Short-term Arterial Blood Reperfusion of Normothermic Kidney in Renal Artery and Abdominal Aorta Reconstructive Surgery

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Objective: to prevent kidney injury in renal artery and juxta-renal aortic surgery. After 30 min of cross-clamping ischaemia, renal arterial inflow is temporary re-established for 3 min. The aim of the study was to retrospectively analyse the results of this original technique.

Methods: between January 1987 and May 1999, 48 patients underwent kidney short-term arterial blood reperfusion, directly or through the Pruitt–Inahara shunt. The reperfusion was repeated every 30 min of ischaemia, whenever necessary. Fifty control patients underwent <30 min of kidney ischaemia. Patients were assessed by serum creatinine, digital angiography and radioisotope renography using technecium.

Results: in the study group one patient developed an acute renal failure and died (2% (−95% CI: 0–11%)). In both study and control groups patients showed a similar and moderate but temporary decline in renal function, which returned to preoperative levels after 1 week.

Conclusions: the results of this study indicate that kidney short-term reperfusion may protect renal tissue from prolonged cross-clamping ischaemia (up to 100 min), also in patients considered at high risk for acute renal failure.

Key Words: Kidney protection; Ischaemia reperfusion injury; Aortic surgery.

Introduction

Renal function deterioration is responsible for morbidity and mortality in patients undergoing surgical repair of the abdominal aorta and renal arteries. Renal dysfunction is usually the result of cross-clamping ischaemia, or ischaemia-reperfusion injury. Prolonged renal clamping ischaemia may become necessary during repair of complex renal artery occlusive disease (RAOD) or RAOD associated with an abdominal aortic aneurysm (AAA) and in pararenal or thoraco-abdominal aortic aneurysms.

Cross-clamping of the renal artery is tolerated without complications for about 30 min in physiological normothermic condition. Warm clamping ischaemia longer than 50–60 min was significantly correlated to postoperative acute renal failure. The protective effect of mannitol in preventing ischaemic renal damage has been previously studied, and many surgeons use it routinely during aortic surgery. However, mannitol infusion failed to show any consistent protective effect when cross-clamping time lasts longer than 60 min.

Many authors employ kidney hypothermia to protect renal tissue from ischaemia. However, results are not always reproducible and cooling of the tissue is difficult to reach when kidneys remain in situ. In previous animal experimental studies we showed that it is possible to increase the total time of clamping ischaemia by temporarily re-establishing blood flow into the renal artery for 3 min, after 30 min-intervals of occlusion. Short-term arterial blood reperfusion (STABR) can be safely repeated twice, leading to a total ischaemic period of 90 min. This method is particularly useful to avoid irreversible lesions of cortical renal tissue, the region most vulnerable to the ischaemic insult because of higher O₂ requirement (9 ml of O₂/100 g/min compared to 0.4 ml of O₂/100 g/min of the medulla). In a preliminary report we showed that the method is suitable for clinical application, it is safe and able to protect renal tissue from prolonged clamping ischaemia. Therefore, we adopted this technique routinely when renal cross-clamping ischaemia exceeded 30 min. The aim of this study was to retro-
Kidney STABR is routinely used when clamping ischaemia exceeds 30 min. The reperfusion is achieved by re-establishing pulsatile normothermic blood flow either through the repaired renal artery or, in the majority of operative procedures, through the Pruitt–Inahara shunt (500-50-9F. Ideas for Medicine™, CryoLife® Comp, St. Petersburg, FL, U.S.A.). Application of the shunt may change in different surgical procedures. In the suprarenal abdominal aorta reconstruction (Fig. 1), the proximal aortic anastomosis is first completed. Renal artery (RA) is then reimplanted, with or without eversion endarterectomy, or directly bypassed. When the procedure requires longer than 30 min, the proximal end of the shunt is distally inserted into one branch of the bifurcated graft. The proximal aortic clamp is released; the shunt is blood perfused, and its distal end inserted into the open end of the transected renal artery. After 3 min of blood reperfusion, the aorta and the renal artery are re-clamped, the shunt is promptly removed and the renal artery reconstruction completed. The reperfusion is repeated every 30 min if necessary.

In transverse renal artery endarterectomy with patch closure, the STABR is achieved without any shunt device. Following the one- or two-sided renal RA endarterectomy, patch closure is started. If required (>30 min ischaemia), the aortic clamp is temporarily released for 3 min, while the operator keeps the aortic breach closed with two fingers.

