Quantification of randomness (Entropy) as a clinical tool to assess the severity of skin disease

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ABSTRACT

In today's medical practice, the approach towards quantitative analysis of the skin is considered to be challenging and subjective. The current accepted measures and indexes do not exhibit a universal measurement, carry subjective opinions, and vary from one assessor to another. We propose a novel promising technique that provides a universal measure of various skin conditions which accesses the severity of skin disease in a quantitative manner. In this paper, we describe a clinical tool which provides a quantitative analysis of the skin using a mathematical algorithm of calculating Maximum entropy. The current work had been based on assessing skin lesions of psoriasis as a prototypic disease and adjacent healthy skin of patients in order to prove the concept of using computing entropy results to assess the skin condition. From the collected data of 11 pairs of the diseased and clinically healthy skin, the healthy skin displayed lower Entropy values with mean $\mu = 2.56 \pm 0.10$ while skin affected by psoriasis displayed higher Entropy values with mean $\mu = 3.30 \pm 0.19$.

Introduction

The traditional approach to skin assessment can be characterized as very general in clinical practice. It is usually composed of subjective and objective assessment. The usual approach comprises the physician initiated patient's self-reporting that helps a patient to provide self-assessment of the severity of the condition. Then the physician performs own global assessment. Consequently, the diagnosis is determined by the following criteria: a combination of the subjective report, physician's assessment of how severe skin changes are as well as an assessment on how the patient responds to the given treatment [1].

Most of the skin lesions are quite visible and have certain physical variables that can be quantified relying on various universal indexes and indications. As can be noted, the current objective approach of skin analysis is dependent on morphological factors, such as size, colour, texture, and shape of the skin lesions. However, this method holds a very strong limitation which is the absence of a universal numerical tool that can provide a more accurate and detailed scale for further treatment.

Human skin is quite a unique organ that forms a protective boundary between the body and the external environment. The overall appearance of the skin is an indicator of individuals' well-being [2]. It can be affected by various factors, such as age, gender, ethnic background, and general health. From the first impression, skin can be considered as diverse and just differing based on texture, colour, and morphology of skin condition if it is present. However, observations made with the human eye create more chances of making diagnostic errors [3].

Challenges with traditional methods

In a current report, the skin affected by psoriasis has been used as reference disease to analyse and discuss current measuring tools as well as propose a new approach for skin measurement.

As a prototypic disease, the Psoriasis was chosen as a condition with very defined differences between the healthy and affected skin.

The assessment of the severity of skin involvement in Psoriasis is done through a few well established and acceptable methods.

One of the traditional methods for measuring psoriasis is the Psoriasis Area and Severity Index (PASI). It measures the average value based on redness, thickness, and scaliness of presented lesion on a scale 0–4 taking into account the involvement of body surface area (BSA) [6]. Values of PASI range from 0 to 72 units and each value has been given a word-based terminology and description. Despite its wide usage and ability to define all key elements, PASI does exhibit certain limitations, and is often criticized for being time-consuming, complicated, lacking sensitivity, inability of reaching consensus on each value, and level of difficulty to interpret [8–11].

Overall, it is not a fully quantitative tool analysis due to the fact that the numbers are very subjective and detected based on specialist's

Fig. 1. Photograph of non-affected healthy skin. The image was produced with Visioscope PC 35 camera (Courage + Khazaka, Germany). The camera has a minimal area of 8.00 × 6.40 mm and resolution of 5:4 and 1280 × 1024 pixel. The photograph was used to test a newly developed clinical tool to assess the condition of the skin through calculating the maximum entropy (quantification of randomness). The photograph was obtained from dermatology clinic database of the deidentified dermatoscopic images at the Centre for Medical and Surgical Dermatology (Whitby, ON, Canada).

