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GLUTARALDEHYDE LOWERS SKIN FRICTION AND ENHANCES SKIN RESISTANCE TO ACUTE FRICTION INJURY

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Abstract. Topical glutaraldehyde decreased skin friction and enhanced resistance to friction injury produced at a given load in short-term experiments. A single application produces a detectable effect for up to 3 days. These observations are in part explicable by glutaraldehyde's known antiperspirant action but not entirely, since similar observations have been made with dead skin in vitro. It is suggested that glutaraldehyde and similar materials might be useful where a reduction in friction trauma seems especially desirable, such as in epidermolysis bullosa and porphyria cutanea tarda.

It has been shown that the coefficient of friction (μ) between skin and a variety of materials depends very largely upon the degree of hydration of the surface keratin, dry skin having a much lower friction coefficient than damp skin (1, 4). This in turn depends upon sweating under physiological conditions and it would seem reasonable to expect that any procedure decreasing sweating would reduce μ and thereby the production of friction injury, viz. blisters and erosions.

A variety of topically applied agents can reduce sweat delivery to the skin surface and of these glutaraldehyde is among the most effective (3). Glutaraldehyde is a tanning agent with bactericidal and fungicidal properties and it has been suggested that its effect on sweating is produced by closure of the pores (5). It was decided to examine the effect of this substance on (*a*) the coefficient of friction of skin, (*b*) the time taken to produce friction erosions under standard conditions.

METHODS

A friction-producing machine was manufactured in co-operation with Mr Attila Fogarasi, Lecturer in the Department of Mechanical Engineering, Newcastle University, to whom grateful acknowledgement is due.

The machine consists of a head, a signal oscillating and amplifier system, and a recording unit. The head is composed of a steel U-bar spring as a single sensing element, with the plane of the limbs set vertically and at 90° to the direction of rubbing. The weight of the head, plus additional load, acts vertically on the spring, altering the distance between the plates of a proximity gauge linked to a transducer; horizontal movement similarly alters the gap between the plates of another proximity gauge set at 90° to this. Both movements alter the frequency of a signal passing between an oscillator tuning device, these signals being amplified and then recorded on sensitive paper in an ultraviolet recorder. Thus both load and frictional (horizontal) forces are recorded simultaneously and almost instantaneously as the rubbing head traverses the material rubbed. The head itself consists of a screw-on piece of steel almost hemispherical in shape, over which materials under examination were secured as required (Figs. 1, 2). The rubbing head is attached by a girder arrangement to a framework incorporating a motor capable of 0–50 r.p.m. (Automat, Switzerland) (Fig. 3).

When rubbing the skin, it is necessary to maintain a constant tension, since the coefficient of friction tends to vary unless this is done. Constant tension is achieved by using an extending device with a spring (Fig. 4).

Calibration

(*a*) *Load calibration.* The load transducer was calibrated by placing the head upside down and adding known weights to the U-spring up to a maximum of 1 195 g. The response, measured in millimetres on the chart, was linear up to this limit; the weight of the head was 305.5 g.

(*b*) *Friction calibration.* The friction transducer was calibrated by placing the head and driving shaft vertically, that is at right angles to their normal working position. Known weights were again added up to a maximum of 709 g; the recorder response was linear up to this limit.

Operation of machine

For in vitro experiments the skin or other material was either pinned out on a cork board or stretched to a given tension using the device illustrated in Fig. 4. In vivo experiments were begun by stretching the skin (usually of the forearm) to a given tension in the longitudinal axis

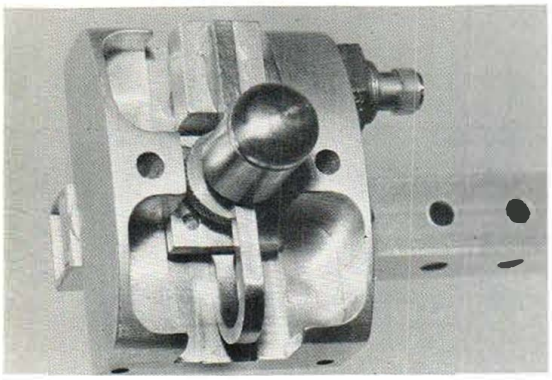

Fig. 1. Rubbing head of friction machine viewed from below.

