SERIAL MEASUREMENTS OF INTRARENAL BLOOD FLOW DISTRIBUTION
IN DOG KIDNEY

W. ROWIŃSKI, W. GRABAN, I. KUBAS, M. SKOŚKIEWICZ and
J. NIELUBOWICZ

Surgical Research Laboratory, Centre of Experimental and Clinical Medicine, Polish
Academy of Sciences and Department of Radioisotopes, Warsaw Medical School,
Warsaw, Poland

In certain pathological conditions the measurement of intrarenal blood flow distribution
with $^{133}$Xe washout technique gives more detailed information than the measurement of the
total renal blood flow. This may be of special value after kidney allotransplantation.
The present work was undertaken to compare the intrarenal blood flow distribution in
normal (‘in situ’) and in autotransplanted kidneys of the same dog.

MATERIAL AND METHODS

Experiments were performed on 11 mongrel dogs weighing 14–20 kg.
Under general anaesthesia (Eunarcon, 0.4 ml/kg body weight), the right kidney was
transplanted into the right iliac fossa, the renal artery being anastomosed, end-to-end to the
common iliac artery, and the renal vein, end-to-side to the inferior vena cava. The ureter was
dissected all its way down without division so that a new uretero-vesical anastomosis was not
necessary (Fig. 1). In all cases before the transplantation the kidney was perfused with a
cold (+4°C) Ringer’s solution. The total ischaemic time ranged from 23 to 30 minutes.
Polyvinyl catheters were inserted into both renal arteries, being fixed with one suture to the

Fig. 1. Model of the experiment.

258
adventitia. Insertion of the catheter did not cause profuse bleeding. On four occasions the bleeding persisted beyond the usual time causing some renal ischaemia due to necessary clamping of the renal artery.

Serial measurements of the intrarenal blood flow distribution were performed under general anaesthesia on the 1st, 3rd, 5th, 7th, and 14th postoperative day. At that time 300–400 µc of $^{133}$Xe dissolved in 1 ml of saline (0.9%; room temperature) was injected intra-arterially through the catheter. The rate of disappearance of the $^{133}$Xe was counted by a scintillation probe with a 10 cm crystal of sodium iodide coupled with a linear ratemeter connected to a Texas recorder. Recording was carried out for 15 minutes.

The obtained disappearance curve was plotted on semilogarithmic paper and the mathematical curve analysis was carried out. Three exponential components were derived from this curve (Kety, 1951). The blood flow per 100 g of tissue per minute in each compartment was calculated from the rate of decay of activity in the component.

Component I represented the blood flow through the outer cortex.

Component II represented the blood flow through the juxtamedullary cortex and outer medulla.

Component III represented the blood flow through the inner medulla.

The blood flow in ml/min./100 g of tissue was calculated from equation:

$$ F = \frac{100 \text{Ln} 2}{T/2}; \text{Ln} 2 = 0.693. $$

The fraction of the total blood flow that constituted each component was calculated by dividing the number of counts in that component at zero time by the sum of counts in all components at zero time. This will be referred to later in the text as 'percent of activity'.

**RESULTS**

The results will be discussed under two major headings: normal curves obtained from in situ and autotransplanted kidneys, and the curves obtained in pathological conditions such as bleeding from the renal artery that occurred at the time of catheter insertion or in cases of renal artery thrombosis.

