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PLETHYSMOGRAPHIC RECORDINGS OF SKIN PULSES

II. *Piezoelectric and Photoelectric Measurements in Psoriasis*

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Abstract. This paper describes pulsations obtained from active psoriatic lesions by means of piezoelectric and photoelectric plethysmography. The two methods differ in that the piezoelectric pulse meter is influenced by the pulsating skin surface whereas the opacity pulses depend on the absorption of light by the pulsating blood flow. In the present investigation no pulsations could be obtained by the piezoelectric pulse meter from unaffected skin close to the lesions whereas the opacity pulse meter showed waves with only small amplitudes. Large pulsations were obtained from psoriatic lesions by both methods. A marked reduction in pulse height was produced by betamethasone-17-valerate applied under plastic occlusion as recorded every 24 hours for 3 days. 24 hours after conclusion of the occlusive treatment the pulse amplitude increased to its previous height. Occlusive treatment with placebo ointment did not alter the pulse amplitude. Intradermal injections with adrenaline reduced the pulse height whereas injections with methacholine and normal saline had no effect. Similar results were obtained by both methods although the pulse amplitudes showed some interindividual variations as regards the height of the pulse amplitude. The investigation indicates that (*a*) the piezoelectric pulse waves originate in the minute skin vessels and are due to the altered circulation as met with in psoriasis, (*b*) the surface of active psoriatic lesions pulsates, (*c*) betamethasone-17-valerate produces a reduction in pulse amplitude which is due to the vasoconstrictive effect of the steroid.

Some results concerning piezoelectric (=pressure transformed into electric charge) pulse recordings from psoriatic lesions were illustrated in a preliminary report (26). It was shown that the pulsations disappeared during treatment with corticosteroid ointment under plastic occlusion and that they reappeared after conclusion of this therapy. It is the purpose of the present article to show that (*a*) the pulsations obtained originate in the minute skin vessels and are due to the altered circulation as met with in psoriasis, (*b*) the surface of active psoriatic lesions pulsates, and (*c*) the disappearance of the pulse waves during occlusive steroid treatment is due to vasoconstriction.

Piezoelectric pulse plethysmography has generally been accepted as a reliable method of assessing the peripheral circulation in extremities (12, 13). However, no reports of similar measurements from dermatologic disorders could be found in the available literature. Photoelectric measurements using reflected light have been applied in the study of the vasoreaction in delayed blanch (21), but as far as known the method has not been used in other skin lesions. The functioning of peripheral vessels in neurodermatitis was observed by Blaich (2) by means of transmitted light. The investigations were performed on fingers and toes. Normal skin from other regions has been investigated by photoelectric plethysmography using reflected, incident, or scattered light (10, 11, 14, 18, 20). In the present investigation reflected light and piezoelectric plethysmography have been used in order to record pulsations from psoriatic lesions and to observe the vasoconstrictive effect of betamethasone-17-valerate.

Advancing pharmaceutical research has created a need for reliable methods of assaying the vascular action of various topically applied medicaments, particularly corticosteroids. The vasoconstrictive properties of the steroids are still under dispute (1), and recordings of the opacity pulse are certainly of great interest in this connection as the method gives reliable indication of vasoconstriction and vasodilatation of the cutaneous vessels (7, 14, 15, 21, 25).

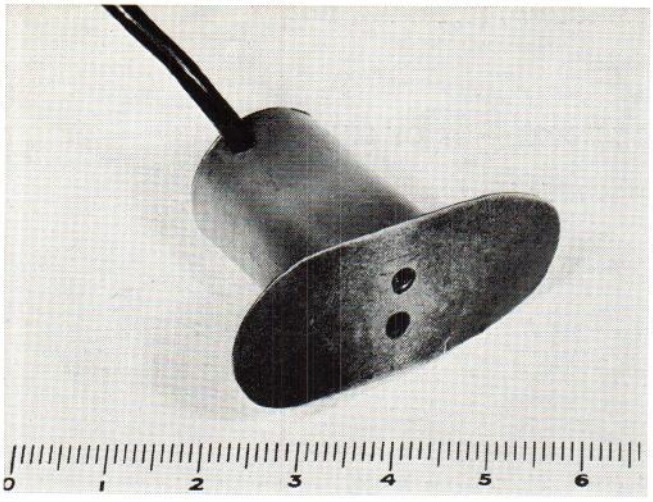

Fig. 1. The photoelectric detector seen from below showing the site of the light source and photocell.

