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PLETHYSMOGRAPHIC RECORDINGS OF SKIN PULSES WITH PARTICULAR REFERENCE TO THE PIEZOELECTRIC METHOD

I. *Preliminary Report*

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Abstract. A piezoelectric plethysmograph measuring skin pulses is described. The piezoelectric method may be applied on extremities, normal skin of the forehead and on hyperaemic diseased skin. Some results of the registrations are reported. Advantages and drawbacks compared with the photoelectric method are briefly outlined. The recording of skin pulses gives objective information on vasoconstriction and vasodilatation of the cutaneous vessels. This study suggests that recordings of this type may have great value in investigations of the vasoconstrictor potency of some topical drugs, for instance corticosteroids.

This report deals with a new method for pulse registration in normal and diseased skin by means of a piezoelectric plethysmograph (piezo = pressure). The method may have several applications in dermatology (1, 2, 3, 8). The preliminary results are described of a study of vasoconstrictor effects of corticosteroid ointments in normal and psoriatic skin, and of pulse registrations from extremities.

METHOD

The piezoelectric applicator is shown in Fig. 1. Fundamentally a piezoelectric crystal transforms pressure in the crystal into an electric charge proportional to the force applied. The piezoelectric crystal is hermetically sealed in a small microphone capsule ($18 \times 18 \times 6$ mm) used in the transducer. A sensitive bar (sensor) which transforms the skin pulses is glued to the centre of the crystal. During registration the transducer rests freely on a wing-formed plate (Fig. 1 *a*). In investigations of the extremities the plate is replaced by a hollow capsule which encloses the pulpa of the finger or the toe (Fig. 1 *b*). The part of the sensor which touches the skin measures 3 mm^2 and exerts a pressure of approximately 2 mm Hg against the skin surface. This pressure may be regulated by turning the plate or the capsule, but is considered to be constant during registration. The transducer is sensitive to pressure variations of 0.5 mm Hg minimum. The pulse waves were recorded on an electrocardiograph with a speed of 50 mm/sec. The pre-amplifier circuit is shown in Fig. 2. In order to obtain equal external conditions and diminish the vasoconstrictive effects of low temperatures, all registrations were performed at a room temperature of 25°C (5, 10). In pa-

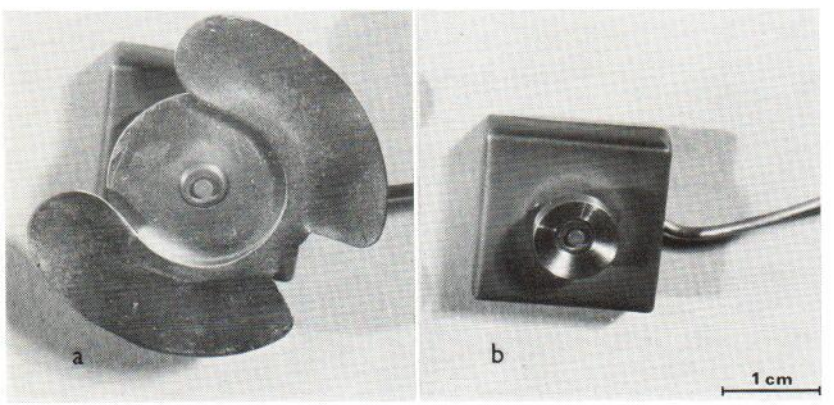

Fig. 1. Close-up of transducer showing applicator for skin regions (*a*), and for extremities (*b*).

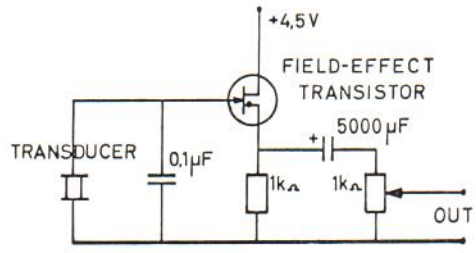

Fig. 2. The pre-amplifier circuit.

tients with psoriasis, lesions on the upper trunk and patella were used for the recordings. The forehead was the site in subjects with normal skin. Recordings from the extremities were performed on the third finger and second toe respectively. Further details of the method will be reported subsequently.

