Some Characteristics of Adrenergic Human Eccrine Sweating

A previous report[1] from this department has clarified the quantitative aspect of human adrenergic sweating. The present communication centres on the chemical components of adrenergic sweat, as well as on the ultrastructural alteration of the eccrine sweat gland after epinephrine stimulation. Human as well as monkey eccrine sweat glands are composed of 4 cell types; clear, dark, myoepithelial and ductal cells. If epinephrine stimulates these cells differently from acetylcholine, then secreted sweat of different composition can be expected to occur and the function of each individual type of cell can be further deduced.

Methods. Since the amount of epinephrine-induced sweat is extremely small, an anerobic sweat collection method[2] was used with some modification throughout the study. This method also helps to prevent the contamination of sweat by epidermal components. After thoroughly cleansing and drying the forearm skin of 6 adult men and women, a Lucite ring[3], either 2 cm^2 or 4 cm^2 inside space, was glued to the skin and the inside of the ring filled with paraffin oil. Basic sweating (so-called insensible perspiration) or sweat secretion by the injection of Ringer's solution alone is not detectable, or is negligible under the experimental conditions used. Epinephrine (5×10^{-5} *M*) plus atropine (10^{-5} *M*) in Ringer's solution was injected into the upper dermis of the test site from outside the ring[3]. Outpouring beads of sweat under oil were sucked into a clean glass capillary whose tip had been pulled to a fine point. Sweat was collected every 20 min and was blown out into a small polyethylene sample cup (Coleman Instr. I11.) filled with paraffin oil. The volume of sweat sample was measured with a constant bore glass capillary. Calibrated constriction pipets, volume range from 0.2 to 3 µl, were used for taking an aliquot of the sweat sample for the determination of Na^+ and K^+ with an Eppendorf flame photometer, lactate with the enzymatic method[4] and protein by the method of LOWRY[5]. Injection of epinephrine causes a strong local vasoconstriction and thus ischemia of the test site. In an attempt to differentiate the effect of the interference with the blood supply per se on the sweat components, a tourniquet was applied for 10 min on one arm during the sweat induction in the forearm skin with i.d. injection of Mecholyl (5×10^{-3} *M*). The methods of sweat induction, collection and determination of electrolytes have been previously described[6]. For the electron microscopic study, human as well as monkey palm eccrine sweat glands (an ideal model for the human eccrine sweat gland[7]) were isolated and incubated for 30 min in Ringer's solution with or without the addition of Mecholyl or epinephrine. The sweat glands were then prefixed in glutaraldehyde, postfixed in OsO_4 and were processed for the ordinary epon-embedded ultrathin section.