Patients and methods

Between January 1987 and May 1999, 48 consecutive patients underwent kidney STABR. The control group was a series of 50 consecutive patients operated on in the same time period. Control patients underwent similar reconstructions, including renal cross-clamping ischaemia, but of shorter duration than 30 min. Patients were identified by examining our department vascular registry and theatre log books. Patients were included in the study group and the lesion (requiring longer than 30 min) was considered unilateral when cross-clamping ischaemia was shorter than 30 min on one side and longer than 30 min on the other during bilateral renal artery repair. All data were compiled on a spreadsheet (Excel, Microsoft Corp., Redmond, Washington, U.S.A.). Patients undergoing repair of a thoracoabdominal aortic aneurysm were excluded from the study.

Before surgery, all patients underwent serum creatinine (Cr) evaluation and digital subtraction angiography. Radioisotope renography using technecium was selectively employed. An angiographic renal artery stenosis >75% was considered haemodynamically significant. When renovascular hypertension was suspected, patients underwent captopril renography and renal venous renin assay to document the functional significance of a renal artery stenosis.

Preoperative renal insufficiency (RI) was defined for creatinine values above 1.5 mg/dl. Single functioning kidney was defined as (1) surgically or congenital absent kidney; (2) no visible nephrogram on contrast angiogram, and (3) less than 10% of total renal function in a kidney as assessed by technecium. Indications for surgery included renal artery occlusive disease (RAOD) responsible for renovascular hypertension and/or excretory renal insufficiency (ischaemic nephropathy), significant RAOD adjunctive to an aortic reconstruction, para- or suprarenal AAA not involving the superior mesenteric artery and renal artery aneurysm. The operative approach was the standard transperitoneal, infracolic exposure. All patients were given 50 mg of heparin and 250 cc as units of mannitol (18%) before clamping ischaemia. Blood pressure and serum creatinine levels were evaluated on a daily basis until discharge and at day 30 after surgery. Radioisotope renography using technecium was performed when renal artery occlusion was suspected after surgery. A higher risk for acute renal failure...
Table 1. Demographic characteristics and risk factors.

<table>
<thead>
<tr>
<th></th>
<th>Study group (n = 48)</th>
<th>Control group (n = 50)</th>
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</thead>
<tbody>
<tr>
<td>Mean age (y)</td>
<td>60 (38–80)</td>
<td>64 (44–84)</td>
</tr>
<tr>
<td>Females</td>
<td>8 (17%)</td>
<td>13 (26%)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>19 (40%)</td>
<td>21 (42%)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>10 (21%)</td>
<td>9 (18%)</td>
</tr>
<tr>
<td>Smoking</td>
<td>29 (60%)</td>
<td>26 (52%)</td>
</tr>
<tr>
<td>Coronary artery disease</td>
<td>14 (29%)</td>
<td>12 (24%)</td>
</tr>
<tr>
<td>Single functioning kidney</td>
<td>5 (10%)</td>
<td>1 (2%)</td>
</tr>
<tr>
<td>Baseline creatinine &lt;1.5 mg/dl</td>
<td>18 (40%)</td>
<td>6 (12%)</td>
</tr>
</tbody>
</table>

(HRRF) was investigated in patients undergoing a bilateral STABR (>30 min of bilateral kidney ischaemia) and a double STABR on one side (>60 min of unilateral kidney ischaemia). Acute renal failure may have a detrimental outcome in patients with single functioning kidney (SFK). HRRF was also examined in SFK patients.

Interpretation and statistics

Renal function was considered improved when preoperative creatinine levels decreased ≤ −20%, declined when creatinine levels increased ≥20%, and stabilised when creatinine changes remained within the 20% deviation of preoperative levels. The procedure was considered successful when renal function was stabilised or improved. According to changes in renal function, patients were classified into improved, stabilised or declined and the Fisher Exact test was used to analyse the behaviour of the study and control group, as well as the HRRF patients, within the study group.

A p-value less than 0.05 was considered to indicate a statistically significant difference. The statistical analysis was performed using the SPSS software (SPSS Inc., Chicago, IL, U.S.A.).

Results

Demographic characteristics and risk factors (Table 1) were similar in the study and control group, except for renal insufficiency (Cr>1.5 mg/dl).

Renal artery and abdominal aorta lesions requiring kidney cross-clamping ischaemia are shown in Table 2. Vascular lesions were similar in both groups, though isolated RAOD appeared more frequently in the study group (p<0.01).

In the study group we performed 30 aortorenal bypasses alone or in association with infra- or suprarenal aortic grafts, seven transverse RA endarterectomies and vein patch, three transaortic RA endarterectomies, five RA eversion endarterectomies and reimplantations and three reimplantations of normal renal arteries onto suprarenal aortic grafts. Thirteen patients (27%) underwent a bilateral STABR and 12 (25%) a double STABR on one side.

