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Research paper

Irritability of the skin barrier: A comparison of chronologically aged and photo-aged skin in elderly and young adults

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ABSTRACT

Purpose: The epidermal barrier resides in the stratum corneum (SC). Compared to young adults baseline barrier function of aged skin is comparable. Stress to the aged barrier results in decreased rates of repair. Barrier irritability of young vs. old, chronologically aged vs. photo-aged skin has not been examined in direct comparison.

Patients and methods: Geriatric patients (mean age 81 ± 7 SD; $n = 104$) underwent a dermatological examination. The irritability of young (24 ± 3; $n = 21$) vs. old (82 ± 5; $n = 21$), chronologically aged (ventral side of the upper arm) vs. photo-aged (dorsal aspect of the lower arm) skin was assessed, including transepidermal water loss (TEWL), SC hydration before and after 10 minutes irritation with 0.5 N NaOH under occlusion.

Results: Clinical examination of aged subjects revealed a correlation between excessive dry skin and photo-aged, but not chronologically aged skin ($P < 0.05$). Compared to young adults' SC hydration was lower in photo-aged skin sites of the elderly ($P < 0.001$). Basal TEWL was comparable in young, chronologic and photo-aged skin. Only photo-aged skin of old subjects revealed increased irritability to the alkaline irritant compared to chronologic aged and young skin ($P < 0.001$).

Conclusion: Skin dryness and irritability in the elderly is enhanced only in photo-aged skin.

1. Introduction

Chronologic aging (genetic, intrinsic aging) is an inevitable process occurring in every organ system at a genetically determined, species- and organ-specific rate [1]. To aged skin, including: dermis, epidermis and its outermost layer the stratum corneum (SC), various structural and functional changes have been attributed. Within the dermis a decline of thickness [2], flattening of the dermal/epidermal junction [3] as well as a reduction in blood flow [4] has been studied extensively. Moreover, sebum and sweat production are decreased in aged skin [5]. The thickness of epidermis also decreases with age, which is mainly observed in sun-exposed skin [6], though SC thickness remains unchanged [7]. An increased pH [8], reduced intercellular lipid content [9] and reduced hydration [10] were observed in aged SC. Furthermore, the reduction in epidermal turnover reflects an age-dependent decrease in epidermal repair rate after minor damage, i.e. age-dependent increase in skin irritability [11].

The barrier to transepidermal water loss (TEWL), which resides within the SC, is not impaired in aged compared to young adults [12]. This finding is still discussed [6]. Moreover, the aged barrier in murine and human skin is more easily perturbed by tape stripping and reveals a delayed recovery compared to young [13].

Dry, rough and scaly skin, a skin disorder called xerosis, has been attributed to decreased:

- sebaceous gland activity [14];
- SC hydration [15];
- and epidermal lipid synthesis and/or content [9,16].

Therefore, high incidence of xerosis in the elderly may not be attributed solely to sebaceous gland activity. Aged SC indeed shows a reduced water-binding capacity, which seems to be linked to a decrease in cutaneous natural moisturizing factors (NMF) [17,18]. In healthy young skin epidermal lipids, i.e. ceramides, free fatty acids and sterols are required for normal barrier function. The composition of these epidermal lipids is unchanged in aged skin, but the global lipid content decreases with age [19]. Stress to the barrier leads to increased synthesis of these lipids, which is significantly slower in aged compared to young mice [16]. Therefore, the high prevalence of dryness and itching in the elderly can be linked to decreased barrier lipid synthesis in the aged, along with reduced barrier integrity and an imbalance of barrier homeostasis [20].

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Extrinsic aging results from the superposition of environmental effects on intrinsic (chronologic) aging. UV radiation is the best-studied environmental effect [21], therefore the term "photo-aging" is well established. Over lifetime the skin of the face, neck, hands and dorsal aspect of the lower arms are primarily exposed to UV-light, whereas the inner aspect of the upper arm and thigh as well as the buttock reflects chronologic epidermal aging. Differences in barrier function of photo-aged and chronological aged skin have been described. Reed et al. [22] revealed a delayed barrier recovery after tape stripping in photo-aged compared to chronological aged skin. However, in barrier integrity (number of tape stripping required to increase TEWL to $\geq 20\,g/h/m^2$) no differences were observed between photo-aged and chronological aged skin. The present study was designed to evaluate barrier function, i.e. barrier irritability of chronologic versus photo-aged skin in 21 elderly compared to 21 young adults, employing a standardized irritability test, applied in occupational dermatology [23].

2. Methods

2.1. Volunteers

One hundred and four volunteers, mean age 81 ± 7 years (25 male, 79 female) were subjected to a full body examination by a dermatologist, with focus on xerosis. None had a positive history of skin diseases. All volunteers were pigment type according to Fitzpatrick I-II to avoid pigment type dependent influences. Skin irritability was examined in 21 elderly, mean age 82 ± 5 years (inclusion criteria: age > 70 years; 7 m, 14 f) and compared to a group of 21 young volunteers, mean age 24 ± 3 years (inclusion criteria: age < 30 years; 10 m, 11 f). The study was approved by the University ethical committee, which gave its unanimous approval. Informed consent was obtained from all participants prior to their inclusion in the study.

