cord is surrounded by a thickened glassy membrane external to which is a thin band of inflammatory cells.*

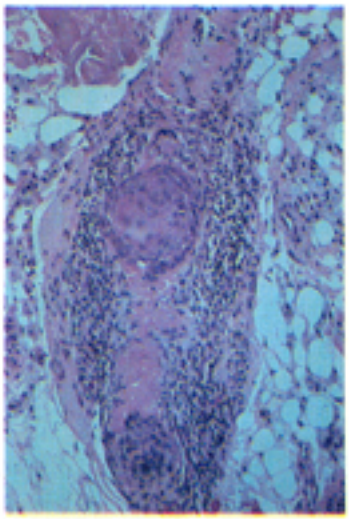

Figure 7. *Scalp, two weeks after Integrated System. This is pseudocatagen as in Figure 6 with an extensive inflammatory reaction at the base of follicle, mainly composed of lymphocytes with moderate numbers of macrophages. Papilla is still present. Above is a cluster of undifferentiated epithelial cells which is really a portion of the epithelial cord.*

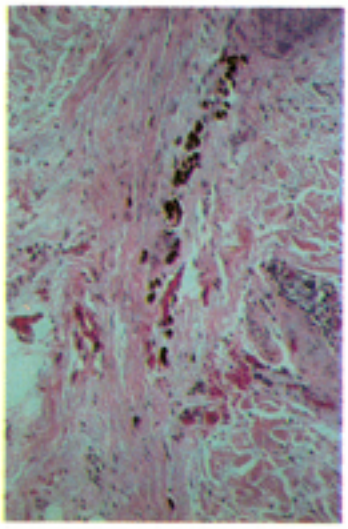

Figure 8. *Scalp, seven weeks after Integrated System. A long fibrous streamer extends downwards from the follicular remnant; it consists of parallel, vertical bundles of collagen through which are strewn macrophages containing greater clumps of melanin. This is a histologic scar.*

mainly consisting of lymphocytes with scattered macrophages. The papillae were swollen and paler but still easily recognizable. Below, cords of undifferentiated epithelial cells were forming, evidently from surviving matrix cells. These were rather irregular in outline and surrounded by a thickened glassy membrane which was moderately infiltrated by mononuclear cells (Figure 6). The appearance was unmistakably of abnormal catagen, the involutional phase of the hair cycle that precedes telogen.

With IS the upper periinfundibular inflammatory cell infiltrate was smaller. Below, fewer follicles showed the catagenlike cord of undifferentiated epithelial cells, evidently reflecting more complete obliteration. Many dead cells were clustered over

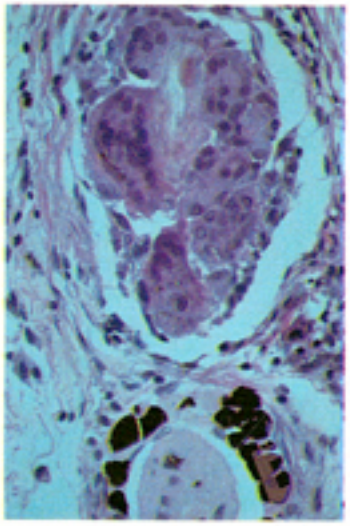

Figure 9. *Scalp, seven weeks after Integrated System. Ghost of papilla is still evident, capped by melanin-engorged macrophages. Immediately above is a nest of foreign body giant cells, lying at the base of a fibrotic streamer.*

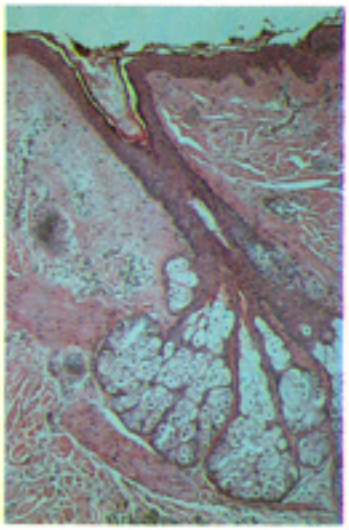

Figure 10. *Scalp, seven weeks after Integrated System. The infundibulum has been completely restored with minimal perifollicular scarring. The sebaceous glands are large and well-formed, in normal relationship to unaffected arrector pili muscle.*

the edematous but well-defined papilla, interspersed with macrophages containing large amounts of melanin. A dense substantial mononuclear infiltrate enveloped the bulb. Foreign body giant cells began to appear among the necrotic matrix cells.

A dense lymphocytic infiltrate with spotty hemorrhages occupied the upper subcutis and lower dermis, and was far more prominent with IS than with CE.

Two weeks after CE, the infiltrate had largely disappeared, small lobules of sebaceous glands were reforming and were connected to a mostly reformed infundibulum.

Below, the epithelial cords were disorganizing, admixed with lymphocytes, histiocytes, and foreign body giant cells but still with a prominent, folded glassy membrane. Melanophages among the infiltrate were distended with masses of melanin.

With IS, the infundibulum, except for being thicker and hyperkeratotic, had a near-normal outline with a slight surrounding lymphocytic infiltrate. The sebaceous glands had largely regenerated and exhibited normal architecture.

Below, the papillae could often be made out clearly though their constituent fibroblasts were shrunken and had pyknotic nuclei. The peribulbar inflammatory cell infiltrate of mononuclear cells was a prominent feature, and was far more conspicuous than with CE (Figure 7). Streamers of thin, hyalinized collagen bundles aligned in parallel replaced the lower portions of the follicles, commingled with fibroblasts and mononuclears.

