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Quantification of erythema using digital camera and computer-based colour image analysis: a multicentre study

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Background/purpose: Colour measurements obtained from digitized images have been proposed as a simple and cost-effective way to evaluate skin colour and the activity of treatments. The main disadvantage of the method is the fact that it is highly dependent on ambient light: even if an accurate control of subjects' illumination is provided, readings remain not comparable among different laboratories. The purpose of this study was to develop a highly reproducible system for computerized colour image analysis of skin erythema, making it possible to compare readings from different environmental light conditions.

Patients and Methods: Three hundred and forty-eight Caucasian adult healthy subjects (age range: 18–60 years) of both sexes (14% males, 86% females), were enrolled in the study by 49 dermatologists distributed all over Italy. They were recruited among patients who required aesthetic treatments involving skin erythema, like chemical peeling and laser epilation. Once the treatment was administered, clinical evaluations and pictures were taken at the level of treated areas. Visual assessment of erythema was done on the basis of conventional clinical grades (0 = absent; 1 = slight; 2 = moderate; 3 = intense). The clinicians participating in the study were asked to put a standard colour marker (red, green and blue coloured self-adhesive ring) in the photographed skin area. The difference between r, g, b values of photographed colour markers on the skin of single patients participating in the study and the r, g, b values obtained photographing the colour marker in fixed illumination conditions was used to adjust skin colour measurements. Then erythema index (E.I) on digitized images was calculated subtracting red value to green one by averaging procedure of different pixels.

Results: Erythema index. average value among the groups divided according to the conventional clinical score increased progressively from score 0–2, while it decreased from score 2 to score 3. The differences in E.I. mean values among the score groups (0 vs. 1, 1 vs. 2, 2 vs. 3) were statistically significant ($P < 0.05$).

Conclusion: We developed a method for the measurement of skin erythema using digital camera, normalized r, g, b colour co-ordinate system and computerized calculation of E.I. Clinical usefulness of our method for absent, slight and moderate erythema, was demonstrated. For intense erythema lesions we did not find a correspondence between clinical and computerized evaluation, probably due to other factors involved in skin inflammation (e.g. oedema).

Key words: colour image analysis – computer assisted – digitized images – erythema

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In the clinical field, reproducible and comparable assessments of skin colour are needed for objective evaluation of lesions and treatments' activity. In order to provide objective accurate quantitative colour information about skin lesions, devices as reflectance spectrophotometer and reflectance colorimeter have been successfully used during the past decade (1–5). However, these techniques are too expensive and technically complex to be handled in the clinical routine. Furthermore, reflectance skin colour measurements require direct contact of the probe with the skin, while it has been demonstrated that skin compression significantly influences readings (6). Computerized image analysis of skin colours captured by a video camera or digital camera and processed using a pixel averaging procedure has been recently proposed as a simple, cost-effective and no-contact method to evaluate skin colour and the activity of treatments (7, 8). Colour measurements obtained from digitized images have proven to be more efficient than the conventional visual assessment by observers. Nevertheless, this method is highly dependent on ambient light.

In fact, even if an 'intralaboratory' accurate control of picture illumination is provided over time, still there is a great 'interlaboratories' variability of data making the results not comparable among various researchers. The purpose of this study was to develop a standard system for computerized colour image analysis of skin erythema, making it possible to compare readings taken by different observers in different environmental light conditions.

Patients and Methods

Patients

The present study included 348 Caucasoid healthy subjects of both sexes (49 males, 299 females) aged about 18 to 60 years old were treated by 49 dermatologists* distributed all over Italy. All the subjects participating in the study, whose informed consent had been obtained were patients undergoing chemical peeling or laser treatment for aesthetic indications.

