Renal parameter estimates in unrestrained dogs*

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Abstract—A mathematical formulation has been developed to describe the haemodynamic parameters of a conceptualised kidney model. The model was developed by considering regional pressure drops and regional storage capacities within the renal vasculature. Estimation of renal artery compliance, pre- and postglomerular resistance and glomerular filtration pressure is feasible by considering mean levels and time derivatives of abdominal aortic pressure and renal artery flow. If the level of flow is not greatly altered during an experimental sequence, it may also be feasible to estimate changes in glomerular filtration rate. Changes in the smooth muscle tone of the renal vessels induced by exogenous angiotensin amide, acetylcholine and by the anaesthetic agent halothane were estimated by use of the model. By employing totally implanted telemetry, the technique was applied on unrestrained dogs to measure renal resistive and compliant parameters while the dogs were being subjected to obedience training, to avoidance reaction and to unrestrained caging. An increase in vasoconstrictor tone in the renal artery and in the afferent arterioles in response to an increasing level of stimulation was demonstrated using this model.

Keywords—Model of renal haemodynamics

Introduction

The sympathoadrenal-system complex is responsive to a variety of psychological and physiological factors which, via alterations in renal resistance and compliance, cause variations in fluid and electrolyte factors which, via alterations in renal resistance and to a variety of psychological and physiological influences renal functions. To have instantaneous phenomenon in the kidney lies a rapidly acting balance. Thus, superimposed on the autoregulatory are used to measure renal parameters, such as renal clearance (SMITH, 1956) and isotopic washout measures of these resistance and compliance values would permit assessment of renal responses on a beat-to-beat basis. In much of the present research, renal clearance (Smith, 1956) and isotopic washout rates (Wilson et al., 1970; Pomeranz et al., 1968) are used to measure renal parameters, such as renal blood flow and glomerular filtration rate. Because of the nature of the measurement the result is an average value; the data are obtained during restraint and/or anaesthesia; and the segmental renal resistances and compliances cannot be determined. Recently, research in renal circulation has benefited from the ability to measure dynamic flows and pressures. Analysis of these data has typically considered mean flow and pressure as a means of assessing renal responses to selected stimuli.

Work with simultaneous pressure and flow measurements in unrestrained dogs by Rader (1972a, 1973) has shown that waveshapes and amplitudes can be used to estimate values of renal vascular compliances and resistances. This technique permits the total renal resistance to be separated into pre- and postglomerular components and the compliance of the vasculature preceding the afferent arteriole to be estimated. From the pre- and postglomerular resistance values, the glomerular filtration pressure can also be estimated. It is believed that these relationships provide an indicator of change in renal haemodynamics which is more revealing than analysis by considering mean pressure and flow, and perhaps this technique can supplement information obtained by plasma-clearance techniques. The application of implanted telemetry for chronically monitoring systemic blood pressure and renal artery flow permits a quantification of haemodynamic components of the renal vascular bed in unrestrained dogs. It is proposed that these component values may then be used as indices of renal function, levels of autonomic arousal, and possibly in determining the level and location of developing renal atherosclerosis. Furthermore, because of the apparently differing effects that neurogenic and humoral influences have on the component values, an assessment of the relative contribution of the neurogenic and humoral factors operating in a given situation may be possible.

Renal haemodynamic model

Blood flow in the kidney is through multiple individual channels branching from the interlobular artery. These channels are similar in anatomical arrangement but vary in diameter, in length and in their relative amounts of collagen and elastin. In each channel the first major pressure drop occurs at the afferent arteriolar vessel which branches from the interlobular artery and opens into the glomerular capillaries. These capillaries have a large surface area and behave hydraulically as a very distensible storage volume. On the exit side of the glomerular capillaries, the efferent arterioles, in parallel with a shunt flow from the glomerular capillaries to the peritubular capillaries via the tubules, form the site for a second major pressure drop. Downstream from the compliant peritubular capillaries a third pressure drop occurs in the venules. From the venules the

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Fig. 1

Top: Illustration of pressure decreases within the renal vascular tree. Adapted from Folkow (1971) and Selkurt (1971).


Bottom: An electronic model of the renal vascular tree. The C's and R's represent major compliant and resistive sites and the c's and r's represent lesser values of distributed compliance and resistance. Accordingly the large artery section is represented by r's and C's because the site is responsible for a comparatively small pressure drop, but a significant compliance. On the other hand, the behaviour of the afferent arterioles is predominantly resistive; therefore, this section is represented by a large resistance and a small compliance. The flow path through Rg and Rp represents glomerular filtration and absorption. Rg is a filtration resistance and Rp is an absorption resistance. Re represents the resistance of the efferent arterioles. Tubular capillaries and the large veins outside the kidney are shown as constant pressure elements rather than compliant elements.