Four to seven weeks after CE, there was a moderate-sized zone of hyalinized collagen around the upper follicles made up of thin parallel collagen bundles, which is typical of a scar.

Below, fibrotic streamers in various stages of formation replaced the entire lower follicle. The outlines of shrunken degenerating papillae were easily discerned.

With IS, the perifollicular zones of hyalinized collagen were much narrower and larger sebaceous lobules had regenerated, attached to a well-formed infundibulum.

Below papillae were discernible with difficulty. Well-defined fibrous streamers replaced the lower two-thirds of the follicles, containing numerous melanophages (Figure 8). The lymphocytic infiltrate of the subcutis had disappeared. Occasionally, "ghosts" of papillae could be made out, along with foreign body giant cells (Figure 9). The infundibulum had reformed along with variably sized lobules of differentiated sebaceous glands, situated eccentrically below the atretic follicles (Figure 10).

In every specimen at every sampling time, a small proportion of follicles were not altered in any way and were presumed to have been in telogen at the time of epilation. Vellus hair follicles were intact.

Comments

With CE, early damage to the infundibular portion of the follicle was far greater, with marked necrosis of the infundibular epithelium, surrounded by a fairly wide area of coagulated dermis. More of the sebaceous glands were destroyed, leaving lobulated ghosts. On the scalp, with its more closely spaced follicles, the coagulated zones between adjacent follicles sometimes almost fused, resulting in a wider zone of degeneration.

With IS, injury to the infundibulum was on a smaller scale, with less destruction of the epithelium, decreased exudation within the follicular canal, and a narrower zone of dermal perifollicular coagulation. The converse occurred in the peribulbar region where destruction of the papilla and the zone in the dermis around the hair papilla was greater with IS. The destruction was accompanied by hemorrhages and a greater inflammatory cell infiltrate extending into the subcutis. More follicles were completely obliterated and never went through a phase of catagen.

The end stage of a successfully epilated follicle with either method was a fairly normal infundibulum with well-developed sebaceous glands, subtended by a streamer of fibrotic tissue with total loss of matrix cells and "ghosts" of acellular papillae.

This study showed appreciable differences between the two systems which, on balance, would strongly favor IS. We construe its advantages to be: 1. greater destructive effect on the germinative portion of the lower portion of the follicle, hence less likelihood of regrowth of follicular epithelium and hair shafts; 2. less degeneration of collagen of dermis around the upper part of the follicle, which reduces the probability of clinical scarring; and 3. greater certainty of extraction, reducing the need for retreatment thus minimizing tissue damage.

CE usually requires multiple retreatments of the

same follicle to extract the hair. This can result in depressed, angulated, follicular and perifollicular scars. When electrolysis is inexpertly performed, requiring multiple treatments at different times, scarring is inevitable. Scars become even more noticeable with the laxity accompanying aging. On the upper lip, follicular scarring is distressingly frequent and often accompanied by unsightly hyperpigmentation.

Also, the flexibility of the bulbous-tipped probe facilitates its being guided down curved or distorted follicles without perforating the epithelial wall and missing the germinative bulb. This is a considerable advantage in treating pseudofolliculitis barbae in blacks.

We were surprised that there was relative sparing of the papilla immediately after electrolysis. Even with IS the papilla was not eliminated completely, though it was clearly injured as evidenced by hemorrhage, edema, and decreased staining. Naturally the papillae subsequently disappeared, which is an absolute prerequisite for permanent epilation.

The epithelial cells of the matrix were not always killed outright. At forty-eight hours, many were in various stages of necrotic degeneration: swollen, pale, and detached. Often clusters of matrix cells survived and then differentiated to form irregular epithelial cords, mimicking the catagen stage of the hair cycle. Faulty catagen is a stereotyped response to a variety of injuries, such as x-rays and inflammatory disorders; these put the follicle into a resting phase. By one to two weeks, there was a marked inflammatory reaction consisting of lymphocytes, macrophages, and foreign body giant cells. This reaction evidently destroys the matrix and papillae. The epithelial cords were engulfed by these inflammatory cells and underwent necrosis, leaving a streamer of fibrotic tissue, admixed with macrophages, fibroblasts, giant cells, and melanin-engorged macrophages. With IS, peribulbar destruction was sometimes so great that scarring took place directly without the intervening catagenlike stage. With IS the inflammatory reaction in the subcutis was appreciably greater, indicating deeper action.

The final change was replacement of the lower follicle by densely packed, parallel, thin bundles of eosinophilic collagen, having all the hallmarks of a scar.

The epithelial lining of the upper follicle generally reformed by two weeks. It was thickened and the lumen was filled with loose horny cells. Later, the infundibulum resumed a fairly normal architecture.

The sebaceous glands also reformed, although they tended to be irregular in size and shape, emptying into the base of the infundibulum. We have observed sebum issuing from the mouths of such follicles. The hair erector muscles were not destroyed and sometimes even looked hyperplastic. Unlike the hair, which cannot form in the absence of a viable papilla and matrix, sebaceous glands can regenerate from the pluripotential external root sheath. Reformation of sebaceous glands from newly formed epidermis has been observed following dermabrasion.[10] Neogenesis of sebaceous glands can, therefore, occur.

Editor's Note: The Integrated System™ will soon be available in many dermatologists' offices.

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