THE RENAL CIRCULATION: PHYSIOLOGY AND HORMONAL CONTROL

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Although much attention has been paid to the immunologic aspects of kidney disease (Germuth and Rodriguez, 1973; McCluskey, 1974; Wilson and Dixon, 1974), it is clear that many of the more common afflictions have a predominantly circulatory rather than an immunologic basis. Vascular abnormalities and altered renal perfusion play a key role in the renal disorders associated with arteriosclerosis, hypertension, shock, liver disease, sepsis, trauma, diabetes, and the toxic effects of certain drugs (Barger, 1966; Siperstein et al., 1968; Hollenberg, 1973; Hollenberg and Adams, 1974). Disturbed renal hemodynamics are pathogenetically important even in disorders of undisputed immunologic origin, such as renal transplant rejection (Hollenberg et al., 1972).

In order to understand circulatory disorders of the kidney it is necessary first to understand the physiology of the renal circulation. Two excellent reviews of this subject have been published covering the period up to 1971 (Thurau and Levine, 1971; Barger and Herd, 1973). The present chapter does not attempt to duplicate the coverage of these comprehensive reviews but rather endeavors to provide complementary information.

Part I of this chapter briefly discusses some of the more important aspects of the physiology of the renal circulation, emphasizing work published between 1971 and June of 1975. Part II deals with the influence of hormones on the circulation of the kidney, a subject not extensively discussed in the review articles mentioned above. (The anatomy of the renal circulation has been described in an earlier chapter.)
I. PHYSIOLOGY OF THE RENAL CIRCULATION

A. GENERAL CONSIDERATIONS

Renal blood flow in man and other animals accounts for approximately 25% of the cardiac output at rest despite the fact that the kidneys constitute less than 0.5% of body mass (Kiil, 1971; Valtin, 1973). Average renal blood flow per gram is approximately 4 ml/min, about four times the level of perfusion in such metabolically active organs as the liver, brain, gut, heart, and exercising skeletal muscle (Fig. 1). Renal blood flow clearly exceeds that which is necessary to provide the kidney with oxygen and metabolic substrates.

Renal oxygen consumption does not exceed 10% of the oxygen consumption of the whole body and the a.v. oxygen difference (1.7 vol %) is less than half the difference in oxygen content between arterial and mixed venous blood (Kiil, 1971). Renal oxygen consumption is proportional to renal blood flow at levels above 3 ml/min/100g and thus the renal arteriovenous difference remains relatively constant. There is a linear relationship between sodium reabsorption and oxygen consumption. This relationship appears to hold even when sodium reabsorption is changed without a similar change in glomerular filtration rate (Valtin, 1973). Approximately 80% of renal oxygen consumption is thought to support tubular transport functions. The remaining 20% (100 μmoles/100g/min) represents basal oxygen consumption of the kidney tissue itself and is comparable to that of other epithelial tissues (Valtin, 1973).

Alterations in total renal blood flow in man brought about by disease are often masked by the extremely wide normal range (Hollenberg et al., 1975). Studies of total renal blood flow in dogs using the chronically implanted electromagnetic flow probe have demonstrated considerable day-to-day variability in resting blood flow in individual animals (Reinhardt et al., 1975).

Large changes in medullary blood flow are not detectable as changes in total blood flow, since 93% of total renal blood flow perfuses the cortex alone (Thurau and Levine, 1971). In the rat, the inner medulla makes up only about 3% of kidney mass and has a plasma flow of 32 ml/min/100g as opposed to 300 ml/min/100g for the kidney as a whole (Solez et al., 1974b; Arendshorst et al., 1975). Nevertheless, alterations in inner medullary perfusion which may have no significant effect on total renal blood flow can have a profound influence on renal concentrating ability (see Section D) (Thurau, 1964).

B. INTRARENAL DISTRIBUTION OF BLOOD FLOW

Trueta et al., (1947) generated considerable interest in the distribution of blood flow within the kidney by suggesting that there was a "diversion" of blood flow from the cortex to the medulla in