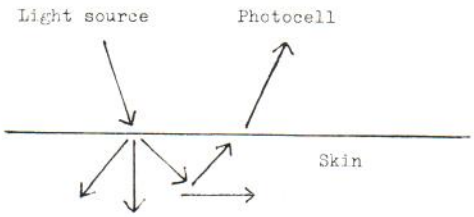

Fig. 2. Detection of photoplethysmograms by means of reflected light.

METHODS

The piezoelectric device has been described in a preliminary report (26). The applicator containing the piezoelectric crystal, rests freely on the skin by means of a wing-formed plate. The sensor which touches the skin surface exerts a very low pressure and as the transducer is only sensitive to pressure variations, this does not influence the curve.

The photoelectric plethysmograph (Fig. 1) employed in this investigation was constructed after the principles described by Weinman (29). The method was first outlined by Hertzman (10) and has later proved to be of great value in assessing the cutaneous circulation (9, 11, 18). The detector containing the light source and photo-sensitive cell was fixed gently to the skin by means of adhesive strapping. This has been recommended by other investigators (18, 23), and the pressure effect has been outlined by de Pater et al. (20).

A 0.5 W lamp is used as a light source and does not affect the circulation to any noticeable extent (20). The light passes into the skin and a variable amount is absorbed by the pulsating blood flow in the small skin vessels. Light that is not absorbed passes back out of the skin into the photoelectric cell (Fig. 2). The resistance of the latter varies proportionally with the light intensity. Fig. 3 shows the arrangement of the photometric system. Constancy of illumination was assured by a stable power supply and the amplifier gain was also kept constant during the investigation as variation might influence the pulse amplitude. The photocell was coupled to the amplifier and the output was inscribed by an electrocardiograph at a speed of 50 mm/sec.

All registrations were performed at the same room temperature, 25°C (±1°), and acoustic stimuli were reduced to a minimum. The patient rested for 20 min before performance of the registrations in order to obtain a basal physiological state and a normal respiration as the curves might otherwise be disturbed (3, 17). All plethysmograms were recorded from recumbent subjects with the detector placed at about heart level (3, 18). The study comprised 40 subjects, age 20–40 years. The lower extremities or back were used as test site. 20 fresh

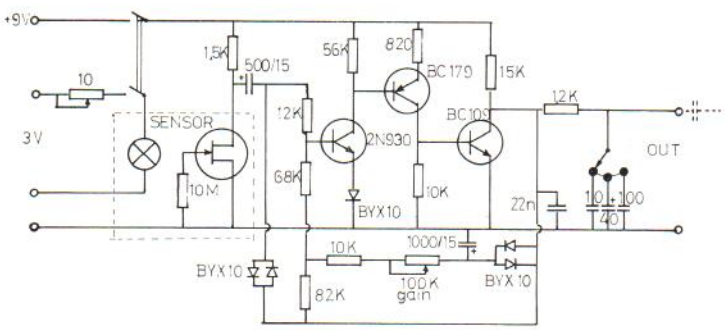

Fig. 3. Arrangement of photometric system.