Fig. 2. Photograph of affected skin by psoriasis. The image was produced with Visioscope PC 35 camera (Courage + Khazaka, Germany). The camera has a minimal area of 8.00 × 6.40 mm and resolution of 5:4 and 1280 × 1024 pixel. The photograph was used to test a newly developed clinical tool to assess the condition of the skin through calculating the maximum entropy (quantification of randomness). The photograph was obtained from dermatology clinic database of the deidentified dermatoscopic images at the Centre for Medical and Surgical Dermatology (Whitby, ON, Canada).

visual perception [1].

In addition to PASI, static Physician Global Assessment (sPGA) is also being used. The purpose of sPGA is to help dermatologist develop objective and standardized measures in order to use them in the clinical setting and exhibit dermatologic value. The following clinical variables are assessed for the sPGA – psoriatic plaque induration, erythema, and scaling [7].

Hypothesis and theory

In this section, we propose a theory of Quantitative approach that helps to access skin lesions and methodology.

It was theoreticized that healthy skin is more structured than affected skin that exhibits more alterations due to inflammatory, neoplastic or traumatic processes. For, instance healthy skin reflects a certain repetitive pattern (Fig. 1) that usually lacks in the affected skin (Fig. 2) which makes the overall picture more complex and random. Consequently, the baseline with minimum randomness can be represented by a blank white paper (Fig. 3), the simplified model of the skin can be represented by a simple geometric grid pattern (Fig. 4), and random drawing pattern may represent the affected diseased skin (Fig. 5).

Quantitative evaluation of skin is a new, non-invasive, quick, and very easy method to quantify skin changes. It can be used for various health assessments, determining skin conditions, and assessing how the skin responds to the treatment course.

#### Mathematical algorithm of calculating maximum entropy

The complexity and level of randomness of the image can be assessed through certain image analysis. For the quantitative skin assessment, entropy is the most suitable algorithmic approach. It measures the randomness in an image through the assessment of the various grey level probabilities.

In order to quantitatively measure the entropy of the skin, Shannon entropy was used to produce a reasonable and reliable algorithm.

The total calculation gives Maximum Entropy [4]:

$$TE\ (s') = \max_{s \in Gm} TE\ (s)$$

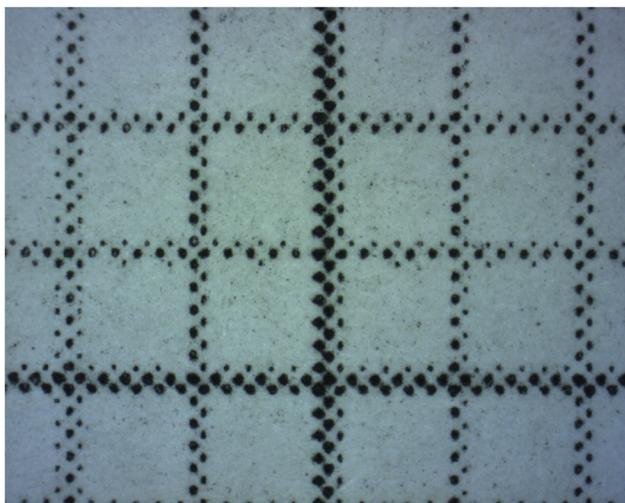The calculated Entropy of each image was 2.6 (see Fig. 1), 3.42 (see
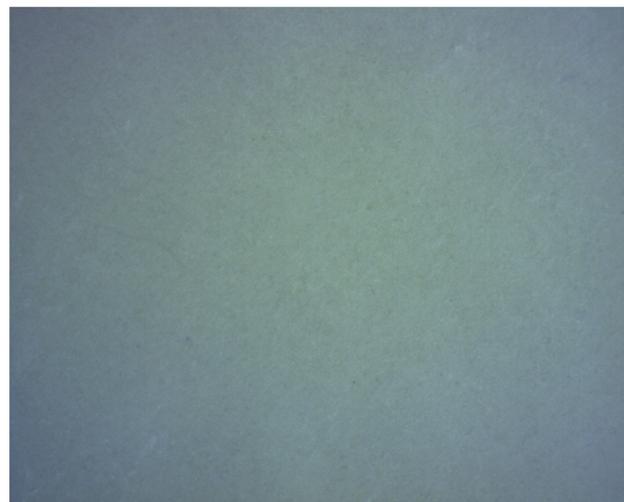
Fig. 3. Blank paper image. The image was produced with Visioscope PC 35 camera (Courage + Khazaka, Germany). The camera has a minimal area of 8.00 × 6.40 mm and resolution of 5:4 and 1280 × 1024 pixel. The image was used to represent the baseline with minimum randomness. The image was taken at the Centre for Medical and Surgical Dermatology (Whitby, ON, Canada).