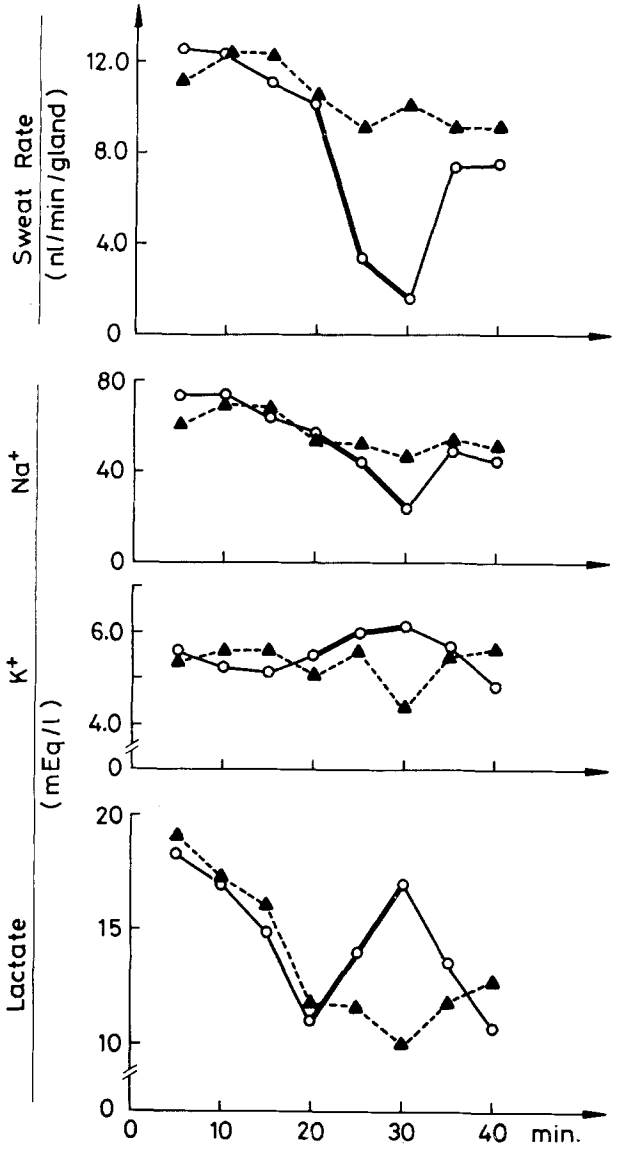

Fig. 1. Effect of arterial occlusion on sweat rate, Na^+, K^+ and lactate contents of Mecholyl-induced sweat in a typical experiment. Open circle, right forearm where a tourniquet was applied from time 20 min to 30 min illustrated with thick lines. Closed triangle, left forearm used as control. Sweat samples were collected serially at 5 min intervals.

Results. As listed in the Table, adrenergic sweat showed a considerably smaller sweat rate, being only 1/5 to 1/10 that of cholinergic sweat. In most cases sweat secretion lasted for more than 1 h although the flow rate dropped markedly after 1 h (data not shown). Both Na^+ and K^+ concentration were within the ranges of those of cholinergic sweat[6]; however, when related to the sweat rate, Na^+ concentration in adrenergic sweat of between 45 to 35 mEq/l can be regarded as considerably higher than that of cholinergic sweat[6]. Lactate concentration is also within the range of that of cholinergic sweat[8] (see also Figure 1). Protein concentration in adrenergic sweat was twice as high as in cholinergic sweat in all 3 cases studied. Figure 1 shows that ischemia causes a marked drop in flow rate and a marked increase in lactate concentration in Mecholyl-induced sweat. The decrease in Na^+ concentration can be ascribed to a drop in sweat rate. Figure 2 is an electron microscopic picture of human sweat gland after

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Data given as mean ± SEM ($n = 6$) except for protein ($n = 3$)

Sweat collection period (min)	Sweat rate (µl/20 min/cm²)	(nl/min/gland [a])	Na^+ (mEq/l)	K^+ (mEq/l)	Lactate (mM/l)	Protein (mg/100 ml)
Adrenergic sweat						
0–20	0.90 ± 0.20	0.42 ± 0.10	43.4 ± 7.5	10.1 ± 1.1	15.4 ± 1.51	38.1
20–40	0.69 ± 0.19	0.32 ± 0.09	45.3 ± 9.0	14.6 ± 2.5	19.3 ± 0.22	37.5
40–60	0.56 ± 0.18	0.26 ± 0.09	35.0 ± 5.5	18.0 ± 4.6	19.3 ± 2.27	38.9
Cholinergic sweat [b]						
0–20	5.75 ± 1.40	2.85 ± 0.69	—	—	—	19.0

[a] Mean sweat pore number per cm² of 108 was used for calculation. [b] Mecholyl (10^{-3} M) was injected into the test site of the other forearm as control and only protein contents were measured ($n = 3$).

incubation with epinephrine. There was no essential difference between Mecholyl and epinephrine stimulation in both human and monkey eccrine sweat glands. The most significant finding is the dilatation of intercellular canaliculi and of the lumen of the secretory coil after the pharmacological stimulations. In no cases did we observe a clear-cut picture showing the release of dark cell granules into the lumen.

