An Examination of the Xenon Clearance Method

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Summary. A definition of cortical and juxta-medullary regions is suggested based on a grouping of nephrons of common flow characteristics. A possible error is suggested in the xenon clearance method of measuring the regional flows. Experiments to test the source of error and its magnitude are described. It is concluded that while the error is present its effect on conventional component analysis is small.

Key words: Intrarenal distribution of blood — Intrarenal compartments — Xenon clearance — Xenon fluxes.

INTRODUCTION

The renal cortex contains two types of nephrons — cortical and juxta-medullary — defined by their morphology and to a lesser extent their position. Each nephron can be conceived as a flow unit. Furthermore, when grouped into populations, it is possible to view the intrarenal circulation as a pair of parallel compartments. This could be the basis of a functional division.

Some methods available for measuring intrarenal blood flows are based on sensors placed in the kidney or post mortem histology. These must give data which relate to precise sites. The assumption is then made that each site is representative of its compartment. This can be valid only in the outer cortex where the cortical nephron is universally present. In the deeper layers, where intermingling with juxta-medullary nephrons occurs, patterns of uniformity of flow within the strata must similarly be disrupted.

The method of inert gas clearance monitors at a distance representative areas of whole kidney. Thorburn et al. (1963) have used krypton and Ladefoged (1966) xenon. The clearance exponential is taken to be a model of flows through kidney regions of common flow characteristics — cortex and juxta-medulla, principally. These definitions, based on an understanding of the method, lean more to haemodynamics than strict anatomy. For example, the cortex is defined as that region which contains the faster flowing units.

It is clear that the cortex is the most rapidly cleared. During subsequent clearance from the juxta-medullary nephrons it might be expected that some of the gas might move down the concentration gradient into the cortex. It is argued that this flux between contiguous tissues, because it is a disappearance of gas not attributable to blood flow, might be great enough to constitute an error in the clearance calculations.

The purpose of the experiments reported here was to test this postulated error when xenon is the inert gas of choice.

MATERIALS AND METHODS

Experiments were performed on greyhounds in which the left kidneys were found to be supplied by paired or branched renal arteries. Six experiments are reported.

The animals were anaesthetised with pentobarbitone. The left kidney was exposed through a flank incision. Both branches of the renal artery were cleared. One was ligated and cannulated with polythene tubing. The resulting unperfused segment was injected with heparinized blood. The intact branch was punctured with an indwelling narrow-bore needle. To prevent clotting the needle was perfused with normal saline delivered at a constant rate of 1-2 ml per min. The ureter was catherized.

The kidney now existed as two adjacent segments — perfused and unperfused, by systemic arterial blood — whose circulations were accessible to the injection of xenon. Figure 1 shows the preparation. Across the dividing interface, concentration gradients for xenon were set up by injecting doses into either segment, and their disappearance monitored through a scintillation counter placed over the whole kidney.

Xenon, as $^{133}$Xe in saline solution, was injected into the chosen segment in doses of 200 µCi. During the subsequent clearance,
counts were made from the kidney over successive periods of 5 s and put in store.

All experiments started with monitoring a xenon clearance from the normally perfused segment. Thereafter an identical dose of isotope was injected into the non-perfused segment and its disappearance monitored. In order to clear this after an extended run, the non-perfused segment was "autoperfused" with a blood flow led from a cannulated femoral artery. Variations in this basic protocol are described later.

Analysis of the clearance curve was approached through the conventional 3 component model (Ladefoged, 1966). However, in most cases the total time span was not long enough to extend to the third component. Analysis was, therefore, directed towards:

i. A two component analysis.

ii. Keeping rigidly to the time spans: $C_1 = 5 - 20$ s, $C_2 = 110 - 300$ s.

iii. Limiting the analysis to a single component calculation for the slow disappearance from unperfused tissue.

iv. Recording $t_{1/2}$ values.

Before the experiments were terminated a final dose of $^{133}$Xe in saline was mixed with a volume of Indian ink and injected into the unperfused segment. The renal pedicle was tied and the kidney removed. After varying periods of time extending to 24 h, stained and unstained tissue were compared for isotope content.

RESULTS

In the experiment shown in Figure 2 xenon was injected into the perfused segment at zero time and is seen to be rapidly cleared. Two component analysis gives $t_{1/2}$ values of 9.9 s for the fast component and 262 s for the slower component. The disappearance of an identical dose, injected at the first arrow into the unperfused segment is significantly slower; $t_{1/2}$