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MEASUREMENT OF WATER VAPOR LOSS THROUGH HUMAN NAIL *IN VIVO**

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ABSTRACT

A capsule is described which can be used for the measurement of the water vapor loss of the nail with the aid of the same instrumentation that has been used for the measurement of the water vapor loss of skin.

The effective area of the described capsule has been determined applying an electric analog.

The specific water permeability of the nail plate appeared to be independent of nail thickness in the finger nails of a healthy volunteer.

The water vapor loss from the nail is of the same order as the water vapor loss from the skin of the palm; it is relatively high in comparison with the water vapor loss from most parts of the human body (1–3). The reliability of the methods used previously may be criticized because the possibility of displacement of the normal water flow through the nail by the rim of the measuring capsule was not considered.

METHODS

Water vapor loss measurement. Dry nitrogen or dry air (less than 5 ppm water by volume) is passed over the nail. The gas is led through a capsule attached to a polyethylene tube of the same diameter as the opening of the capsule (Fig. 1). The water loaded gas is led into an electrolytic water analyzer. Except for the polyethylene tube, the method is exactly the same as the one published before for the measurement of the water vapor loss from skin (7). The pressure of the capsule upon the nail is greater than the pressure of the skin capsule upon the skin, since considerable force must be exerted in order to keep the capsule closely connected to the nail in spite of the flexibility of the polyethylene tubing. However, the deformation caused by the pressure of the capsule in skin measurements is not significant in measurements performed on the more rigid nail material.

The environmental circumstances of the measment are the same as those for the measurement of water vapor loss from the palm. The main precautions are to keep the subject calm and the temperature of the environment at about 18–19° C in order to avoid sweat gland activity.

The water vapor loss from the nails of all fingers of a healthy volunteer was measured for 15 minutes on three successive days.

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The standard deviation of the measurements was determined subsequently and was found to be less than 15%.

Thickness measurement. The thickness of the nail plate was measured by means of a vernier caliper.

Electric analog. The real effective capsule area was determined by means of an electric analog (Fig. 2). The interfaces a) nail plate/inside of capsule, b) nail plate/outside atmosphere, c) nail plate/nail bed, were represented by copper plates; the interface d) nail plate/polyethylene tube of capsule, was represented by a plastic insulating ring. The water potential between the nail bed and the nail plate was represented by a 30 mV electric potential. The nail plate material was represented by a 2% acid copper sulfate solution in dioxane. This solution was chosen since it undergoes minimal electrolytic decomposition with a 30 mV electric potential. The thickness of the nail plate was represented by the distance between the copper plates. The water permeation was therefore represented by the electric current measured.

Figure 2 shows the apparatus set up as an analog of the actual water loss measurements on skin, including the effects of the displaced flow due to the rim of the polyethylene tubing. By lowering the insulating ring, through the copper sulfate solution, to the lower copper plate, a model is obtained of the situation where no lateral "potential flow" occurs. The ratio between the two values obtained from the analog provides a correction factor for the skin measurements.

RESULTS

Water vapor loss. The standard deviation expressed as a percentage of the water vapor loss measurements was 11%; the same value as has been found in water vapor loss measurements on the skin of the forearm and the palm (6).

Results of the measurements of the water vapor loss from normal finger nails are shown in column B of the Table. The results are similar

to the results of other investigators (1–3). It is moreover obvious that the thicker nail yields the smaller water vapor loss. Therefore the "specific" water vapor loss has been calculated from the values of column B by multiplying these values with the thickness of the relevant nail plate (Column A). The results are shown in column C.

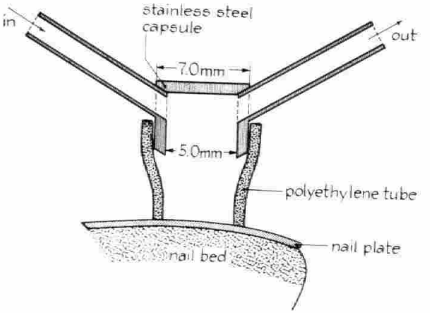

FIG. 1. Capsule for carrying water loaded gas from the nail surface to the analyzer.

Electric analog. The results of the experiments with the electric analog indicated that when the thickness of the nail plate was between 0.4 and 0.8 mm and the humidity of the ambient atmosphere was between 20 and 80% at 19° C, the effective area of the described capsule appeared to be between 0.27 and 0.25 cm^2. For the sake of simplicity the effective area of the capsule was considered to be 0.26 cm^2. The actual inner diameter was 0.20 cm^2, and the outer was 0.38 cm^2.