Discussion. We have recently reported [9] that an isolated monkey palm eccrine sweat gland secretory coil responds equally well to both Mecholyl and epinephrine by secreting isotonic sweat in vitro. The present report provides additional evidence that both cholinergic and adrenergic drugs stimulate the secretory coil in a similar, if not identical, manner. A marked dilatation of intercellular canaliculi is interpreted as evidence that epinephrine did induce secretion of sweat, and that adrenergic sweating is not just due to the contraction, if any, of myoepithelial cells and the expulsion of preformed sweat. This is further supported by the following comparison between the adrenergic sweat rate and the space of the secretory coil lumen. Mean protein content per 1 human forearm sweat gland of 2.3 µg [9] gives an approximate wet weight of 30 µg for the whole gland and 15 µg (15×10^{-6} cm³) for the secretory coil, assuming that the duct comprises half the volume and the specific gravity of the wet tissue is unity. Thus the adrenergic sweat rate 20 nl (20×10^{-6} cm³) far exceeds the total space of the secretory coil lumen, which is much smaller than the volume of the secretory coil itself. The low in-vivo adrenrgic sweat rate can probably be explained by a vasoconstrictive effect of epinephrine, since ischemia alone markedly suppresses cholinergic sweat (to 15% of control). The significance of the doubled protein content in adrenergic sweat is not clear since we were unable to obtain comparably low and sustained sweat rates with Mecholyl for comparison with the protein content in adrenergic sweat, and since we have no data on the water reabsorption (permeability) of the duct.

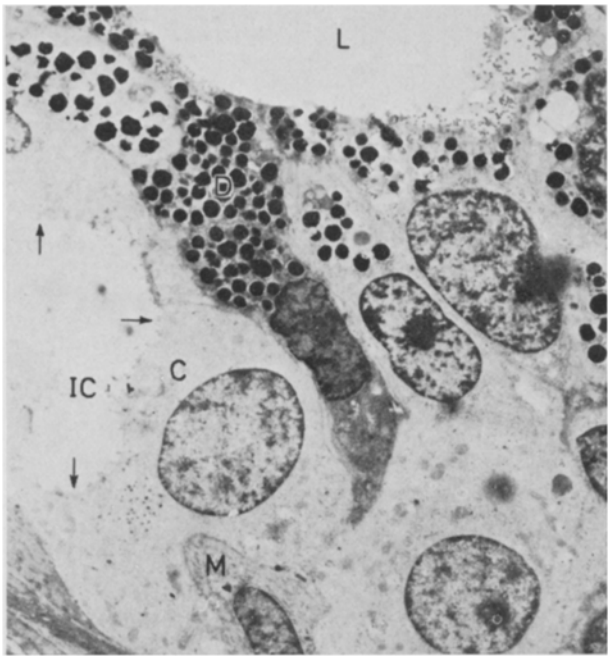

Fig. 2. Electron micrograph of isolated human eccrine sweat gland incubated in epinephrine containing Ringer's solution. L, lumen; D, dark cell; C, clear cell; IC, intercellular canaliculi- markedly dilated as shown by arrows; M, myoepithelial cells. ×3,800.

Zusammenfassung. Durch Epinephrine stimulierte menschliche Schweissdrüsen produzierten ein Sekret, welches 35–45 mÄq/l Natriumionen, 10–18 mÄq/l Kaliumionen und 15–19 mÄq/l Lactat enthielt. Adrenergisch stimulierter Schweiss hat demnach eine ähnliche Zusammensetzung wie cholinergisch stimulierter Schweiss. Mit dem Elektronenmikroskop liess sich nach der Stimulation durch Epinephrin eine deutliche Erweiterung der interzellulären Kanälchen zeigen. Diese und andere schon berichteten Beobachtungen sprechen dafür, dass Epinephrin die sezernierenden Zellen in einer ähnlichen Weise wie die cholinergischen Pharmaka direkt stimuliert.

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