

## **Skin capacitance imaging for the dermatologists**

**Gérald E Piérard**

**Department of Dermatopathology, University Hospital of Liège, Belgium**

Dermatologists perceive the skin aspect through its optical properties. The use of a magnifying lens or dermoscopy increases the sensitivity of the observations (1, 2). However, some characteristics remain invisible to the human eye. Bioengineering is working in this field to help visualizing and quantifying some of these aspects in a non-invasive way. For instance, our laboratory worked on the ultraviolet light-enhanced visualization (ULEV) method showing the skin with otherwise imperceptible details of its melanization patchwork (2, 3).

In very recent years a considerable progress has been made by the access of nonoptical images of the skin surface capacitance showing a high resolution map of the stratum corneum hydration. A series of dermatological disorders exhibit some surprising aspects that can be interpreted in terms of disease evolution and improvement of treatments. This new era in skin bioengineering is named skin capacitance imaging (SCI) based on silicon image sensor (SIS) technique. The dedicated device is called SkinChip® (4).

SCI has a nonmedical origin. This technique was primarily used for security purposes for the biometric recognition of fingerprints. For instance, restricted access to some protected rooms, buildings, cars and microcomputers can be guaranteed by this system which works by close contact between finger skin and the sensor.

The SkinChip® sensor is a plate 2.3 cm<sup>2</sup> in size which contains 92160 microcapacitors measuring skin capacitance every 50 µm. These microcapacitors

are protected by a very thin silicon oxide layer. When the measuring plate is closely applied to the skin surface, nonoptical images are produced corresponding to the hydration map of the stratum corneum. Such images come from the assembly of 256 grey-level pixels with the darker ones representing high capacitance and the clear ones the lower capacitance values (4-6). In addition to the computer software providing images, the mean grey level of the image histograms allows measuring the mean skin surface capacitance. As such, SkinChip® can be used in research laboratories dealing with skin physiology, as well as for diagnostic purposes and for assessing the efficacy of cosmetic and dermatological treatments.

The SkinChip® information is the paradigm combining skin surface imaging including its microrelief and detailed analytical quantification of corneocyte hydration (4-6). Any other factor modifying the electrical properties of skin alter the SkinChip® grey-scale image. For instance, sweat microdroplets, fuzzy hair and adsorbed ions onto the stratum corneum are conveniently revealed.

Beyond physiology and cosmetology (6-11), dermatology takes also benefit from the fascinating SCI method by revealing aspects of skin disorders that had never been seen before by the human eye.

### **Sweat gland disturbances**

SCI sharply reveals the site of active sweat glands by the presence of black spots at the orifices of the corresponding acrosyringium openings at the skin surface (6, 10, 11). Any pathological condition associated with hypohidrosis or hyperhidrosis can be studied by this method which is by far the most sensitive and specific procedure currently available for this purpose. SCI demonstrated for the

first time the anhidrotic character of lesions of pityriasis (tinea) versicolor (12) and psoriasis (13).

SCI is also useful in exploring neural dysfunctions altering the sweat gland function. For instance, spinal cord injury and neurovegetative alterations associated with diabetes are responsible for changes in the imperceptible perspiration as seen by the SCI presentation.

### **Subclinical irritation by surfactants**

The dynamics of stratum corneum reactivity to surfactants is complex. Surfactants present in hygiene and skin care products are in part adsorbed at the skin surface and they also permeate the stratum corneum. These products interact with proteins and lipids. Indeed, a number of physicochemical interactions exist between corneocytes and surfactants. One of the earliest events following surfactant-induced protein denaturation is perceived as corneocyte swelling. This condition leads to a paradoxical and transient corneocyte hydration following surfactant challenge. In a second step, there is reversal of the phenomenon. The water holding capacity of corneocytes collapses and a drying effect takes place. SCI has an added value to the conventional methods of assessment of these changes (14, 15). Indeed, the sensitivity of SCI allows to disclose focal and minute changes in the corneocyte swelling or drying that are blurred by the conventional methods averaging data on a relatively large area corresponding to the size of the measuring probe.

### **Acne**

Acne is a typical skin condition where SCI can highlight the heterogeneous patchwork of electrical properties of the skin. SCI conveniently reveals the open and the keratin-filled funnel-like acroinfundibular structure in acne (2, 10, 16).

These structures are revealed as whitish low capacitance pin-point spots due to the absence of contact between the probe and the epithelial lining of each empty infundibulum, or to the dry nature of a microcomedo. When inflammation is present, the papules appear as targetoid structures centered by a whitish comedo surrounded by a darker rim revealing a weakened skin barrier function and the presence of a discrete serosity exsudate (16).

### **Xerosis and related diseases**

Epidermal hyperkeratosis is a typical feature of pityriasis (tinea) versicolor. The condition is easily highlighted by SCI because the skin surface is dryer than the surrounding skin. The method allows to detect small lesions of pityriasis versicolor almost invisible at the naked eye (12).

Psoriasis is the paradigm of inflammatory hyperkeratotic dermatoses. SCI reveals a map of heterogeneous electrical properties on lesional skin (13). Whitish low capacitance appears characteristic for stable hyperkeratotic plaques. More inflammatory and evolving plaques show darker areas of higher capacitance. SCI can thus provide clues of disease activity in the plaque stage of psoriasis. This may help in monitoring the treatment.

### **Hyperkeratotic tumors**

Viral warts are typically hyperkeratotic. They are easily identified using SCI (12). No difference in capacitance reduction was found between different types of warts. Thin lesions of melanocytic nevi and pigmented seborrheic keratoses are sometimes difficult to distinguish on clinical ground. SCI shows variable aspects irrespective of the nature of these lesions (17). Low capacitance is commonly yielded, but increased capacitance is also possible, particularly on minimally inflamed lesions (17).

## **Conclusion**

SCI is a novel and astonishing technique representing a breakthrough in skin bioengineering. Some applications are emerging in clinical dermatology.

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