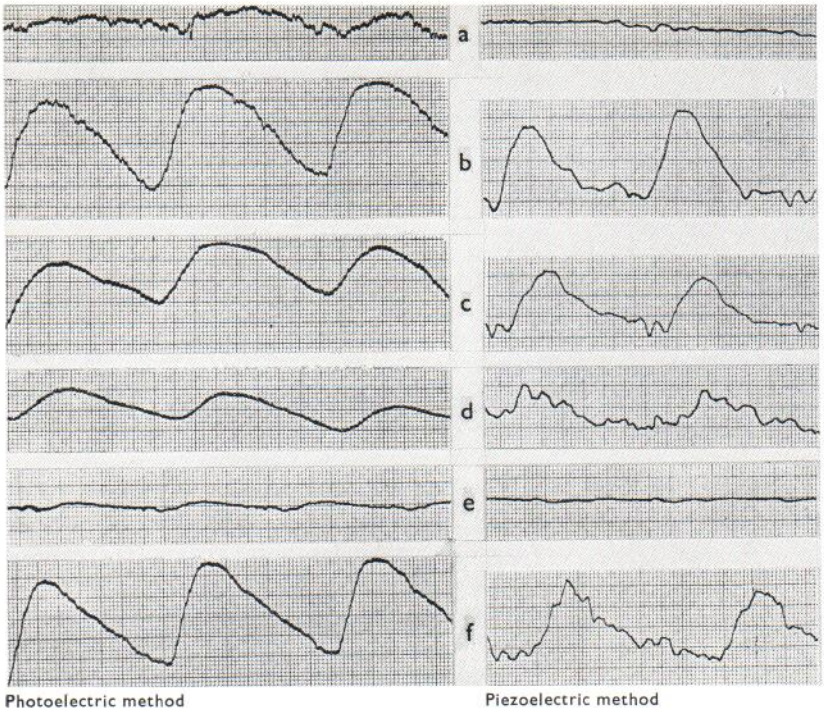

Fig. 4. Occlusive treatment with betamethasone-17-valerate. (*a*) unaffected skin; (*b*) before occlusion of psoriatic lesion; (*c*), (*d*), (*e*) at 24, 48 and 72 hours of occlusion; (*f*) 24 hours after conclusion of treatment.

psoriasis lesions were treated with betamethasone-17-valerate ointment under plastic occlusion and 20 with a placebo ointment (the base of the steroid ointment), 10 lesions were injected intradermally with 0.1 ml of 1 : 10,000 methacholine chloride in normal saline, another 10 lesions with 0.1 ml of adrenaline 1 : 10,000 in normal saline, and 10 lesions with normal saline only. Control measurements were performed with both the piezoelectric and the photoelectric pulse meter before each procedure. Successive recordings were taken every 24 hours during the occlusive treatment which lasted 3 days, and at 10, 20 and 40 min after each injection. Controls were also taken 24 hours after conclusion of the occlusive treatment. Scales were carefully removed at least 20 min prior to the first recording so as not to influence the cutaneous circulation during the registration. Piezoelectric and photoelectric pulse registrations were also performed close to each lesion. In order to obtain identical concentrations of steroid, equal amounts of ointment were applied to equal areas of lesion (4 cm^2) using tubes of

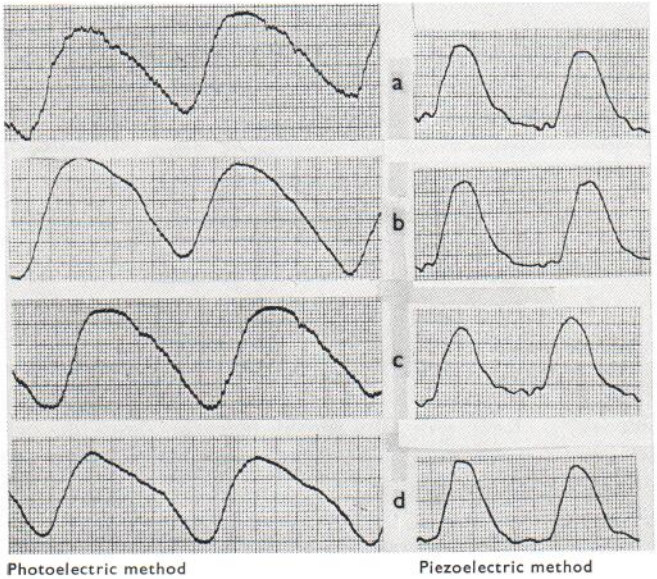

Fig. 5. Effect of intradermal acetyl-beta-methyl-choline. (*a*) before injection; (*b*), (*c*), (*d*), 10, 20 and 40 min after injection.

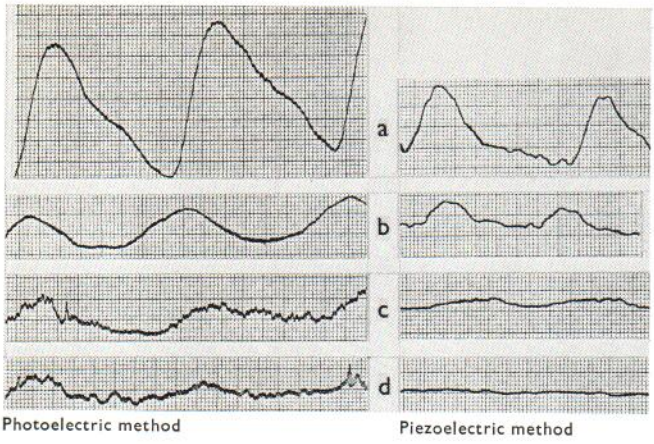

Fig. 6. Effect of intradermal adrenaline. (*a*) before injection; (*b*), (*c*), (*d*), 10, 20 and 40 min after injection.

the same calibre. The lesions were occluded with plastic wrap which was secured by pieces of tape and then covered with adhesive occlusive strapping. Ointment was applied after the first registration only and the occlusive bandage was changed at each test.

