Hyperosmotic Secretion at Low Transport Rates in the Cat Sweat Gland

Evidence for Two Separate Potassium-Release Mechanisms

J. F. G. Slegers and W. M. Moons
Department of Physiology, University of Nijmegen, The Netherlands

Received May 29, 1973

Summary. The hypertonicity of the secretory fluid produced by the cat sweat gland is due to a potassium release mechanism which operates in series with an isosmotic NaCl transport process.

The potassium excretion rate is not coupled with volume flow but is determined by the frequency of electrical stimulation.

Evidence is presented for the presence of two potassium release mechanisms during the secretory process. A small potassium flux is due to cellular redistribution at the onset of stimulation potassium secretion perhaps originating from dark cells. The major potassium flux is related to the bicarbonate excretion rate.

Key words: Potassium-Release Mechanisms — Isosmotic NaCl Transport — Hyperosmotic Secretion — Sweat Gland.

The sweat glands of the cat’s paw produce a hypertonic primary fluid, especially at lower rates of transport when osmotic equilibration would be expected to be most nearly complete (this paper). This was also found for the salivary glands by Burgen (1956) and Petersen (1967). Schulz (1969) also measured a hypertonic fluid in the human sweat gland coil and suggested that the reflection coefficient of the solution, responsible for the driving force in fluid movement, changes in proportion to the state of stimulation. Since sodium is probably the actively transported ion species in most glandular systems, the reflection coefficient for sodium should change with the transport rate. However, the sodium concentration of the primary fluid remains constant and equals the plasma level et all stimulation frequencies (Slegers et al., 1971). This, together with the available information on the threedimensional ultrastructure of the glandular cells, led us to postulate a modified model based on a standing osmotic gradient system described by Diamond et al. (1967) and Slegers et al. (1971). This model, however, did not account for hypertonicity, because we were not aware of this at that time.
Based on the observation of Burgen (1956) and Petersen (1967) it seemed worthwhile to investigate more carefully the pattern of potassium excretion and the osmolarity in an attempt to explain the discrepancy between the prediction of the model and the observed hypertonicity. The results of this study suggest that the hypertonicity is due to a potassium-release mechanism operating independently of the standing osmotic gradient system.

Methods

Sweat glands of the cat’s paw were used because they have a short, non-functioning, rudimentary duct (Munger et al., 1961). For this reason the fluid delivered on the skin surface has the same composition as the primary secretory fluid.

Cats were anaesthetized with sodium pentobarbital. Sweat secretion was generated by electrical stimulation of the lateral branch of the internal plantar nerve. The secretion rate was measured as described earlier (Slegers, 1968) and recorded.

For direct cryoscopy a small lucite cup glued onto the pad was filled with mineral oil and the appearance of droplets was observed microscopically. A glass micropipet with a tip diameter of about 15 μm was inserted into the droplet with a micromanipulator and sweat collected by capillary attraction or by gentle application of negative pressure. After collection the samples were transferred immediately to a nanoliter osmometer (Clifton Technical Physics). A modified sample holder of 1 mm thick gold plate was used. To achieve better heat conductivity between sample holder and the freeze unit, the diameter of the holder was enlarged to 1 cm.

The central portion, 0.5 mm thick, contained 9 channels with a diameter of 0.4 mm. Sample sizes were of the order of 1—2 nanoliters. Standard NaCl solutions of 350 and 500 mOsm/L were used for calibration. The percentage error in 130 determinations with the lowest concentration was 4.0%. Seventy-four determinations with the higher concentration showed an error of 2.4%.

Sodium and potassium concentrations were determined by flame photometry.

The potassium excretion rate was measured by filling the lucite cup with distilled water (50 μl) which was removed each minute with an Eppendorf micropipet.

Results

Hypertonicity and isosmotic NaCl transport: Sodium secretion at different frequencies of electrical stimulation is linearly correlated with flow rate (Fig. 1). Since the slope is a measure of sodium concentration, the sodium concentration must be independent of both flow rate and stimulation frequency. The values obtained are shown in Table 1. These differ from the observations of Foster (1966) who reported an increase in sweat sodium concentration from 135 mEq/L at low rates up to 160 mEq/L at high rates. With respect to the potassium concentration, however, our findings agree with those of Foster. The upper part of Fig. 2 shows the relation between sweat rate and frequency of stimulation, the bottom part shows the measured potassium concentration for the corresponding stimulation frequencies. The continuous line