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# Measurement of Water Transport Through the Skin

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Dedicated to Torsten Teorell

ABSTRACT

A method for measuring water exchange through human skin has been developed. It is based on estimation of the vapour pressure gradient immediately above the surface of the skin and permits the skin area investigated to be exposed to the ambient air during the entire period of measurement. Influence on the microclimate above the skin, with respect to humidity and temperature, is thereby minimized. An instrument for measuring small amounts of water evaporated from or absorbed by a surface per unit time and area is described and its accuracy discussed. The instrument has a high degree of accuracy and better sensitivity than previously described devices used for this purpose. It has been used primarily to investigate the rate of evaporation from the skin surface in newborn infants and from the skin in patients with burns.

## INTRODUCTION

In neonatal intensive care (1,2,3) and in the care of patients with burns (4,5) quantitative measurement of water transport through the skin can contribute to better treatment and to a more thorough understanding of the mechanisms underlying the transport process. It can also be of value in studies of physiological phenomena such as periodicity in sweat production (7).

In earlier investigations of insensible water loss, several methods have been applied. These have included measurement of the amount of water vapour supplied to and leaving a closed ventilated chamber, and gravimetric techniques. All these methods had disadvantages in the clinical situation, as they are difficult to use in critically ill patients and do not allow measurement of rapid changes in evaporation. Inaccuracy may also be introduced by condensation or absorption of water in surrounding materials or by

long-term instability in the measuring equipment.

For a method to be suitable for both scientific and clinical use, it should permit:

- direct measurement of the evaporation rate from the skin surface
- free evaporation from the skin surface
- quick measurements
- repeated measurement at short intervals
- measurement of relatively rapid changes
- measurements without discomfort to the patient.

On the basis of the thermodynamic theory for diffusion of water vapour in air, a method satisfying the above requirements has been developed (6). This paper gives a brief description of the method and of its application in neonatal care and in studies of periodic sweating.

## METHOD

In the air layer immediately above an evaporative or absorptive surface there is a linear relationship, in the absence of air currents, between the vapour pressure and the distance from the skin surface. It is thus possible to calculate the amount of water evaporated per unit area if the vapour pressure at two distinct points situated on a line perpendicular to the skin surface is known, using the expression

$$\frac{1}{A}\frac{dm}{dt} = -D' \frac{\partial p}{\partial x}$$

where

$\frac{1}{A}\frac{dm}{dt}$ is the evaporation rate ($g/m^2h$)

$D'$ is a constant ($0.670\ 10^{-3}$ g/mhPa)

$\frac{\partial p}{\partial x}$ is the vapour pressure gradient (Pa/m).

The relative humidity is measured with capacitive thin-film sensors based on an organic polymer dielectric, sensitive only to changes in relative humidity. The temperatures are measured with fast thermistors. The sensors are protected from mechanical damage and air currents by a polytetrafluorethylene (Teflon) cylinder that can be removed and sterilized.

The signals from the sensors are processed in two identical amplifier channels for evaluation of the relative humidity and the vapour pressure at the two points of measurement. The difference

between the signals is low pass filtered, presented on a digital display and supplied to an analogue output. The instrument gives data on the evaporation rate (ER, $g/m^2h$), the relative humidity and the vapour pressure at each point of measurement.

## RESULTS

The use of the instrument is exemplified by its application in neonatal care (1) and in the study of periodic sweating (7). In newborn infants ER was measured at 18 different skin areas, representing all parts of the body surface. The measurements were made on the first day after birth under standardized environmental conditions and with the infants at rest. Particularly high ER values were found on the forehead (18 $g/m^2h$) and the palm of the hand (19 $g/m^2h$), with lower values on the abdomen and the chest, for instance. From the areas of the evaporative surfaces and the ER data the mean evaporation, i.e. the transepidermal water loss (TEWL, $g/m^2h$) was obtained.

The correlation between TEWL and the arithmetic mean of the ER values from different combinations of a few measurement sites was tested. It was found that the ER values from an interscapular skin area (a), the chest (b) and a buttock (c) could be used to estimate TEWL with reasonable accuracy, using the equation

$$TEWL = 0.92\ \overline{ER}_{(a,b,c)} + 1.37$$

At room temperature the humidity sensors have time constants of less than one second, which means that rapid fluctuations in water transport from the skin can be measured. In recent studies (7) it has been shown that water evaporation from the skin varies rhythmically with a period of about 0.7 s.

## CONCLUSIONS

With this measuring system, which allows rapid and accurate measurements of the evaporation rate, it is possible to study the water transport through the skin under conditions of intensive care both in newborn infants and in patients with burns. Rhythmic phenomena in sweating have been revealed.

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