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Methods

Each patient was subjected to a selected aesthetic treatment (chemical peeling or laser) according to physician's usual procedures. After 24 h from this, presence and degree of erythema were clinically verified and registered in the case report form, treated sites being specified and intensity of the erythema graded on the following scale: 0 = absent; 1 = slight erythema, not well demarcated margins; 2 = moderate erythema, with well demarcated margins; 3 = intense erythema, with raised margins. The modality of treatments, although registered in the case report forms, did not influence data processing, since the symptom erythema and its intensity were the main endpoints of the study. Evaluations were conducted at room temperature ($20 \pm 4\,^{\circ}C$) and relative humidity varied between 40% and 60%. Before treatment, each volunteer was acclimatized under relax conditions for at least 30 min, with test site uncovered. During 3 h before the visit, the volunteer had not to smoke, drink coffee or alcohol or take drugs.

Photographic documentation

Pictures of treated areas were taken using a standard model of digital camera (MVC-FD73, Sony Inc., Japan). The camera was delivered to each dermatologist participating in the study together with a distancing device, self-adhesive coloured markers and standard operative instructions (flash: auto; flash level: low; quality: fine; rec mode: normal; picture effect: normal; bright: segments and points 50/50; program: retarded soft mode). The markers were ring-shaped adhesive tapes (external diameter: 30 mm; internal diameter: 10 mm) divided into three sectors: red, green and blue (Fig. 1). The clinicians participating in the study were asked to put a colour marker in the photographed skin area so as to place the erythematous skin area in the center of the ring. One of the rings had been photographed in the following illumination conditions: open air, in Monza, no clouds in the sky, at noon, on 31st January 2000. Its r, g, b values were taken as reference for colour image analysis.

Colour image analysis

The first step of our study was to verify reproducibility of the photographic system. A sample of 24 colour markers was photographed in our laboratory, in standard conditions, and measurements of r, g, b values were made on each sector of each marker. Uncertainty of measurements was calculated on the basis of standard deviation of all obtained data for r, g, b and expressed as a percentage of the mean value: it resulted to be 6% for each parameter (r, g, b) which was considered

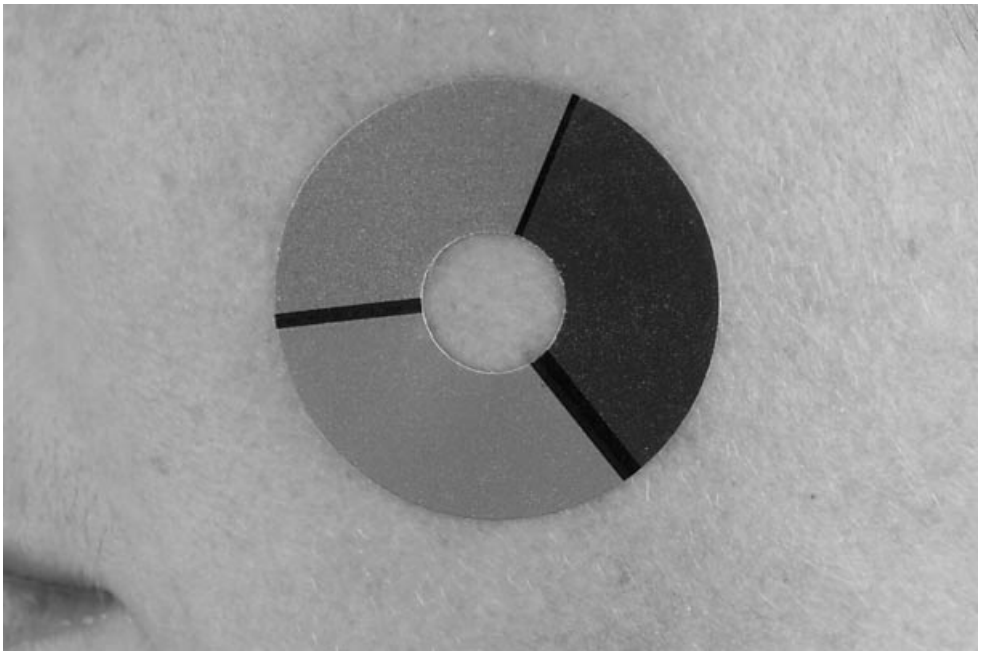

Fig. 1. Example of a colour marker on normal skin.