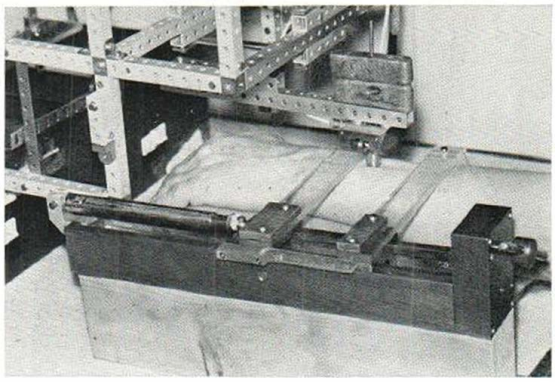

Fig. 2. Rubbing head in position prior to test on extensor surface of forearm.

and a few slow rubs carried out to ensure that the system was working satisfactorily. Zero adjustments were then made with the rubbing head suspended in air above the skin, and then rubbing proper was begun. In most experiments a rate of 90–100 strokes on the skin surface per minute was used. The experiment was ended when an erosion appeared—usually 1–2 mm in diameter. This provided a clear endpoint and the procedure was practically painless if rubbing was not continued beyond this stage. Healing occurred without scarring within a few days. If the experiment was discontinued before erosion occurred, an intact blister arose some 2–6 hours later if sufficient trauma had been inflicted. Histology of specimens from both in vivo and in vitro experiments confirmed that the complete erosion was a "blister equivalent" in that the major split occurred intra-epidermally (Fig. 5).

The friction head was cleaned with 0.5% chlorhexidine in spirit between experiments. Unless the skin was obviously dirty it was not treated in any way before rubbing. After the erosion had been effected, the skin was lightly swabbed with the same solution and a sterile dressing applied. The subject was instructed to leave this in position for 24 hours. No case of sepsis occurred, nor was any other adverse complication noted by any subject al-

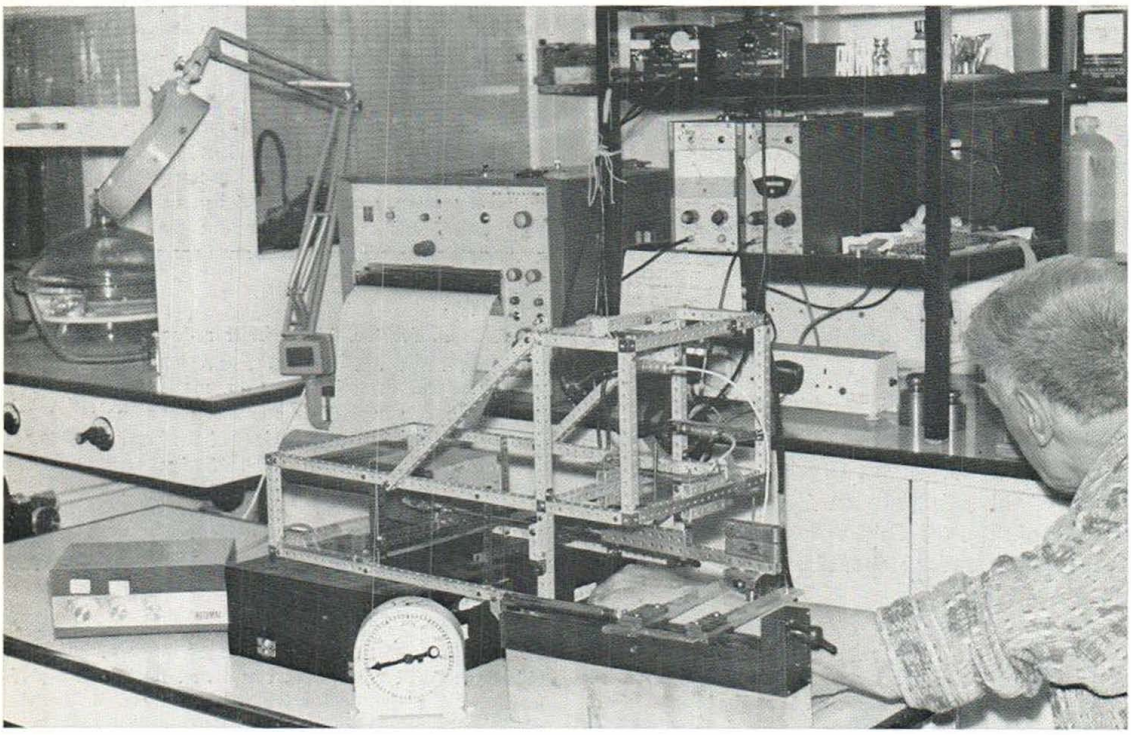

Fig. 3. General view of apparatus in use.