RESULTS

Fig. 3 shows registrations from normal skin of the forehead before and after the application of betamethasone-17-valerate, 0.1 % in an ointment base under plastic occlusion. Large pulse waves (Fig. 3 *a*) are seen with an ascending and a descending branch. On the latter, a rebound, *E*, is observed which is the positive wave produced by the closure of the aortic valves. After 24 hours occlusion the pulsations are reduced (Fig. 3 *b*), and after 48 hours the pulse waves have disappeared (Fig. 3 *c*). The skin pulses reappeared within 24 hours of removal of the occlusive bandage (Fig. 3 *d*). Corresponding registrations were performed on psoriatic skin (Fig. 4). These showed more flattened pulse curves without rebound. After 24 and 48 hours' application of betamethasone-17-valerate under plastic occlusion the pulse amplitudes were successively reduced (Fig. 4 *b* and *c*) and disappeared after 72 hours (Fig. 4 *d*). At that time the eruptions appeared pale and less infiltrated.

However, within 24 hours of conclusion of the treatment the pulse waves reappeared (Fig. 4 *e*). As control the same experiments were performed with the ointment base only and on the same sub-

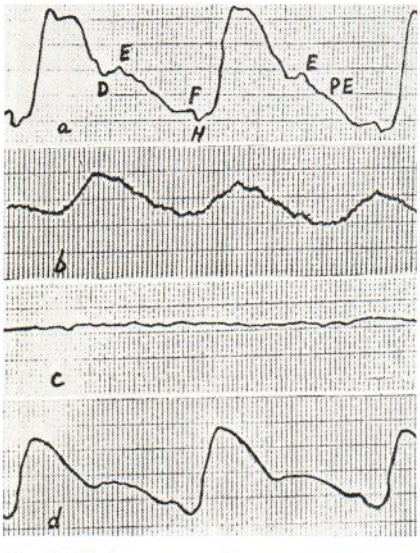

Fig. 3. Plethysmogram from normal skin of the forehead. Before treatment (*a*), after 24 and 48 hours of treatment (*b*) and (*c*). 24 hours after cessation of treatment (*d*).

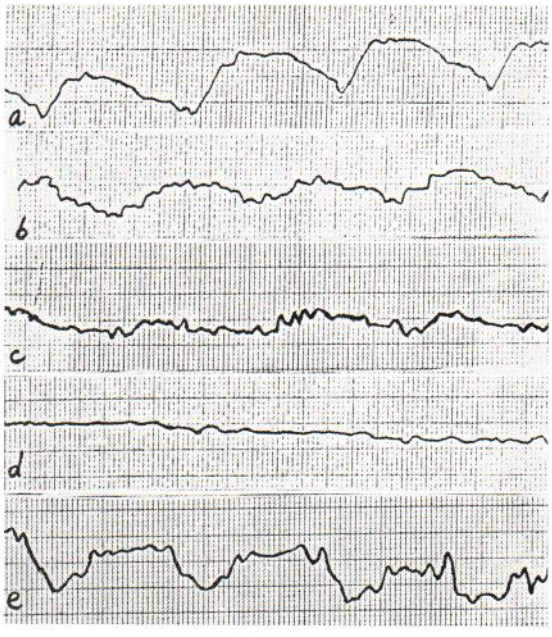

Fig. 4. Plethysmogram from psoriatic skin. Before treatment (*a*), after 24, 48 and 72 hours of treatment (*b*), (*c*) and (*d*). Reappearance of pulse waves 24 hours after cessation of treatment (*e*).

