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Intrarenal venous glucose levels in the dog: An evaluation of the sampling technique

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Summary. Analysis of samples of intrarenal venous (IRV) blood from anesthetized dogs demonstrated that IRV glucose concentrations were greater than renal venous and arterial glucose in most samples. However, IRV glucose fluctuated with time such that this technique is unreliable for assessing changes in renal cortical glucose handling during experimental interventions.

Previous attempts to detect renal glucose production in the in vivo canine kidney have been largely unsuccessful since renal venous-arterial (V-A) glucose concentration differences are usually quite small or zero. This is because renal venous drainage reflects both glucose production by the renal cortex and glucose utilization by the medulla[1]. Thus there are directionally opposite processes occurring which tend to negate each other when one attempts to determine glucose differences across the entire organ.

In a previous report[2], we determined that blood samples obtained from the deep veins of the kidney above the corticomedullary junction had plasma glucose concentrations which were usually greater than both arterial and renal venous samples. Therefore, this intrarenal venous drainage apparently has more of a pure cortical component than the mixed drainage into the renal vein.

The present study was undertaken to further evaluate this technique of sampling intrarenal venous blood as a means for studying renal cortical glucose metabolism. More specifically, the question addressed was if the glucose concentration in this drainage remained constant over time.

Methods. Adult mongrel dogs were anesthetized with sodium pentobarbital (30 mg/kg). The left femoral artery and vein were cannulated for sampling arterial blood and administering an infusion of isotonic NaCl (2 ml/min), respectively. The left kidney was exposed through a flank incision and the ureter cannulated. A catheter was inserted into the renal vein via the gonadal vein for sampling renal venous blood and an electromagnetic flow probe (Carolina Medical) placed around the renal artery if the latter was not bifurcated. A catheter was then inserted through a stab incision into the renal vein, tied in place with a purse-string suture and advanced up into the deep venous system of the kidney using the criteria of Hinshaw[3] for correct intrarenal venous catheter placement. Arterial pressure and renal blood flow were monitored throughout the experiment with a Grass Model 7D Polygraph.

The experimental protocol consisted of simultaneously taking samples of intrarenal venous, renal venous and arterial blood at 3 min intervals until 10 samples of each were obtained. Thus, the total sampling portion of the experiment took 27 min. All samples were obtained by disconnecting the luer stub adapters from the catheters and letting the blood free-flow into chilled heparin-lithium fluoride treated microfuge tubes, i.e. no syringe withdrawals of blood were used. All tubes were centrifuged with a Beckman Microfuge and plasma glucose determined with a Beckman Glucose Analyzer 2. Urine glucose concentration was also determined and any animal with greater than trace amounts of glucose in the urine was not used for data. At the end of each experiment, the kidney was dissected and checked for correct placement of the intrare-

Glucose concentration differences for intrarenal venous (IRV), renal venous (V) and arterial (A) plasma in the dog (mean ± SE)

Dog	V-A (mmol/l)	p	IRV-A (mmol/l)	p	IRV-V (mmol/l)	p
1	0.03 ± 0.15	n.s.	0.79 ± 0.25	< 0.02	0.76 ± 0.15	< 0.001
2	0.09 ± 0.08	n.s.	0.46 ± 0.06	< 0.001	0.37 ± 0.07	< 0.001
3	0.19 ± 0.07	< 0.05	0.65 ± 0.08	< 0.001	0.46 ± 0.03	< 0.001
4	0.41 ± 0.11	< 0.005	0.82 ± 0.11	< 0.001	0.41 ± 0.07	< 0.001
5	0.58 ± 0.13	< 0.002	0.34 ± 0.17	n.s.	− 0.24 ± 0.09	< 0.05
6	− 0.90 ± 0.09	< 0.001	0.56 ± 0.12	< 0.002	1.46 ± 0.11	< 0.001
7	0.51 ± 0.10	< 0.001	0.36 ± 0.11	< 0.01	− 0.15 ± 0.08	n.s.
8	0.44 ± 0.09	< 0.001	0.16 ± 0.15	n.s.	− 0.28 ± 0.15	n.s.
Mean	0.17 ± 0.06	< 0.005	0.52 ± 0.05	< 0.001	0.35 ± 0.07	< 0.001

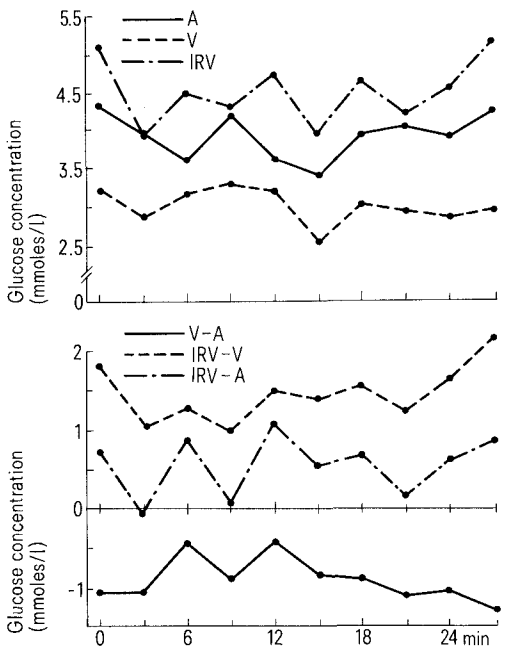
nal venous catheter. Statistical analysis utilized the paired t-test with probability (p) values of < 0.05 being considered statistically significant.