acceptable. Once verified the reproducibility of the system, the clinical phase of the study was started. At the end of clinical phase, pictures were available for colour image analysis of the skin. According to the colour definitions employed in computer graphics, each colour can be expressed as red, green and blue co-ordinates and represented like a point in the space a set of Cartesian axes. In our method, the same point P, can be represented in two different sets of Cartesian axes: one for standard measurements (Rs, Gs, Bs co-ordinates) and one for actual measurements (Ra, Ga, Ba). The difference among 'r, g, b' co-ordinates of the colour marker photographed by the dermatologists and the same values photographed in fixed illumination conditions, was used to calculate a normalization factor of measurements. To do so, the distances (Dr, Dg, Db) between each colour of the marker in reference illumination conditions (rs, gs, bs in Fig. 2) and the corresponding one on the markers in the clinical pictures (ra, ga, ba) were calculated in order to translate colours obtained in any environmental illumination into the same colours obtainable in reference illumination and to make them comparable. Endpoint of this study was the measurement of skin erythema index. Erythema is due to vasodilation and consequently to an increase in erytrocites and haemoglobin in the interested site. Haemoglobin absorbs green light and reflects red one. Therefore, to higher quantities of haemoglobin in the skin corresponds an increase of absorbed green light and of reflected red light (2). Based on this phenomenon, we can quantify the erythema index by subtracting obtained red value (r) to green one (g). After having normalized the measurements, erythema index (E.I) was calculated subtracting red value to green by an averaging procedure on the considered area of digitized images. For each image, we decided to analyse a region of 5×5 pixel, in a selected part of the image characterized by colour uniformity. This was done on both erythema areas and colour markers (red, green, blue). The software allowed to highlight a selected area with the cursor, obtain normalized r, g, b, values and transfer them on the electronic sheet.

Statistical analysis

Instrumental data were analysed according to the Student's *t*-test for paired data, to assess statistical significance. A level of $P < 0.05$ was considered statistically significant.

Results

By the conventional clinical grading method, 10 examined areas resulted to be grade 0 (no erythema), 50 were grade 1 (slight erythema), 164 grade 2 (moderate erythema) and 124 grade 3 (intense erythema). The E.I. of the lesions (E.I. $= g - r$) ranged from 8 to 198. E.I. average values among the groups (Fig. 3), divided