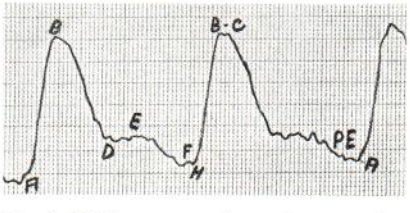

Fig. 5. Plethysmogram from the second toe in a patient with venous ulcer.

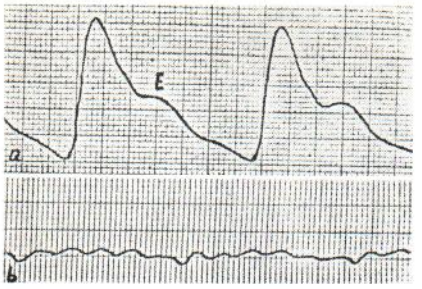

Fig. 6. Normal subject. Plethysmogram from the third finger (*a*). After immersion in cold water (15°C) producing vasoconstriction (*b*).

jects investigated with betamethasone-17-valerate. No changes of the pulse curves were observed in psoriatic or normal subjects during these control experiments.

Fig. 5 shows pulse waves from the second toe of a patient with venous leg ulcer. According to Jacquet (7), the pulse waves and the small waves superimposed upon these indicate the following: *A* for the foot of the systolic, ascending branch, *B* and *C* for the beginning and ending of the systolic plateau, *D* for the catacrotic incisure, *E* for the top of the dicrotic wave or rebound, *PE* for the part of the descending limb distally to *E*, *F* for the positive wave due to the contraction of the auricles and *H* for the negative wave due to the isometric contraction of the heart chambers. The second part of the top of the curve and the descending branch—the angiologic part of the pulse curve—represent the microcirculation.

Registration from the third finger of a normal subject is shown in Fig. 6. After immersion in cold water, 15°C (6), the pulse waves disappeared.

DISCUSSION

The method used in this investigation measures pulsations of blood in the small skin vessels. An increase in pulsation indicates vasodilatation and vice versa. In 1938 Hertzman (4) was the first to describe a photoelectric method recording skin pulses in regions other than the extremities. Later (5) he made the following statement: "The estimation of the rates of cutaneous blood flows from the photoelectric recordings of the skin volume pulses is sufficiently correct to have value in the study of vascular reactions in the skin." Hertzman calibrated the method and found maximal flows in facial skin including the forehead, and in fingers and toes, implying a corresponding larger vascular bed. His method of recording the skin pulses was not applied in dermatological investigations until recently (9). It is emphasized, however, that according to Winsor (13) the instrument gives qualitative but not quantitative information relative to skin flow. At the skin clinic of the Ullevaal Hospital the piezoelectric method has been used for two years, and appears to give valuable information concerning the vasoconstrictor potency of topical drugs, e.g. corticosteroids. Recordings of the skin pulses which give objective evidence of vasoconstriction and vasodilatation, as well as the microcirculation, have also proved to be of value in the study of various dermatoses.

Comparing the piezoelectric and photoelectric methods, the latter has the following limitations: it measures only the variations of the optic density (7, 11), which depends on the various tissues traversed by the light. Furthermore, the pulsations may be reduced by venous stasis. These facts make the photoelectric method less convenient than the piezoelectric one for comparative investigations performed on the extremities (11). However, the method is well suited for studies performed on the skin in other regions (5).

The use of the piezoelectric method is restricted to the regions referred to in this paper. In hyperemic states and in dermatoses accompanied by vasodilatation it is very useful. Concerning registration from the extremities it is superior to the photoelectric method (7, 11).

The piezoelectric method can be calibrated in terms of pressure. In applying the capsule which encloses the pulpa of the finger and the toe, the apparatus is registering tissue volume changes during the systole. The method is thus a plethysmograph, according to Jacquet (7). The curves are distinguished by their reproducibility and the great sensitivity of the apparatus makes it possible to observe even the smallest oscillations. The latter are important in the study of the microcirculation, e.g. in venous leg ulcers (8, 11, 12). The possibility of applying the apparatus on extremities as well as other areas makes it suitable in dermatological investigations.

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