RESULTS

Fig. 4 shows recordings from affected and unaffected skin. No pulsations could be obtained by the piezoelectric pulse meter from unaffected skin close to the lesions whereas the opacity pulse meter showed waves with only small amplitudes. The pulse waves obtained by the piezoelectric method from psoriatic lesions showed mostly a rather slow ascent and descent with a somewhat flattened crest as compared with the opacity pulses. They were also more influenced by the mechanical and electrical noise level of the system disturbing the curve. Presumably the pulsations are generally smaller than those obtained by the photoelectric method, although in some subjects the pulse amplitudes were exceptionally large with concave descending branch. This comparison must be judged with caution, however, since one is dealing with two different methods.

During occlusive treatment with betamethasone-17-valerate the pulse amplitudes were gradually reduced as recorded by both methods (Fig. 4). The piezoelectric pulse waves disappeared at 72 hours whereas the opacity pulses were scarcely obtainable at this time. However, at 24 hours after conclusion of the treatment both the piezoelectric and opacity pulse amplitudes showed approximately the same height as before the treatment. Occlusive treatment with placebo did not alter the pulse amplitudes.

Injections with methacholine caused no visible alterations of the pulse waves (Fig. 5), whereas the pulse amplitudes were successively reduced after the adrenaline injections (Fig. 6). At 40 min after the injection only small opacity pulses could be recorded, while the piezoelectric waves disappeared. Injections with normal saline had no effect on the pulse waves. The results obtained were uniform although the pulse amplitudes showed some interindividual variations as regards the height of the pulse amplitudes.

DISCUSSION

Pulse plethysmography has previously been used for studying the microcirculation (8, 15, 19, 24, 30) and has furnished valuable information on the function of small blood vessels. Recently Ramsay (21) and d'Agrosa & Hertzman (7) have stated the significance of the pulse amplitude in relation to vasodilatation and vasoconstriction. The latter studied opacity pulses and blood flow in frog's mesentery, and found a direct correlation, confirming previously observed relations (9, 10). Such a correlation has been disputed by other investigators (4). One must assume, however, that adrenaline generally produces a reduced blood flow and vasoconstriction which is recorded as reduced pulse amplitudes. Methacholine has the opposite effect. The present paper concerns only vasoconstriction and vasodilatation, the rate of blood flow is disregarded.

It is generally agreed that capillaries do not have intrinsic contractile power, but passively follow changes in their associated arterioles (5). Pulsations of the capillaries in psoriasis have been observed by Davis et al. (6) using capillary micro-

scopy. Normally the pulsatile flow is limited to the arterial side of the circulation, but in psoriasis the skin vessels are dilated with elongated and tortuous capillaries. These pathological changes may thus be responsible for the pulsations observed.

In the present study the results obtained by piezoelectric and photoelectric measurements were nearly identical. Large pulsations were observed in psoriatic lesions indicating vascular dilatation. The effect produced by intradermal injections and the lack of response observed after methacholine, indicate that the dermal vessels are in a state of maximal vasodilatation, and prove that the piezoelectric pulsations originate in the skin vessels. This is furthermore confirmed by (1) the fact that piezoelectric pulses could not be obtained from normal skin close to the lesions, (2) the opacity pulse amplitudes were considerably increased in psoriatic lesions as compared with unaffected skin, and (3) intradermal injections with normal saline into the lesions and placebo ointment had no effect on the pulse amplitudes. These results indicate further that the surface of active lesions pulsates.

During occlusive corticosteroid treatment the pulse amplitudes were reduced, whereas placebo caused no such effect. As far as the above discussed results and the observations of others (7, 18, 21, 25) about the significance of the pulse amplitude are concerned, one must assume that the reduced pulse height is caused by the vasoconstrictive activity of betamethasone-17-valerate.

