Albumin Permeability Times Surface Area (PS) Product of Peritubular Capillaries in Kidney

In 1964, RENKIN[1] proposed a formula for quantitative estimation of capillary permeability:

$$PS = L \cdot \frac{R}{1 - R} \quad (1)$$

where P (cm/sec) is permeability, S (cm^2) is capillary surface area, L (ml/sec) is lymph flow from unit volume of tissue and R is the ratio of concentrations in lymph over plasma of the substance under study. The PS product (ml/sec) represents that volume of plasma which gives up its content of the particular solute to interstitial fluid per unit time, and is given, as a rule, as a value for 100 g tissue. In deriving this formula. RENKIN considered 3 processes that contribute to the formation of lymph: a) Bulk filtration from and b) bulk reabsorption into the capillaries, and c) diffusional exchange between plasma and interstitial fluid. Simplifying assumptions were introduced, and it is implicit in formula (1) that diffusion is the principal mechanism of transport between capillary and interstitial spaces. By substituting the following quantitative estimates obtained in non-hydrated dogs into formula (1): total renal lymph flow = L = 0.005 ml/sec per 100 g kidney[2], and $R = 0.5$[3], we calculate a PS value of 50×10^{-4} ml/sec per 100 g kidney. Since renal lymph originates mostly from the cortical region[4,5], this figure should characterize primarily the peritubular capillaries in the kidney.

Owing to the unique fluid circulation in the kidney, it appeared questionable whether RENKIN's formula could be applied to this organ. The major points to consider were that 1. along their entire length there is a large net inflow of tubular reabsorbate into the peritubular capillaries and 2. a free diffusion of macromolecules between capillaries and interstitium may be modified by this bulk flow. It seemed uncertain whether the simplifying assumptions invoked by RENKIN for other tissues were equally applicable to the kidney. We have used a supplementary method in deriving the PS product for the renal peritubular capillaries to albumin, based on a kinetic analysis of the interstitial albumin pool. We considered that the interstitial pool of albumin in the kidney, M (g), is in a state of turnover because there is a continuous flux of albumin through the pool, as molecules enter from the capillaries and leave through the lymph and, possibly, by way of return into the capillary blood In steady state the following formula applies[6,7]

$$PS \cdot c_p \cdot \bar{t} = M \quad (2)$$

(where c_p stands for the arterial plasma concentration of albumin) i.e. the flux of albumin multiplied by the mean transit time of albumin molecules through the pool equals the quantity of albumin in the pool. It follows that

$$PS = \frac{M}{c_p} \cdot \frac{1}{\bar{t}}$$

Here M/c_p is the distribution space of extravascular albumin.

In earlier experiments we have measured the quantities on the right hand side of the last equation. The average value of the extravascular albumin space in renal cortex of dogs that received no fluid load was 7.0 ± 1.0 (SEM) ml/100 g tissue[8]. In animals under similar experimental conditions the mean transit time of albumin from plasma to renal lymph was 24.5 ± 1.6 (SEM) min for capsular and hilar lymphatics studied separately and/or simultaneously[9,5]. By substituting these figures we obtain a value of 48×10^{-4} ml/sec per 100 g tissue which is essentially the same as that calculated by using formula (1) and is comparable to a PS product found by GARLICK and RENKIN[10] in dog paws after exposure to 45 °C temperature.

This value, although high, is in accord with other available information. Morphological evidence shows that the structure of the renal peritubular capillaries is compatible with a high permeability to macromolecules[11]. It is also pertinent that a large proportion of the peritubular capillaries is continuously open and functioning in contrast to capillaries in many other tissues. Recent experiments have also indicated that in anesthetized and immobilized dogs approximately 40% of the thoracic duct lymph flow was derived from both kidneys[2], a finding that points to a relatively high rate of drainage of extravasated plasma proteins from this organ.

Although entirely different assumptions are implicit in both calculations of the PS product, the results are nearly identical. It seems, therefore, that RENKIN's formula for macromolecules may be valied beyond the domain of the assumptions that were made explicit in its original derivation.

Résumé. La perméabilité à l'albumine des vaisseaux capillaires fut caractérisée par le produit PS de RENKIN[1]. Cette mesure fut obtenue par une analyse dynamique de la quantité d'albumine contenue dans les interstices de la zone corticale du rein.

G. G. PINTER, J. L. ATKINS and D. R. BELL

Department of Physiology, University of Maryland, School of Medicine, Baltimore (Maryland 21201, USA), 27 May 1974.

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