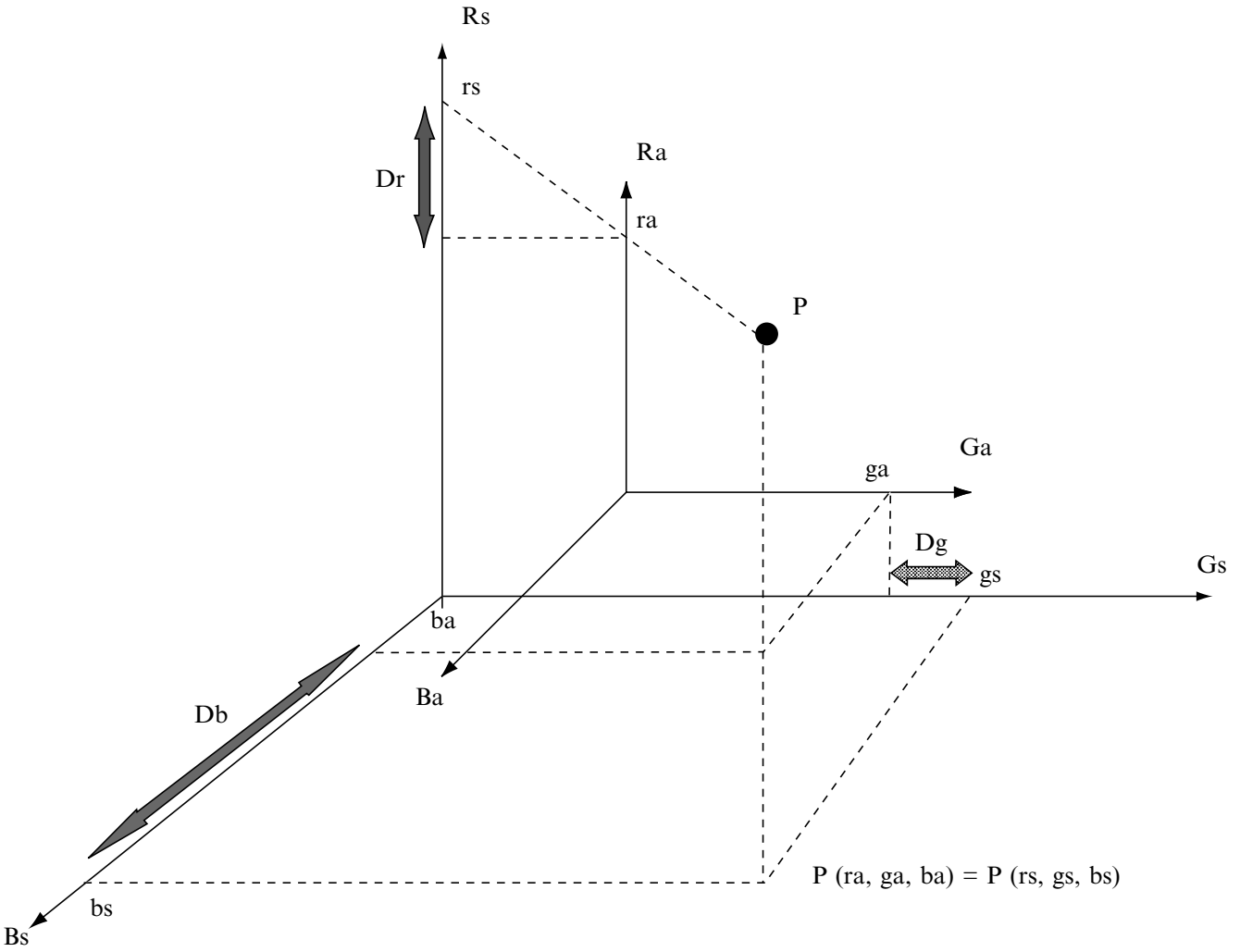

Fig. 2. Example of the distance between each colour of the marker in reference illumination conditions and the corresponding one on the marker from a clinical picture. The same point P, can be represented in two different sets of Cartesian axes: one for standard measurements (Rs, Gs, Bs co-ordinates) and one for actual measurements (Ra, Ga, Ba). The distances (Dr, Dg, Db) between each colour of the marker in reference illumination conditions (rs, gs, bs) and the corresponding one on the marker from the clinical picture (ra, ga, ba) can be calculated.

according to the conventional clinical score, increased progressively from score 0 to score 2, while it decreased from score 2 to score 3 (average E.I. for: score $0 = 41 \pm 10$; score $1 = 51 \pm 16$; score $2 = 54 \pm 23$; score $3 = 49 \pm 18$). The differences among the score groups (0 vs. 1, 1vs. 2, 2 vs. 3) were statistically significant ($P < 0.05$).

Discussion

Nowadays sensitive colour digital cameras have such a resolution that it is possible to use them as a part of colour measurement systems. The main disadvantage of photographic systems in colour measurement is its high dependence on ambient light. Our system allowed us to obtain adjusted colour measurements, referred to standard illumination conditions, in order to obtain data comparable among different researchers. The availability of such a reliable, simple and cheap system to measure skin colour, could be of great advantage for the study of skin physiology, pathology, monitoring of treatments and for routine dermatology. Our data show good agreement between clinical evaluation and the proposed system, demonstrating a progressive, statistically significant, increase in E.I. mean values going from the lesional skin sites graded 0–1 and 2 (according to a conventional clinical scale) and finally a statistically significant decrease from grade 2 to grade 3. This is in agreement with previously reported observations in the literature, which describe that the highest clinical levels of erythema are often accompanied by other symptoms (oedema, infiltration, vesicles, etc.) able to conceal red colour (9, 10).