The vasoconstrictive properties of corticosteroids have been used by many investigators for assaying new derivatives (1, 16). The vasoconstriction test has been a major advance and has shown that clinically effective corticosteroids are potent pallor inducers. The relationship between vasoconstrictor potency and clinical usefulness has, however, been disputed (27), and the mode of action of corticosteroids in inducing skin pallor is controversial (1). Photoelectric measurements of the pulse amplitude in normal or diseased skin presumably make is possible to investigate the vasoconstrictive activity of steroids. Such investigations may also yield information concerning the effect on the microcirculation.

Fig. 4 shows that only a moderate reduction in pulse amplitude was observed after 24 hours of occlusion, indicating a small vasoconstrictive effect. This requires the consideration of two possibilities. The first is a reduction of blood in only the most superficial vessels. The second is that only a small degree of vasoconstriction has occurred at this moment. From the works of the Pater et al. (20) and Ramsay (21) one might expect an increase of the pulse height if the volume of blood decreases in the most superficial vessels, i.e. the capillaries and veins only. More light would then reach the pulsating vessels; the variation in reflected light would consequently be larger, causing an increase of the pulse amplitude. This did not occur. Also some reduction of the pulse amplitude was observed by the piezoelectric method which is independent of the light absorbed. The results obtained thus indicate a low degree of vasoconstriction of the dermal vessels at 24 hours of occlusion with corticosteroids. This explanation does not exclude the possibility of decongestion of the capillaries of the dermal papillae (1, 22) and it accords with the skin pallor observed in the vasoconstriction test. It also implies that capillary pulsations observed in psoriasis (6) might be responsible in part for the pulse waves obtained from untreated lesions.

At 48 hours of occlusion a further reduction in pulse amplitude was observed with both the piezoelectric and photoelectric method, and the small opacity pulse records at 72 hours indicate a high degree of vasoconstriction of the dermal vessels, confirming the results obtained by the piezoelectric method. The piezoelectric pulse waves, however, disappeared after 72 hours of steroid occlusion whereas the opacity pulses were barely perceptible. The two methods are not directly comparable although both depend on the volumetric variation of the vessels produced by internal changes in pulse pressure. The piezoelectric transducer is only influenced by the pressure variations caused by the pulsating skin surface, whereas the photoplethysmographic method is based on the large difference between the extinction coefficient of whole blood and the tissues of the body. Presumably one may assume that the opacity pulses are recorded from somewhat deeper situated dermal vessels. This indicates that the vasoconstriction is not restricted only to the most superficial vessels, and it also implies that the steroid penetrates for some distance into the skin. Considering the rich vascularization of the papillary dermis, however, it is probable that the ste-

roid molecules only move a short distance before they are absorbed by the blood stream. In the present study, increased vasoconstriction was thus observed at 48 and 72 hours of occlusion as compared with the results obtained at 24 hours. Presumably this may be due to a higher concentration of steroid somewhat deeper in the dermis as produced by the occlusive dressing therapy of longer duration.

At 24 hours after conclusion of the occlusive treatment with betamethasone-17-valerate the pulse waves reappeared and showed approximately the same height as before the treatment. This indicates that the vasoconstrictive activity of the steroid had come to an end after removal of the occlusion. According to Vickers (28) the steroid has not at this moment disappeared from the skin but it is probably absorbed from the dermis and is only present as a reservoir in the stratum corneum and hairfollicles.

Vascular changes following steroid treatment for psoriasis have been studied by Ryan (22) by means of capillary microscopy. He observed a reduction in the number of the papillary vessels and in the tissue fluid so that the sub-papillary vessels could be readily seen. It was also demonstrated that in such cases the sub-papillary venous plexus fills as much from a deeper arterial plexus as from the few papillary vessels. The reappearance of the pulse waves after conclusion of the steroid treatment as demonstrated in the present study, indicates that the induced vascular reaction was of temporary character and for the most part due to the vasoconstrictive effect produced by the steroid. This accords with the findings of Ryan (22) who observed that in the case of atrophy associated with steroid treatment for psoriasis the change in pattern of flow is only later followed by a change in the vessel morphology.

Recordings of the skin pulses for assaying new steroids have previously not been performed. The results discussed above have been obtained in psoriasis, but the development of more sensitive methods like incident light plethysmography will probably make it possible to perform similar measurements in normal skin. Further investigations of this kind may presumably yield more information concerning the percutaneous absorption of steroids and the method may also be employed in studies of the existence of a reservoir in the stratum corneum.

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