Effect of i.v. furosemide on pelvic urinary oxygen tension in humans

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Urinary oxygen tension may be an index of renal medullary blood flow. The effect of i.v. furosemide on urinary oxygen tension was studied in four patients with indwelling nephrostomy tubes. An intravascular oxygen sensor (Paratrend 7, Biomedical Sensors Ltd, UK) was inserted into the renal pelvis via the nephrostomy and urine oxygen tension measured. In all cases, furosemide 20 mg i.v. produced a decrease in pelvic urinary oxygen. The possible mechanisms and implications are discussed.

Br J Anaesth 1999; 83: 328–9

Keywords: oxygen, tension; kidney, urine; kidney, diuretics, furosemide; pharmacology, furosemide

Accepted for publication: February 24, 1999

The partial pressure of oxygen in urine ($P_{uO_2}$) depends on many factors. Early researchers\(^1\) proposed that urinary $P_{O_2}$ reflects the $P_{O_2}$ of the medullary tissue and may be an indicator of renal medullary oxygen supply. $P_{uO_2}$ is highest in the renal pelvis and decreases progressively further down the urinary tract. This probably reflects equilibration with oxygen tension in the walls of the ureters or possibly oxygen consumption in the urine itself. Therefore, the best place to monitor $P_{uO_2}$ to reflect medullary $P_{uO_2}$ is the renal pelvis.

Factors that may impair renal function are associated with decreases in $P_{uO_2}$.\(^2-4\) Furosemide and dopamine are used in patients at risk of renal failure. Dopamine has been shown to increase $P_{uO_2}$, suggesting a beneficial effect on renal oxygen balance (Campbell and Bolsin, unpublished observation). The effect of furosemide on urinary oxygen tension is unknown.

Methods and results

After obtaining approval from the Institutional Ethics Committee and informed consent, we studied four ASA I patients aged more than 18 yr. All had undergone percutaneous stone extraction the day before the study and had nephrostomy tubes left in place after operation. All were clinically well hydrated and were not receiving renally acting drugs.

In the operating theatre, we inserted a peripheral venous cannula and monitored patients using automated noninvasive arterial pressure, ECG and pulse oximetry. Patients received Hartmann’s solution 50–100 ml h\(^{-1}\) i.v. The oxygen monitoring probe (Paratrend 7 intravascular blood-gas monitoring electrode, Biomedical Sensors Ltd, UK) was inserted aseptically via the nephrostomy tube into the renal pelvis. Urine drained through a three-way tap for collection.

The probe was connected to a monitor which displayed continuously $PO_2$, $PCO_2$ and pH at the sensor tip.

After a period to establish a baseline $P_{uO_2}$, we administered furosemide 20 mg i.v. We then monitored $P_{uO_2}$ for 1 h, or until it had returned to baseline values. After the study, we removed the oxygen monitoring line.

Results are shown in Figure 1. Time zero is the time of injection of furosemide. $P_{uO_2}$ decreased in all patients to 29–80% of baseline, beginning within a few minutes of injection of furosemide and lasting for up to 1 h. In patient Nos 1 and 2, $P_{uO_2}$ recovered to baseline at 60 and 13 min, respectively. In patient No. 3, $P_{uO_2}$ had recovered to only 82% of baseline at 60 min when the experiment was stopped. The fourth patient had a much higher baseline $P_{uO_2}$ that decreased more slowly but failed to return to baseline by 1 h. None demonstrated any cardiovascular changes.

Fig 1 $P_{uO_2}$ vs time in the four patients studied. Furosemide was injected at time 0.
Discussion
These patients had renal stone disease but no evidence of increased serum creatinine concentration or other evidence of renal impairment. Therefore, this seems unlikely to have affected our results. The nephrostomy tubes allowed us to collect renal pelvic urine, which has a higher $P_O_2$ than bladder urine and better reflects medullary conditions. Variation in $P_O_2$ between patients was large and may reflect different states of hydration. Despite this, all patients showed a decrease in $P_O_2$, albeit with different patterns.

$P_O_2$ decreases when renal blood flow is reduced by aortic cross clamping. However, hypotension caused by hypovolaemia produces little change in $P_U_O_2$ despite causing a rapid decrease in renal medullary and cortical tissue $P_O_2$. In the same study, vasodilators produced a decrease in $P_U_O_2$ in cortical but not medullary or urinary $P_O_2$.

Leonhardt and Landes demonstrated that $P_U_O_2$ was low in dehydrated patients (mean 26 mm Hg), increased with rehydration, and increased again after infusion of mannitol. In patients undergoing cardiopulmonary bypass, $P_U_O_2$ decreased during bypass, and failure to return to normal after bypass was predictive of a postoperative increase in serum creatinine concentration. These studies suggest that factors that may impair renal function are associated with decreases in $P_U_O_2$, but the precise relationships are not clear.

The decrease in $P_U_O_2$, seen normally with nitrous oxide–oxygen–isoflurane anaesthesia is prevented by infusions of both dopamine and prostaglandin E1 and the effect of dopamine in one patient has already been mentioned. The speed of the $P_U_O_2$ response to injection of furosemide suggests that the mechanism is vascular in origin, as other mediators of the response would require a longer time course. Furosemide has been proposed as a logical treatment for incipient acute renal failure because it reduces renal medullary oxygen consumption. I.v. furosemide causes an increase in renal blood flow in most subjects. In those in whom renal blood flow increases, blood is diverted from the medulla to the cortex. The effect on urinary $P_O_2$ depends on the relative importance of any decrease in medullary oxygen consumption vs the decrease in medullary blood flow. Proponents of furosemide as a renal protecting agent would expect that urinary $P_O_2$ would increase after administration of furosemide. These data do not support the notion that furosemide improves oxygen supply and demand ratio in the renal medulla. Whatever the mechanism, these observations are important and require further investigation.

References
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