*Normal curves.* Normal ('in situ') kidneys. Twenty-seven measurements were performed in

| TABLE I |
|------------------|-------|-------|-------|-------|-------|-------|-------|
| No. of measurements | Blood flow ml/min./100 g | % of activity at zero time supplied to component |
|------------------|-------|-------|-------|-------|-------|-------|
|                  | I     | II    | III   | I     | II    | III   |
| The mean value for the whole group (pathology excluded) (± SD) | 22    | 462.7 | 133.5 | 296   | 51.2  | 26.6  | 22.2  |
|                  |       | (164.4)| (77.8) | (2.2) | (15.5)| (10.4)| (11.3) |
| The mean value of the results obtained between the 1st and 7th day (± SD) | 15    | 501   | 145.2 | 3.1   | 52.6  | 25.8  | 21.6  |
|                  |       | (179) | (87)  | (2.5) | (17.7)| (11.1)| (13.0) |
| The mean value of the results obtained between the 7th and 14th day (± SD) | 7     | 370   | 105.2 | 2.65  | 47.7  | 28.7  | 23.6  |
|                  |       | (48.5)| (34.9)| (1.2) | (5.3) | (7.3) | (5.0)  |

259
Fig. 2. Upper curve: The decay of activity curve plotted on a semilogarithmic paper obtained from the normal kidney of dog No. 485 on the first postoperative day.
Lower curve: The decay of activity curve plotted on a semilogarithmic paper obtained from the transplanted kidney of dog No. 485 on the first postoperative day.

11 dogs between the 1st and 14th postoperative day. On 22 occasions the intrarenal distribution of the blood flow was nearly the same, with no difference in the postoperative period.

The mean values in this group of measurements were considered as normal for the healthy dog kidney. They were as follows:

Outer cortex (component I) — 462.7 ml/min./100 g.
Juxtamedullary cortex and outer medulla (component II) — 133.5 ml/min./100 g.
Inner medulla (component III) — 2.96 ml/min./100 g.

Percent of activity (i.e. fraction of total blood flow) at zero time supplied into each component was found to be as follows: 51.2% in component I, 26.6% in component II, and 22.2% in the component III.

If there was no bleeding after the catheter insertion the values of the blood flow per unit mass of tissue did not change during the whole postoperative course.

Statistical analysis of the results obtained within 7 days of operation and later on showed
that the difference between the rate of the blood flow in component I in these two subgroups is highly significant (p = 0.005). There was, however, no statistically significant difference in the percent of activity supplied to all components between two compared groups of results.

Autogenous transplanted kidneys. Thirty-three measurements in 11 dogs were done between the 1st and 14th day. On 28 occasions the results were comparable to those considered as normal during the experiments with normal, in situ, kidney. They were as follows:

Component I — 398.3 ml/min./100 g.
Component II — 104.5 ml/min./100 g.
Component III — 4.5 ml/min./100 g.

The percent of activity supplied to each compartment of the kidney in zero time was found to be 61.2, 23.9, and 14. Neither the blood flow nor its compartmental distribution were significantly changing during the postoperative period. The mean values of the results obtained in the whole group (with the pathology excluded) as well as in the experiments done within 7 days of operation and later on are shown in Table II.

<table>
<thead>
<tr>
<th>TABLE II</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of measurements</td>
</tr>
<tr>
<td>I</td>
</tr>
<tr>
<td>----------------------------------------</td>
</tr>
<tr>
<td>The mean value for the whole group (pathology excluded) (± SD)</td>
</tr>
<tr>
<td>(185)</td>
</tr>
<tr>
<td>The mean value of the results obtained between the 1st and 7th day (± SD)</td>
</tr>
<tr>
<td>(191)</td>
</tr>
<tr>
<td>The mean value of the results obtained between the 7th and 14th day (± SD)</td>
</tr>
<tr>
<td>(104)</td>
</tr>
</tbody>
</table>

Statistical analysis of these results showed significant increase of the percent of activity in component I in the transplanted kidney (p = 0.007) in comparison to the kidney in situ. There were no statistically significant differences in the blood flow per unit mass of tissue through the separate compartments of the transplanted and in situ kidneys.

Pathological curves (renal artery thrombosis, bleeding after the insertion of the catheter). On 11 occasions the results obtained were different from normal.