DISCUSSION

Normal water vapor loss is disturbed by placing the capsule upon the nail plate. Because of the relative thickness of the nail plate the water from the nail bed will reach the inside of the capsule through the nail plate along the flow lines which indicate the direction of the potential gradient, illustrated schematically in the

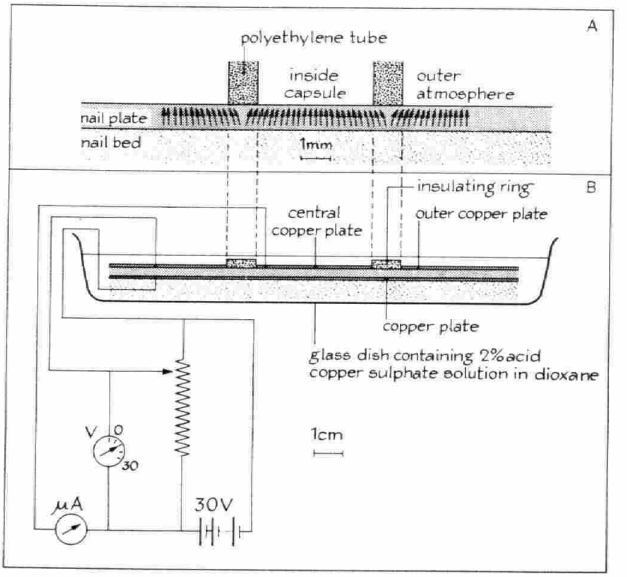

FIG. 2. The upper part of the figure (A) shows the route of the water penetrating the nail plate when a capsule has been mounted. The lower part of the figure (B) illustrates the electric analog used for the determination of the effective permeating area under conditions of variable humidity of the outer atmosphere (variable voltage between outer and lower copper plate) and of variable nail thickness (variable distance between upper and lower copper plates).

upper part of Figure 2. The amount of water reaching the inside of the capsule will, therefore, be related to an area of the nail which exceeds the 0.20 cm^2 internal area of the capsule. The effective area of permeation is dependent upon the thickness of the nail plate and the humidity of the outer atmosphere. The influence of the thickness of the nail plate was studied with the electric analog (Fig. 2, lower part) by raising and lowering the lowest copper plate; the influence of the humidity of the atmosphere was studied by varying the electric potential of the outer copper plate. The results of these variations are largely dependent on the dimensions of the analog, which are analogous to the dimensions of the capsule used in the measurement of the water vapor loss. The sum of these variables gives an effective permeation area of 0.27–0.25 cm^2 and is, therefore, only valid for the described capsule when used on the nail and similarly thick layers. The effective capsule area is therefore 0.26 ± 0.01 cm^2. This variation may be ignored in the measurement of the water vapor loss as it causes an error of less than 4% while the relative standard deviation of the measurement of the water vapor loss is some 10%.

The nail plate has been described as consisting of three different layers; a dorsal, an intermediate and a ventral part (4). Lewis (5) states that there is "a dissimilar variable pattern in the mature digit". If there were any marked differences between the permeability of those different layers, this would appear as a difference in the permeability per unit thickness found for different nails; this is not seen.

The specific permeability of various finger nails may therefore be compared to each other. The specific water vapor loss (Table, column C) being the product of the measured total water vapor loss and the thickness of the nail (Table, columns B and A) has been calculated assuming that this "specific" water vapor loss is constant for all of the healthy nails of one individual. The mean specific water vapor loss appeared to be 0.130 mg/(cm·hr) in the investigated individual; the values of the various individual nails are scattered about this average value, including the thick thumb nail and the thin nail of the little finger, the standard deviation being only 7.5%. Obviously in these experiments the *specific* water vapor loss was the same for all nails of the fingers of the healthy individual.

TABLE

Permeation of water through the nails of the 10 fingers of a healthy human being

Hand	Finger	A Nail thickness in: mm	B Water vapor loss (permeation) in: mg/(cm²·hour)	C (= B·0.1 A) Specific water vapor loss (spec. permeability) in: mg/(cm·hour)
left	thumb	0.70	1.85	0.130
right	thumb	0.65	1.91	0.125
left	index	0.58	1.98	0.120
right	index	0.60	2.18	0.130
left	middle	0.54	2.41	0.130
right	middle	0.48	2.23	0.110
left	ring	0.48	3.00	0.145
right	ring	0.48	2.65	0.135
left	little	0.46	3.07	0.140
right	little	0.47	2.77	0.130
Mean of all nails		0.54	2.40	0.130

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