Fig. 2), 1.81 (see Fig. 3), 2.5 (see Fig. 4), and 4.7 (see Fig. 5) that mathematically reflects an increase of randomness/Entropy. It was hypothesized that the entropy values of healthy looking skin and/or blank piece of paper would be lower compared to the affected skin by psoriasis skin and image with chaotic patterns. In order to prove the concept, the real dermatoscopic images from the clinic database were analyzed.

Evaluation of the hypothesis/proposed technique

The analysis was done retrospectively from the dermatology clinic database of the deidentified dermatoscopic images of the skin affected by psoriasis and adjacent clinically intact skin.

Initially, the dermatoscopic images were obtained with Visioscope

Fig. 4. Gridded pattern image. The image was produced with Visioscope PC 35 camera (Courage + Khazaka, Germany). The camera has a minimal area of 8.00 × 6.40 mm and a resolution of 5:4 and 1280 × 1024 pixel. The simple geometric grid pattern of the image was used to represent a simplified model of the skin. The image was taken at the Centre for Medical and Surgical Dermatology (Whitby, ON, Canada).
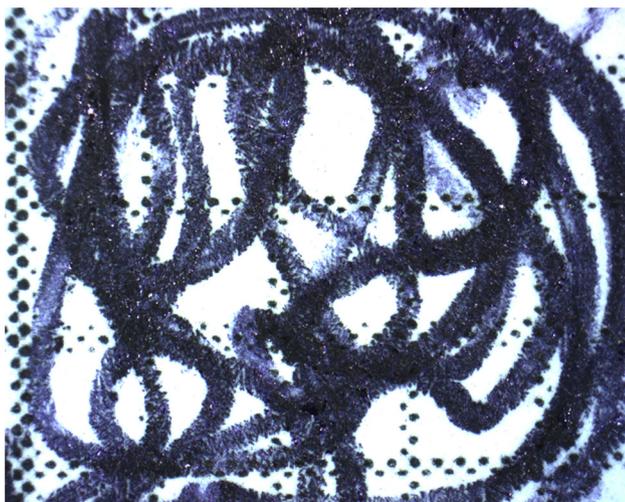
Fig. 5. Chaotic pattern image. The image was produced with Visioscope PC 35 camera (Courage + Khazaka, Germany). The camera has a minimal area of 8.00 × 6.40 mm and resolution of 5:4 and 1280 × 1024 pixel. The random drawing pattern of the image was used to represent the affected skin. The image was taken at the Centre for Medical and Surgical Dermatology (Whitby, ON, Canada).

PC 35 camera (Courage + Khazaka, Germany). This small camera produced images with a minimal area of 8.00 × 6.40 mm with a resolution of 5:4 and 1280 × 1024 pixel. Typically, the image is zoomed by 15–20 times depending on the size of the monitor. The camera

employs the parallel polarized light source [5]. All acquired images have the same scale and resolution which is very beneficial for further analysis since all errors related to different sizes and scale have been already reduced. The data was then transferred to the specially coded and developed proprietary software which enables users to calculate the entropy of diseased and normal skin cases. The software that we have designed is Java-based and allows to upload the image and subsequently analyze the selected area. The pixels in the selected area of the image are subsequently scanned and an average colour value of red, green and blue is assigned to each pixel. Then, this average value is converted into a grayscale value and the distribution of co-occurring pixels, and the level of entropy is calculated. For example, it can help to determine the ranking of skin changes of each patient which will enable to develop a unique numerical scale of any objective score with minimal mathematical and diagnostic errors [1].

