Twelve years evolution of skin as seen by electrical impedance

Ingrid Nicander\textsuperscript{1,2}, Lennart Emtestam\textsuperscript{1}, Peter Åberg\textsuperscript{2} and Stig Ollmar\textsuperscript{2}

\textsuperscript{1}Dermatology, Huddinge University Hospital, SE-14186 Huddinge, Sweden
\textsuperscript{2}Medical Engineering, Karolinska institutet, SE-14186 Huddinge, Sweden

E-mail: lennart.emtestam@ki.se

Abstract. Twelve years ago we reported an electrical impedance baseline study related to age, sex and body locations. The results showed significant differences between different anatomical locations and ages. In this study, the same participants were recalled to explore how the skin had evolved at the individual level over time. A total of 50 subjects, divided into an older and a younger group, were recalled for measurements of electrical impedance at eight anatomical locations. Readings were taken with an electrical impedance spectrometer. Information was extracted from the impedance spectra using indices based on magnitude and phase at two frequencies as in the earlier study. All included body sites had undergone alterations over time, and the size of the changes varied at different locations. The results also showed that changes in the younger group were different over time compared with the older group. In conclusion: Electrical impedance can be used to monitor skin evolution over time and baseline characteristics differ between various locations.

1. Introduction

There are quite large variations in the skin structure and function depending on anatomical location. The skin on the palmo-plantar surfaces has a rather simple function to protect the underlying living tissue with its very thick stratum corneum (SC) from strong external force and friction. Its barrier function is poor. The SC of the facial skin is thinner, consisting of fewer layers of corneocytes than that of the trunk and limbs. There are regional differences not only in the living skin tissue but also in the thin SC reflecting the function of each anatomical location [1]. These differences in the SC have been mostly disclosed by the use of non-invasive biophysical instruments. The in vivo instrumental measurements have disclosed the presence of remarkable differences in the functional properties of the SC particularly between the face and other portions of the body. They will offer clinical parameters to evaluate skin functions and, more importantly, dysfunctions (e.g. psoriasis, atopic dermatitis, epidermolysis bullosa, burns) that result in excessive water loss and are characterized by defective SC lipid organization. The differences of normal, healthy skin at different anatomical locations indicate that there is no single measurement values, or “normal” values, for the entire skin. As for the important issue “sensitive skin” there is no international consensus on the definition and classification of “sensitive skin,” making rational discourse among investigators almost impossible [2].

As an example, a recent study has been published on diaper dermatitis, which affects nearly 50\% of infants as well as many bed-ridden adults, particularly elderly (Xhaflaire-Uhoda et al 2009). It was demonstrated that the application of the anhydrous paste resulted in a shielding effect and a trend to normalize electrometric properties of skin, probably reflecting the combination of transepidermal water loss and the water-holding capacity of the stratum corneum [3]. Several methods and
instruments are now available for the rapid reliable determination of electrical impedance or related parameters reflecting skin condition, which may become a standard research and clinical tool in dermatology [4-6].

Twelve years ago we reported an electrical impedance baseline study related to age, sex and body locations [7]. The results showed significant differences between different anatomical locations and ages. In this study, the same participants were recalled to explore how the skin had evolved at the individual level over time.

2. Materials and Methods
A total of 50 subjects, divided into an older and a younger group, were recalled for measurements of electrical impedance at various anatomical locations. The test persons were interviewed regarding their tanning habits, indoor or outdoor work, etc. Readings were taken with an electrical impedance spectrometer with the original non-invasive electrode system. (SciBase II, SciBase AB, Stockholm, Sweden). The technology has been described in [8]. Measurements were made in April and May, which corresponds well to original data collected in May and September due to seasonal variations [9]. Information was extracted from the impedance spectra using indices based on magnitude and phase at two frequencies as in the earlier study. Data were analysed both on the whole cohort, in various subgroups, and on the individual level. In this paper, only a simple magnitude index is used, and p-values calculated. The p-values in the graphs are estimates of the probability that the median MIX in 1995 and 2008 are the same according to paired-sample Wilcoxon signed rank test. The indices are described in e.g. [7] and can also be found in several of our early publications. Here only the so called MIX-index is used, defined as

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\text{Magnitude index } \text{MIX} = \frac{\text{abs}(Z_{20kHz})}{\text{abs}(Z_{500kHz})}
\]

Before impedance measurements the skin was soaked with saline solution of physiological concentration for one minute.

3. Results
All included body sites had undergone alterations over time, and the size of the changes varied at different locations. The results also showed that changes in the younger group were different over time compared with the older group, an observation made possible by using paired comparison for the same individual test persons now and 12 years ago. In Figure 1, the evolution of the impedance index MIX is presented from two body locations, i.e. the volar forearm and the cheek, for individuals belonging to older female, older male, younger female and younger male subgroups respectively. The changes of the MIX index over 12 years are significant or highly significant in all cases except for the cheek of older females.

4. Discussion and Conclusion
It is known that the properties of skin changes with age and other factors, such as diseases, toxic reactions, allergic reactions, sun exposure, seasonal variations, mechanical stress, etc. In our early studies we investigated the possibility to quantify and classify artificially induced skin reactions using electrical impedance [10-15]. In particular [12] sparked us to look for clinical, even diagnostic, applications of the technology, and it was found that, with more sophisticated data analysis and enhanced electrode systems, it is possible to discriminate between skin cancer and harmless lesions with clinically useful accuracy [16-19].

Future studies aiming at the establishment of the functional mapping in different skin regions will further shed light on more delicate site-dependent differences, as well as explaining the physical causes for the observed phenomena, thereby providing more information to facilitate tailor-made skin care for each location and condition of the body, whether caused by aging, reactions or disease.
Figure 1. Scatter plots of volunteer age vs. measured MIX on volar forearm and cheek for the younger and older men and women. Each subject is represented with an arrow, where the start and endpoints indicate the volunteer age and MIX values in 1995 and 2008.
5. References

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**Acknowledgement:** This study was sponsored by SciBase AB, Stockholm, Sweden.