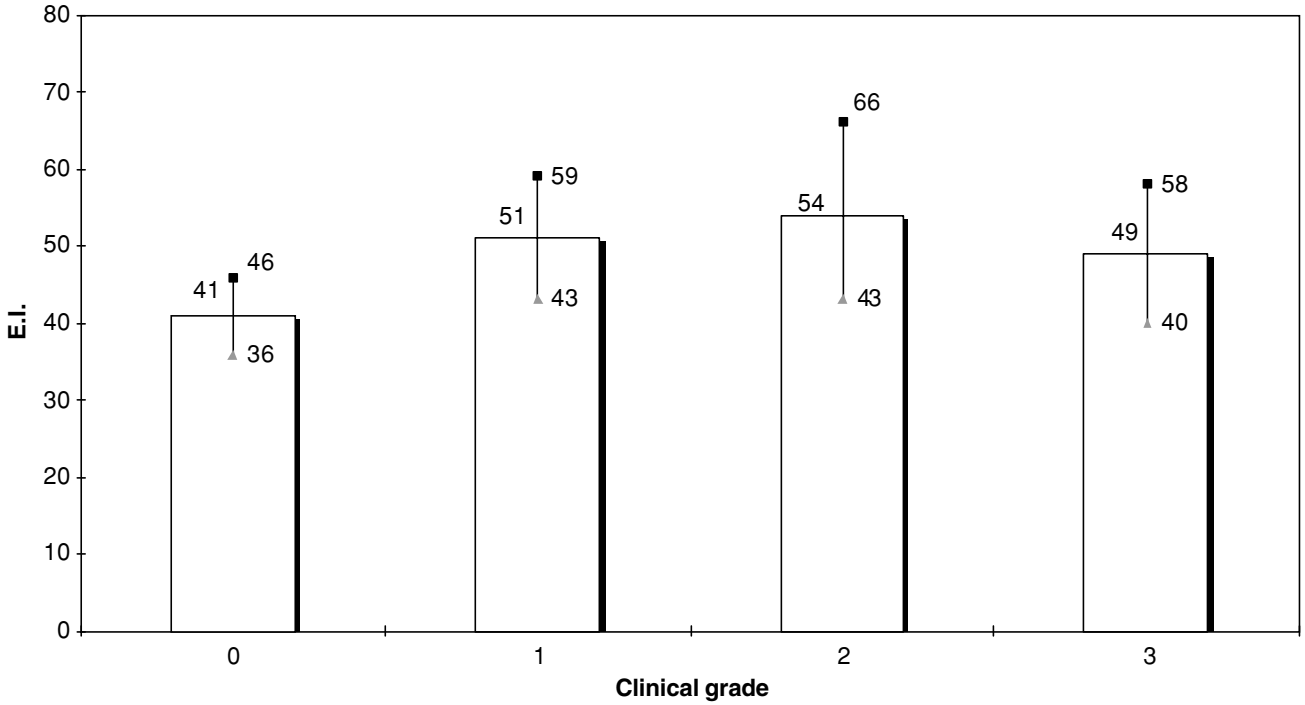

Fig. 3. Differences in erythema index (E.I.) average values among the clinically scored groups.

Evaluation of skin erythema is one of the most frequent endpoints of researchers in the field of dermatology, pharmacology, cosmetology. It has to be objective, reproducible, simple, and cheap. Data must be comparable among various laboratories. Our system has a wide potential of application in dermatology and cosmetology, as well as for quantitative evaluation of the efficacy of therapies for skin lesions.

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