2.2. Bioengineering methods

TEWL refers to the loss of water vapor through the SC in absence of sweat gland activity. TEWL values are regarded as an indication of the skin's barrier function [24]. Barrier perturbation by chemical and/or physical insults is accompanied by an initial increase in TEWL and is followed by a decrease in TEWL in healthy skin.

TEWL was measured on the dorsal aspect of the lower arm (pa = photo-aging) and on the inner aspect of the upper arm (ca = chronologic aging), at random right or left side, using the DermaLab TEWL Module® (Cortex Technology ApS, Halsund, Denmark). Measurements were taken after the participants had rested for 30 minutes in an environment with a temperature of 20–22 °C and relative humidity of 48–50%, according to the guidelines given by the European Society of Contact Dermatitis [25]. Measurements were taken from clinically unchanged skin before and after application of 0.5 N NaOH 10 minutes under occlusion. Prior to the second measurement, a further drying period of 20 minutes was allowed. The difference between the two measurements was recorded as delta-TEWL (Δ-TEWL). Δ-TEWL reflects the skin's – in particular the epidermal barrier's – irritability through exposure to a given irritating chemical (0.5 N NaOH) over 10 minutes duration.

The "electrical conductance", indicating SC hydration, was measured on pa and ca prior to TEWL measurements, using the DermaLab Moisture Module® with a flat faced probe (Cortex Technology ApS, Hadsund, Denmark) according to Berardesca [26].

2.3. Statistical analysis

Data were calculated with SPSS for Windows (Version 18.0, SPSS Inc., Chicago Ill., USA). The median and 25/75 percentiles were chosen as the standard for the descriptive statistics. Differences between groups were tested for their statistical significance employing the Mann-Whitney-U test for not normally distributed non-paired data. Wilcoxon signed-rank test was used comparing results in the course of each group. The Spearman-Rang-Correlation test was used to identify associations between parameters. The significance level was set at $P < 0.05$.

3. Results

3.1. Clinical findings

Out of 104 elderly, 67 revealed xerosis; in 37 elderly xerosis was not diagnosed anywhere on the body. Only 15 subjects suffered of total body xerosis, in 52 cases xerosis was restricted to the face, necks, arms and legs (Fig. 1). Correlation between xerosis and photo-aging was significant ($P < 0.05$).

3.2. Bioengineering methods

SC hydration on pa and ca was measured in 21 old subjects and compared to 21 young subjects prior to irritation with 0.5 N NaOH. SC hydration was significant lower on pa of old subjects (median: 40) than young subjects (median: 55), ($P < 0.001$). No significant difference in SC hydration was found on ca of old patients compared to young patients ($P = 0.86$) (Fig. 2).

Basal TEWL in young and old, ca and pa were comparable (Fig. 3). Δ-TEWL measurements revealed comparable results in ca and pa skin of young adults ($P = 0.763$), i.e. on the dorsal aspect of the lower arm and the inner aspect of the upper arm. However, Δ-TEWL was significantly higher on pa compared to ca skin sites of old subjects ($P < 0.001$) as well as compared to pa skin sites of young subjects ($P < 0.001$) (Fig. 4).

4. Discussion

Xerosis is associated with sensitive skin, reported to occur in 50% of women and nearly 40% of men [27]. Xerosis, known to affect the elderly [28], is linked to changes in epidermal lipid content and composition, i.e. abnormal SC [11], reduced water binding capacity [19], seasonal influences [29] and/or pigment-type [30]. A diminution of water binding proteins has been described in chronologically aged skin (buttock) and photo-aged skin (forearm) compared to young adults: Only in photo-aged skin, an increase in free, i.e. non-protein bound water was detected [10]. Unchanged

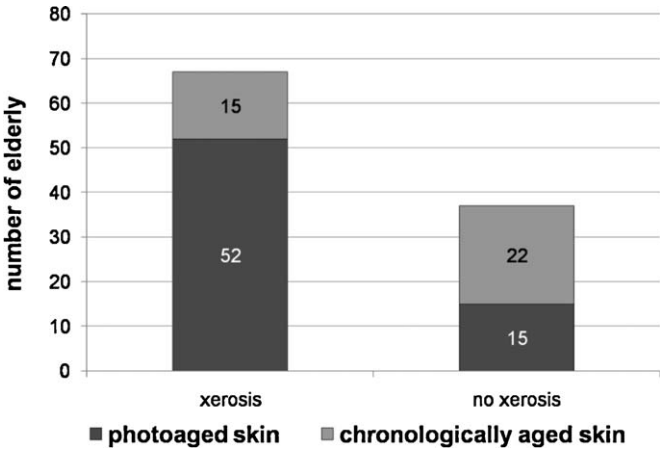

Fig. 1. Of 104 elderly $n = 67$ had xerosis, thereof $n = 52$ xerosis was found in photo-aged skin (face, neck, arms, legs). Correlation between xerosis and photo-aging was significant ($P < 0.05$). In 37 patients xerosis was not detected, of those only $n = 15$ showed signs of photo-aging.