Empirical data

The empirical data consists of eleven pairs of images selected from the dermatology clinic database of the deidentified dermatoscopic images. The average, standard deviation, and standard error were calculated (see Table 1.) In addition, entropy values of blank paper, gridded pattern, and chaotic pattern were also measured as reference points.

The difference among affected and non-affected by the psoriasis skin was assessed through the usage of Mann-Whitney U method. Mann-Whitney U Test was performed on two data sets for normal skin and skin affected by psoriasis. The U-value is 12. The critical value of U at $p < 0.05$ is 30. Therefore, the current result is significant at the parameter $p < 0.05$. The z-score is -3.15192. The p-value is 0.00164. Therefore, the result is significant at the parameter $p < 0.05$. Both results were identified as statistically significant which means that the current data is a reliable and valid source of evidence.

The entropy values for normal skin show normal distribution with mean $\mu = 2.56 \pm 0.10$ and standard deviation $\sigma = 0.33$. The 95% confidence interval is [2.36, 2.75]. The entropy values for skin affected by lesions show normal distribution with mean $\mu = 3.30 \pm 0.19$ and standard deviation $\sigma = 0.62$. The 95% confidence interval [2.93, 3.66]. As can be noted, the entropy value for healthy, non-affected skin exhibited lower values compared to values of entropy measured in skin affected by psoriasis (see Fig. 6).

Conclusion

We have introduced a clinical tool which allows to obtain the quantitative analysis of the skin by using a mathematical algorithm of calculating Maximum entropy. The initial hypothesis that the entropy value of healthy looking skin would be lower compared to the skin affected by psoriasis was confirmed. The healthy skin had lower Entropy values with mean $\mu = 2.56 \pm 0.10$ than the skin that was affected by psoriasis with mean $\mu = 3.30 \pm 0.19$. The healthy skin appears to be more uniformly structured, while the affected skin shows more random features caused due to inflammations, neoplastic, and/or traumatic processes. The healthy skin had an average entropy value similar to the entropy of gridded paper (2.5) which represented the

Table 1
Sampling data results of entropy values (Overall).

	Entropy values											Average	SD	SE
Blank paper	1.81													
Gridded paper	2.5													
Healthy skin	2.6	2.45	2.69	3.28	2.41	2.49	2.19	2.27	3	2.34	2.39	2.56	0.33	0.1
Psoriasis skin	3.42	3.53	3.12	4.76	2.91	3.13	3.64	2.63	3.7	2.64	2.81	3.30	0.62	0.19
Chaotic pattern	4.7													