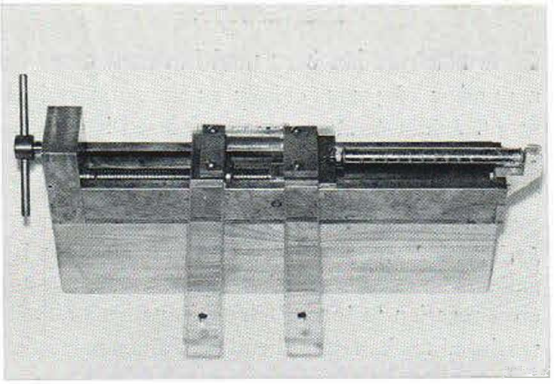

Fig. 4. Skin-stretching device used to maintain constant tension during rubbing.

though some individuals had many erosions produced over a period of several months.

Subjects

The control subjects were the research team (J. S. C., E. B., J. S. and C. B.), volunteers from the medical staff and medical students. Patients who suffered from various skin diseases and to whom the nature and purpose of the experiment were explained were also tested. These were patients who suffered from skin diseases where we believed information about the resistance of their skin to friction trauma might be relevant to further understanding of their disease process, viz. the bullous dermatoses, epidermolysis bullosa, porphyria.

Glutaraldehyde, 5% and 10% aqueous solutions with sodium bicarbonate 1.65% and adjusted to pH 7.0, were used as a 10 minute soak on the skin surface, repeated daily. Saline (0.9%) was similarly applied, to the control side.

Observations on μ and the time taken to produce erosions were then made at varying intervals after treatment; control observations were made on untreated skin, using the symmetrical site on the contralateral arm.

RESULTS

There is an average increase of 50% in the time taken to produce erosions on the glutaraldehyde-treated side (Table I) and this is significant ($t = 2.75$, $p < 0.01$). There is also a significant decrease in μ ($t = 2.90$, $p < 0.05$) with 5 % glutaraldehyde, but a similar decrease in μ with the 10% solution just fails to achieve significance ($t = 2.12$, $0.10 > p > 0.05$). Two subjects were repeatedly tested for periods of up to 3 days following a single application of glutaraldehyde. Table II shows that the effect on μ and erosion time persists during this period at least.

The subjects studied included several with an

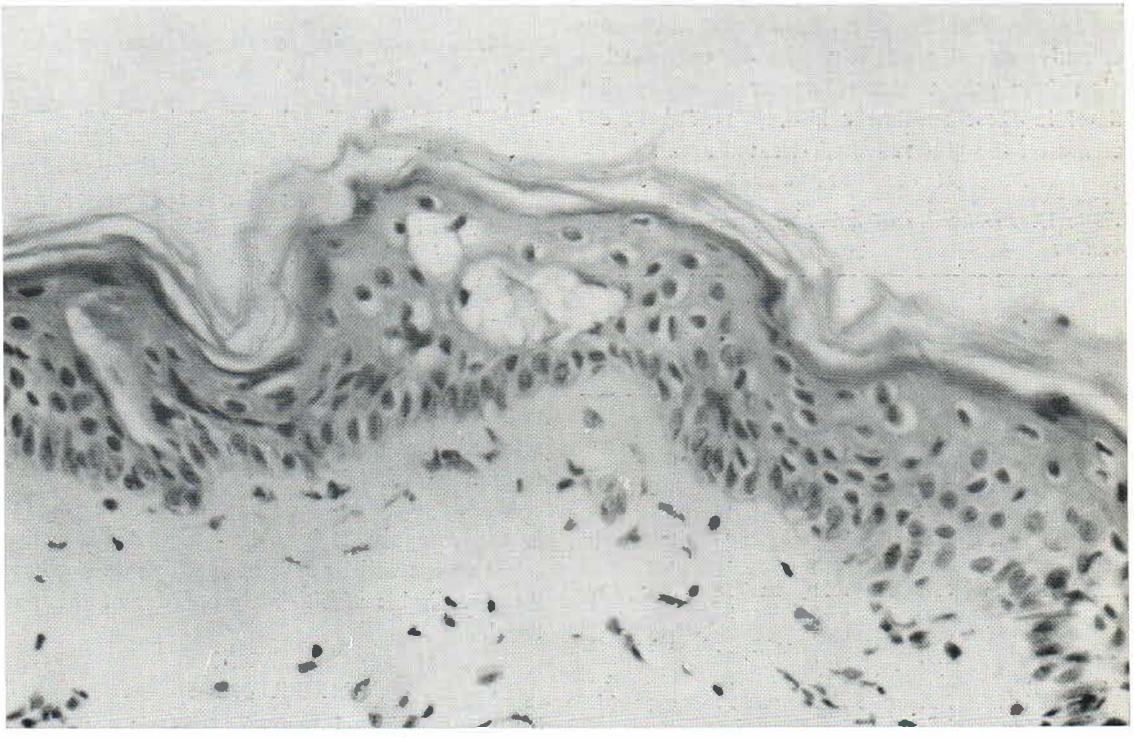

Fig. 5. Early intra-epidermal blister formation at microscopic level (H & E, × 420).