In 4 cases (kidneys in situ) the catheter insertion caused profuse bleeding from the artery with resulting ischaemia of the kidney. In such cases the measurement after the operation showed definite redistribution of the blood flow without changes in the blood flow rate (the blood flow per 100 g of tissue). This was expressed by a marked decrease of the percent of activity in zero time supplied to component I from 51.2 to 25 and its increase in components II and III (see Table III). During the next 24-48 hours this change disappeared and the curve obtained at the second measurement was normal.

On 7 occasions (2 in situ kidneys, 5 transplanted kidneys) in addition to the redistribution of the blood flow in all compartment there was some decrease of the blood flow per 100 g of tissue in compartment I. 24-48 hours later in these animals there was no blood flow through
### TABLE III

<table>
<thead>
<tr>
<th>Bleeding after the catheter insertion (± SD)</th>
<th>No. of measurements</th>
<th>Blood flow ml/min./100 g</th>
<th>% of activity at zero time supplied to component</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
<td>III</td>
</tr>
<tr>
<td>Bleeding after the catheter insertion</td>
<td>4</td>
<td>407</td>
<td>154.3</td>
</tr>
<tr>
<td>(± SD)</td>
<td>(209)</td>
<td>(54.9)</td>
<td>(2.2)</td>
</tr>
<tr>
<td>Renal artery thrombosis</td>
<td>6</td>
<td>368.2</td>
<td>110</td>
</tr>
<tr>
<td>Venous outflow block (± SD)</td>
<td>1</td>
<td>(159)</td>
<td>(80)</td>
</tr>
</tbody>
</table>
the investigated kidney. The diagnosis of renal artery thrombosis was made and confirmed at the postmortem.

Table III shows the mean values of the results obtained in all pathological situations.

Statistical analysis of these results showed the highly significant decrease of the activity supplied to compartment I at the time of bleeding after the insertion of catheters and in cases of partial renal artery thrombosis (p < 0.0004). The increase of activity supplied to component II was statistically highly significant (p = 0.0014) in cases of renal artery thrombosis, and statistically significant (p = 0.02) in bleeding dogs.

DISCUSSION

Xenon is a neutral, lipid soluble, easily diffusible gas. Given into the renal artery it rapidly attains an equilibrium with the parenchyma. Since the amount of xenon getting into the urine and lymph is very low and urine flow is very slow in comparison to blood, the rate of disappearance of xenon injected into the renal artery can be considered as a measure of capillary flow (Rosen et al., 1967). Since xenon is biologically inactive and is easily diffusible when in contact with respiratory surface, 95% of injected gas is exhaled after passing the lungs.

According to Thorburn et al. (1963) who introduced this method the mean values of intrarenal distribution of the blood flow in unanaesthetized dogs were as follows:

- Component I — 472 ml/min./100 g (% of activity — 80)
- Component II — 132 ml/min./100 g (% of activity — 16)
- Component III — 17 ml/min./100 g (% of activity — 2)
- Component IV — 21 ml/min./100 g (% of activity — 2).

Similar results were obtained by Rosen et al. (1967).

In our experiments the values of blood flow rate in ml per unit mass of tissue in separate compartments were similar to the results obtained by others. Some differences might be due to the time of recording (15 minutes in our experiments) which allowed us to analyse only 3 instead of 4 components.

In cases of bleeding or partial renal artery thrombosis there was definite increase of the percent of activity in zero time supplied to components II and III and the decrease of the same value in component I, with no change in the blood flow per 100 g of tissue. This might be explained by the diminution of the active mass of the cortex with subsequent decrease of the percent of activity in this component.

Conclusions

1. The blood flow rate in separate compartments of the dog kidney is the same in auto-transplanted and in situ kidneys.
2. Insertion of the catheter into the renal artery does not, per se, cause any changes in the intrarenal distribution of the blood flow.
3. Redistribution of the blood flow (without changes in the flow rate) can be observed at the time of bleeding due to the catheter insertion, or in cases of partial renal artery thrombosis.

REFERENCES


263