

Computer-aided skin prick test

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Abstract: The interpretation of the skin prick test is subject to inter-observer variation. To remove this variation, a computerized procedure for the skin prick test is suggested. Instead of manually measuring the emerging wheals, a series of photographs is automatically taken of the forearm. The photographs thus taken are then analyzed with a digital image processing algorithm to give the measurement results. The computerized test has the added benefit of being able to produce a time series for the wheal

size. This makes it possible to see the onset time of the reaction in addition to the size of the wheal. Preliminary feasibility test suggests that the simple setup described in this letter is able to perform the skin prick test automatically and to show the kinetic behaviour of the wheal. The main challenges with the test setup are related to illumination and wheal detection algorithms.

Key words: algorithm – allergy – digital – skin prick test

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Background

The skin prick test is the most widely used test for detecting allergies, especially in primary health care. It is inexpensive, easy to carry out and relatively fast. A number of allergens can be tested at the same time, which makes the test very economical; on the other hand, clinical information obtained using recombinant reagents allows correct identification of the sensitizing molecule (1).

Previously wheals have been marked with a pen or other similar methods and then transferred with translucent adhesive tapes to a white paper form carrying predefined markings. The results are then either measured manually or scanned (2–5). A computer-aided method with a standard photograph editing program has been tested with good results (4).

Questions addressed

The main weaknesses of the skin prick test are related to the interpretation of the results, especially at the primary health care level. As the results are observed visually, the inter-observer variation may be significant. More uncertainty is introduced by the fact that the time between introducing the allergen and reading the results is somewhat variable.

The shortcomings can be overcome by utilizing a series of digital photographs which are evaluated by a computer-

ized algorithm. Thus, it is also possible to trace each individual wheal in time. This method reduces the manual labour, as well.

Experiment design

The equipment used in the experiment (Fig. 1) consists of a simple fixture which gives support to the hand and keeps the camera stationary. The illumination requires light sources which are also attached to the fixture.

As restraining the hand completely would introduce discomfort and possibly also change the blood flow and thus the reactions, some movement has to be allowed. To compensate for any geometry errors caused by this movement, some reference points are marked to the skin by utilizing a marker pen.

The camera used in the experiment is a Canon Power Shot G3 (Canon Inc., Tokyo, Japan) a relatively old digital camera. In this application, the resolution of the camera is not critical, noise performance is more important. Also, the camera has to allow computer-controlled image capture.

A 60-W incandescent bulb is used as the light source. This choice is not ideal, either, as the light from the small light source provides uneven illumination and the incandescent bulb provides little short wavelength radiation. To compensate for possible spectral changes, there is a neutral grey target included in the scene.

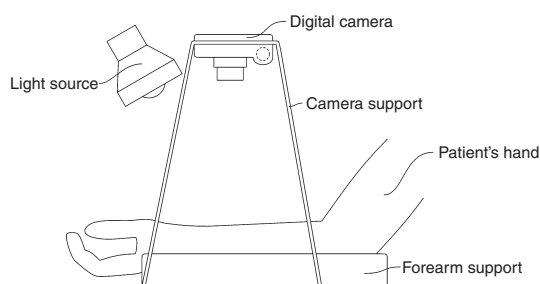


Figure 1. The test setup used in the experiments.

Essentially, there are three measurable physical changes in the area: swelling, temperature rise and colour change. Of these, the only visible change in a photograph is the change in colour. Swelling may introduce some shadows to the scene but without very special lighting arrangements they cannot be used in determining the size of the wheal.

The skin colour is not constant, as different individuals have different pigmentation and the general blood flow changes the skin colour. Instead of the absolute colour, the colour is measured in respect to the colour of the surrounding skin.

The actual image processing starts by making the necessary geometry corrections with the help of control points on the skin and transforming the colour (RGB) image into a greyscale one by using the Fisher projection. This transformation projects the RGB data into greyscale so that the contrast between the surrounding skin and the wheal is maximized.

The size of the wheal is then determined from an area which contains the reaction completely and some surrounding skin. An ellipse is then fitted into the scene so that the colour difference between the inside and outside of the ellipse is maximized. The lengths of the axes of the ellipse are then used as the results for that wheal.

Surface area determination would also be possible and there are some indications that it could give a more accurate result (4). However, as the diameter measurement method is the standard method, the ellipse fitting gives results which should be directly comparable with those obtained by the manual evaluation.

In these preliminary experiments, the reactions have been interpreted semi-automatically, so that a single point in each reaction is first pointed manually and the size of the wheal is then automatically determined around this point. Automatization of this phase is straightforward when suitable templates or position marks are used.

Results

The experimental setup has been tested with a small number of patients ($n = 10$) with 20 reagents (including saline water and histamine) for each patient. The full data analy-

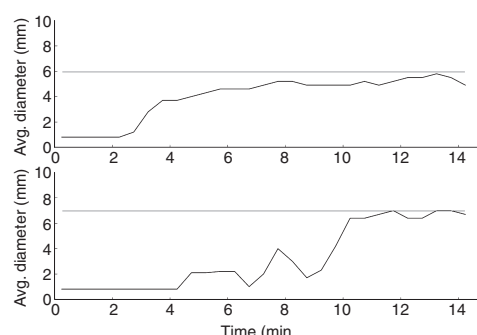


Figure 2. Average wheal diameter for two different wheals, fast (upper curve) and slow (lower curve).

sis has not been carried out yet, the preliminary results are encouraging.

Figure 2 shows some typical results from different allergens and patients. The kinetic behaviour illustrated in the figure shows that while the final size for both wheals is the same, the time of their onset differs. The examples also illustrate the added noise because of low-contrast borders of the wheal. The horizontal lines in the curves represent the value observed by a human observer after 15 min.

Conclusions

These preliminary results are encouraging. It seems that full automatization of the skin prick test with very simple apparatus is possible and the kinetic data can be easily obtained from the photographs.

Several different image processing algorithms have been tested with the experimental data. The Fisher projection for colour conversion gives good contrast and the ellipse fitting for the wheal size determination mimics the manual evaluation closely.

The most important factors contributing to the success of the automatic evaluation seem to be the colour conversion algorithm, the geometry correction, illumination and camera noise.

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