Pressure and Flow in Proximal Tubules of Rat Kidneys

The technique of collecting tubular urine in rats has involved blocking of the tubule with oil or mercury droplets, and collection of the urine against a slight positive pressure[1]. The question may be raised as to whether the pressure relationships are such, that the collecting procedure interferes with the process of urine formation since a positive tubular pressure may (1) reduce glomerular filtration; or (2) cause bulk transfer of the tubular contents across the tubular wall. Either of these two possibilities would result in a reduction of urinary flow at the site of collection. The experiments to be described are concerned with the measurement of minimal flow rates in proximal tubules, and the results suggest that collection of tubular urine by luminar blocking does not give rise to important deviations in the rate of delivery of tubular contents. Furthermore, certain approximations have been made regarding the pressures causing flow of tubular contents.

The procedure of preparing the animals for tubular injections has been described elsewhere[2] with the modification that mineral oil was layered across the surface of the peritoneal Ringer's solution, allowing for enhanced visualization of the surface of the exposed kidney. Individual proximal tubules were punctured with 3–5 μ diameter soft glass pipettes. A droplet of oil was extruded from the pipette tip which was just large enough to fill the tubular lumen. The pressure of the tubular contents was great enough to then tear the oil droplet from the pipette tip and the oil was swept along the lenght of the tubule. The time required for the droplet to pass tubular loops distal to that at which the puncture was made was measured with a stop watch. When the time of passage was less than 0.5 sec the determinations were discarded since it was felt that times of this magnitude could not be measured by the author because of the inherent error in manual operation of a stopwatch. The dimensions of the selected loop were estimated with an ocular micrometer. Tubular volumes were calculated using the appropriate geometric formulae for the cylinders or curved cylinders.

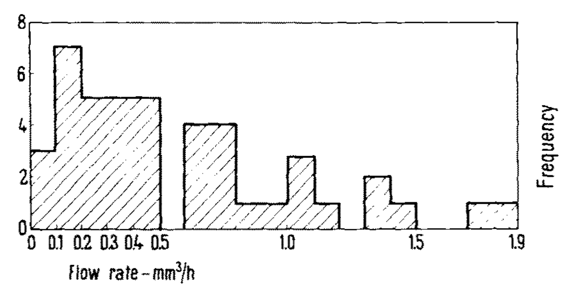
In estimating flow rates by the above method the assumption is made that the oil droplet travels through the tubule at the same rate as any volume increment of tubular urine. Since, however, the possibility exists that some of the tubular urinary contents may slip past the oil droplets the numbers obtained for flow rates must be considered as minimal. In certain cases such has actually been observed when oil droplets were seen to hang for a short while within the tubule, usually when the tubule made a sharp bend. A second major source of error resulted from the eventual blockage of a tubule when repeated determinations were made, such was indicated by a sharp decrease in flow rate.

The Figure shows the distribution of flow rates in the proximale tubule. The values are skewed toward low rates. Such skewness is to be expected, since determinations were made on loop segments distal to the site of puncture, and since a bias is introduced in excluding loops with transit times less than 0.5 sec. The distribution of rates obtained by this method fit fairly well with values obtained by other investigators[3] using the blocking procedure. Although flow ranges from less than 0.1 to about 2 cm^3/h, this does not mean that over 95% of the glomerular filtrate is reabsorbed at the level of the proximal tubule. The excessive wide range of values probably arises from the fact that data from twelve animals are pooled in this one Figure.

Several attemps have been made to calculate the pressure gradient in the proximal tubule using Poiselle's equation. Although the use of this equation is not thoroughly justified since the tubules are somewhat elastic, it probably gives answers of reasonable order of magnitude.

In estimating the pressure gradient the following assumptions are made: (1) The pressure fall is linear over the lenght of the tubule. (2) The average tubular length is 1 cm. In a series of 44 determinations the drop was calculated to be 2.55 $\pm$ 0.34 mm Hg/cm (mean $\pm$ standard error).

Using fixed tissues, the required pressure gradients in the tubules have been estimated as 25 mm Hg in the rabbit[4] and 80 mm Hg in the dog[5]. Gottschalk and Mylle, on the other hand, calculated the proximal tubular pressure gradient in the rat to be of the same general magnitude as that found here[6]. All three investigators assigned values for the tubular radius which are probably too low (8–10 micra), whereas the radii measured in these experiments ranged from 11.5 to 24. It is likely that in the case of the dog and rabbit the magnitude of the error introduced thereby accounts for the discrepancy in results[7].



Frequency distribution of proximal flow rates. Data are grouped in increments of 0.1 mm^3 flow/h with each block representing a single observation.

Zusammenfassung. An proximalen Harnkanälchen wurde die Strömungsgeschwindigkeit der Flüssigkeit bestimmt. Es wurde die Durchgangszeit eines Öltropfens durch einzelne Kanälchen gemessen. Der Druckabfall im Kanälchen wurde aus Durchgangszeit und Dimension des Kanälchens berechnet. Die beobachtete Strömungsgeschwindigkeit variierte von 0.1 bis fast 2.0 mm^3/Stunde, der berechnete Druckabfall ergab ungefähr 2.5 mm Hg/cm.

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1 A. M. Walker and J. M. Oliver, Amer. J. Physiol. *134*, 561 (1941).
2 S. Solomon, J. cell comp. Physiol. *49*, 351 (1957).
3 A. M. Walker, P. A. Bott, J. Oliver, and M. C. MacDowell, Amer. J. Physiol. *134*, 580 (1941).
4 J. M. O'Conner, J. Physiol. *59*, 200 (1924).
5 T. G. Brodie, Proc. Roy. Soc. *87 B*, 571 (1914).
6 C. W. Gottschalk and M. Mylle, Amer. J. Physiol. *185*, 430 (1956).
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