Results. The mean glucose concentration differences for each of the 8 dogs and the group as a whole are shown in the table. The glucose concentration readings from the Beckman Glucose Analyzer (mg/dl) have been converted to SI units (mmol/l).

The renal venous-arterial (V-A) glucose difference was significantly positive in 5 of the dogs, significantly negative in 1 dog and not different from zero (n.s.) in 2 dogs. For the group as a whole, V-A was significantly positive. The intrarenal venous-arterial (IRV-A) glucose difference was significantly positive in 6 dogs and not different from zero in 2 dogs. The intrarenal venous-renal venous (IRV-V) glucose difference was significantly positive in 5 dogs, significantly negative in 1 dog and not different from zero in 2 dogs. For the group as a whole both IRV-A and IRV-V were significantly positive.

Even though IRV glucose was greater than both V and A in most of the samples obtained, there tended to be fluctuations in these values with time. The figure shows the absolute values and concentration differences in dog No. 6. Note that although IRV > V at all times, the IRV glucose values tended to change between samples. This is most evident when looking at the IRV-A differences. For example, at time 0, IRV-A was 0.72 mmol/l whereas 3 min later this difference was -0.03 mmol/l. 3 min after this sample (6 min on graph), IRV-A had returned to 0.86 mmol/l. These fluctuations occurred throughout the experiment even though no interventions took place which should change renal glucose handling.

Discussion. Glucose metabolism in the in vivo kidney is a complex function to study since regional metabolic differences exist within the organ. In general, the renal cortex synthesizes glucose and has a low rate of glucose utilization whereas the deeper medullary regions have a higher rate of glucose utilization with little glucose synthesis taking place[1]. Therefore, renal V-A glucose differences are often-



Absolute glucose concentrations and concentration differences for intrarenal venous (IRV), renal venous (V) and arterial (A) plasma in a typical experiment.

times small because they reflect these opposing processes. Detection of a net renal release of glucose has usually only been possible by using radiolabeled gluconeogenic precursors or isotope dilution techniques[4].

In the cat kidney, it has been possible to study regional glucose metabolism in vivo[5]. This is because the feline kidney is drained by 2 separate venous systems[6]. The superficial venous system, which drains the outer renal cortex, forms supcapsular veins on the kidney surface. Because of this arrangement, blood samples can be directly obtained from these superficial veins and the composition of these samples reflects primarily, if not exclusively, the metabolic functions of the renal cortex. Friedman and Torretti[6] have used this technique to study regional renal handling of glucose and lactate.

In contrast, the dog kidney does not have such an anatomical arrangement for its venous system. Drainage from both the cortex and medulla empty into the renal vein such that there is no separate vessel which can be cannulated to provide an index of regional renal metabolism. In a previous study[2], we attempted to circumvent this anatomical problem by determining if venous blood sampled from deep in the kidney, above the branch point of the arcuate veins, was purer in cortical character than mixed renal venous blood, i.e. if the glucose content of IRV blood was higher than that obtained from the renal vein. Indeed, this proved to be true when multiple samples were obtained and analyzed.

In the present study, this technique of studying renal cortical glucose metabolism by sampling IRV blood was further evaluated. The results showed that this technique is of limited usefulness. First, although IRV glucose concentration was greater than renal V glucose concentration in most dogs, this was not true for all animals. In 1 animal V glucose was greater than IRV glucose and in 2 animals there were no differences. Thus the IRV technique could not consistently detect the cortical function of glucose production in every dog. Secondly, and more important, was the fact that the IRV glucose concentrations and the differences between IRV and A glucose tended to change sporadically with time, even though the samples were obtained every 3 min. We cannot explain these fluctuations in IRV glucose. They may possibly reflect an intermittency in glucose handling by the areas these veins drain or, perhaps, changes in the proportion of cortical venous drainage in IRV samples taken at different times. In order for the IRV technique to be useful for determining changes in cortical glucose metabolism during an experimental intervention, IRV glucose levels must show little or no changes with time alone. This was not the case. Therefore, in view of these results, we feel that the IRV technique, although somewhat interesting, is of questionable value for studying renal cortical metabolism.

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