Table I. *Effect of glutaraldehyde on erosion time (minutes)*

Control side	Test side	Comment
1.2	2.5	Breast skin, in vitro
4.4	14.0	Leg (calf), in vitro
4.4	6.4	Leg (thigh), in vitro
10.7	14.8	Normal control ♀ 36
14.2	26.0	Normal control ♂ 38
18.1	35.0	Bullous pemphigoid ♀ 75
16.5	6.9	Normal control ♀ 67
16.1	24.5	Normal control ♂ 73
12.9	30.0	Epidermolysis bullosa ♂ 24 (hands and feet only)
35.3	23.0	Normal control ♀ 19
13.3	30.0	Normal control ♂ 72
10.0	12.0	Epidermolysis bullosa ♂ 33 (blisters anywhere)
7.0	20.6	Porphyria cutanea tarda ♂ 53
12.0	19.8	Control (psoriasis) ♂ 55
10.0	15.0	Pemphigus foliaceus ♂ 66
9.5	10.5	Normal control ♂ 27
Mean ± S.D.		
12.2 ± 7.7	18.2 ± 9.5	

abnormal tendency to blistering (bullous pemphigoid, epidermolysis bullosa, porphyria) and all of these were noted to have increased erosion times with glutaraldehyde. A similar trend was seen in the in vitro experiments indicating that diminution of active sweating might not be the only mechanism involved in the enhancement of erosion time; in these specimens also, μ tended to decrease on the glutaraldehyde-treated areas.

Table II. *Persistence of effect of glutaraldehyde on friction*

Subject and site	μ Control side	μ Glutaraldehyde-treated side	Hours since application
E. B., dorsum of hand	0.39	0.35	18
	0.31	0.29	42
	0.34	0.33	60
E. B., palm of hand	0.43	0.40	18
	0.42	0.26	42
	0.55	0.29	60
J. S. C., dorsum of hand	0.41	0.24	18
	0.45	0.25	24
	0.63	0.29	48
	0.51	0.30	66
J. S. C., palm of hand	0.62	0.31	18
	0.71	0.25	24
	0.33	0.23	48
	0.48	0.37	66

DISCUSSION

Glutaraldehyde has been used in dermatology for a number of years, chiefly as an antiperspirant agent. Juhlin & Hansson (2) reported it as being effective in the treatment of excessive sweating of the feet using a 10 % aqueous solution with 1.65 % sodium bicarbonate 2–4 times weekly. Over a period of 2 years with observations on over 100 patients no allergic reaction was observed, nor any cross-reaction to formaldehyde in patients already sensitised to the latter chemical. Juhlin noted that concomitant bacterial and fungal infections also responded favourably (3).

Our observations indicate that glutaraldehyde decreases both static and dynamic friction, and also increases the amount of rubbing trauma required to produce erosion. The effect on μ lasts for up to 3 days after a single application. This seems true whatever the diagnosis and even where the disease process is associated with subepidermal blister formation as in pemphigoid and epidermolysis bullosa. It would seem feasible that application of 5–10% glutaraldehyde 24 hours before friction trauma might be a useful way to reduce blister incidence and this would only need to be repeated at 2 or 3 day intervals to give continuous protection over a prolonged period.

Weighed against this is the cost of the material and the risk of sensitisation. Extensive usage would almost certainly provoke some subjects to develop allergic contact dermatitis. If reported and diagnosed early this should not be a major problem but only experience can indicate the potential frequency of this particular side effect. A more selective use of glutaraldehyde might be called for—say, by those whose previous record indicates proneness to friction blisters.

Whilst not advocating glutaraldehyde for general use it would seem reasonable to test it in selected cases where an attempt to reduce friction trauma is especially desirable. Such examples as epidermolysis bullosa or porphyria obviously fall in this category. It is to be hoped however that other agents will be developed which do not have the undesirable sensitizing properties of this material.

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