SD – Standard Deviation, SE – Standard error.
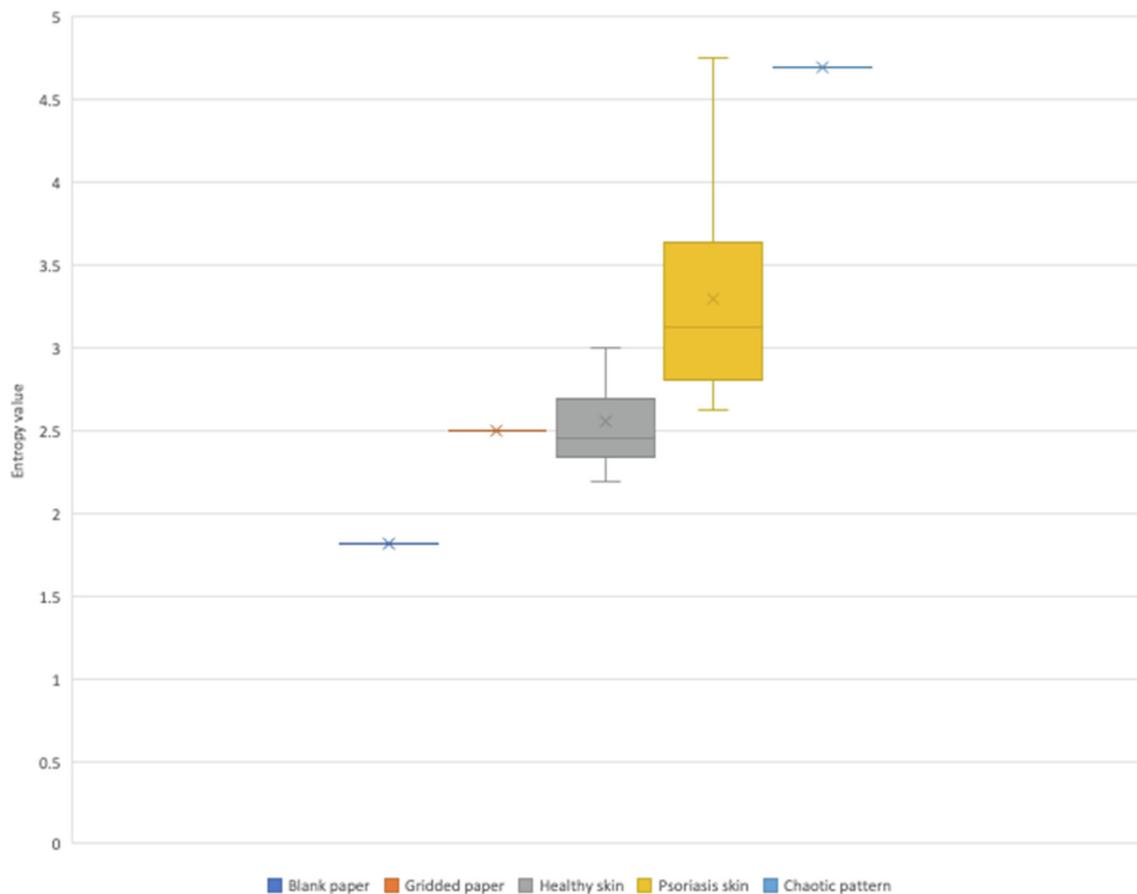
Fig. 6. Statistical representation of entropy values based on different conditions. The current figure summarizes the experimental data results of obtained entropy values. Selected eleven pairs of images from the dermatology clinic database were used to calculate the maximum entropy values of non-affected and affected skin by psoriasis. The entropy values of blank paper, gridded pattern, and chaotic pattern were used as a reference values. Standard error and standard deviation values were calculated for further experimental analysis.

simplified model of the skin. The affected by Psoriasis skin had more similarities in its entropical values with the entropy of chaotic pattern (4.7). Moreover, the value of entropy also increased based on 3 distinct characteristics of psoriasis: redness, thickness, and scaliness. More severe lesions exhibit higher values on the Entropy scale. Overall, the current tools exhibits accurate quantitative skin analysis results with minimal source of error.

Quantitative evaluation of skin is a new technique that still needs a lot of research. However, its purpose is to provide quick and easy method to quantify any skin changes. The current technique shows promising results because its incorporation in medical field would allow physicians to have universal measure of various skin conditions as well as their severity in non-subjective and more accurate manner. The suggested clinical tool can play a very beneficial role in assessing psoriasis on a new scale using Maximum entropy since the produced values would contain less sources of error and be considered statistically significant. Not to mention, psoriasis is not the only skin condition that can be assessed by using this unique approach. Maximum entropy does provide a very accurate universal measuring tool to quantitatively assess each skin lesion with minimal errors and maximum accuracy of results.

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