The median clamping ischaemia time was 52 min (range, 45–100 min) in the study group and 24 min (range, 14–28) in the control group.

One patient died in the study group (2%). The patient suffered a preoperative renal insufficiency (Cr=2.6 mg/dl) and juxtarenal AA aneurysm associated with RA stenosis. After a RA eversion endarterectomy, the RA was reimplanted on a suprarenal aortic graft. The patient developed an immediate postoperative thrombus with acute renal failure, underwent dialysis and died 45 days after surgery.

Postoperative creatinine levels increased at day 1 and then decreased at day 7 after surgery. Beginning from different baseline creatinine levels, the creatinine trend was similar in the study and the control group (Fig. 2).

In patients undergoing bilateral kidney STABR, the median ischaemic time was 50 min (range, 45–80) on one side and 60 (range: 45–90) on the other, whereas in patients undergoing a double STABR on the same side the median ischaemic time was 77 min (range: 70–100). There was no statistical difference in HHRF patients. After the seventh postoperative day, creatinine levels remained unchanged up to the first outpatient follow-up, at day 30 after surgery. The short-term reperfusion did not cause any deterioration in the intraoperative and postoperative systemic blood pressure (data not shown).

Discussion

Postoperative renal dysfunction represents a major cause of morbidity and mortality in aortorenal reconstructive surgery, and it is usually secondary to ischaemia-induced acute tubular necrosis. After suprarenal cross-clamping there is a consistent kidney
Table 2. Lesions associated with renal clamping ischaemia.

<table>
<thead>
<tr>
<th></th>
<th>Study group (48 patients)</th>
<th>Control group (50 patients)</th>
</tr>
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<tbody>
<tr>
<td>Kidney ischaemia &gt;30 min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unilateral</td>
<td>16</td>
<td>6</td>
</tr>
<tr>
<td>Bilateral</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Kidney ischaemia &lt;30 min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unilateral</td>
<td>6</td>
<td>11</td>
</tr>
<tr>
<td>Bilateral</td>
<td>2</td>
<td>1</td>
</tr>
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* More frequent in the study group (p<0.05).

Fig. 2. Changes in preoperative creatinine (day 0) levels at day 1 and 7 after surgery. Data are shown as mean and 95% confidence limits. The trend is similar in the two groups.

haemodynamic response with decreased renal perfusion and glomerular filtration rate, as well as increased renal vascular resistance, also exacerbated by alterations in the renin-angiotensin system. It is believed that ischaemia-reperfusion injury plays a central pathogenetic role in patients with acute tubular necrosis. To protect renal tissue from prolonged cross-clamping ischaemia, an intra-operative procedure can be applied. In thoracoabdominal aneurysms a continuous active blood perfusion from the left atrium into the distal aorta and visceral arteries is now possible, utilising the Bio-Medicus pump. The multiple catheter “octopus” arrangement can provide the continuous blood perfusion to the renal arteries, while intercostal and visceral artery reconstruction proceeds. Good results have been reported with this technique, but at least one study demonstrated a detrimental effect of renal function using multiple selective visceral not physiologically pulsating perfusion catheters.

In the past, we adopted kidney STAR using the Pruitt–Inahara shunt, also in thoracoabdominal aneurysm repair. We are currently comparing this
method with the continuous blood perfusion of renal arteries using the BioMedicus-pump (Medtronic, Inc., Minneapolis, MN, U.S.A.) and multiple catheter “octopus” arrangement in thoracoabdominal aneurysm. However, the use of continuous blood perfusion with an atrium-distal pump it is not feasible in the management of RAOD and juxtarenal AAA. The treatment of these lesions requires a less extensive surgical approach and a different method of protection must be employed.

Cox and Sabiston proposed a continuous blood perfusion of the kidney using the heparin-bonded silastic shunt between the aorta and the renal artery. Remaining in situ during the whole vascular procedure, the silastic tube is uncomfortable for the operator, especially in performing the vascular anastomosis, increasing chances of technical failure and post-operative artery thrombosis. Many authors utilise the local cooling of the kidneys to protect the tissue from protracted cross-clamping ischaemia.

Kidney hypothermia is a technique developed in transplant surgery. It allows to reach 48 h of reversible ischaemia when the kidney is explanted and then preserved by continuous perfusion of special solutions like Euro-Collins or the University of Wisconsin at 4°C. It can be employed when bench surgery is required for complex renal artery reconstruction, but it is technically demanding and costs are high. For less complex renal artery reconstruction, especially ad- junctive to an aortic aneurysm, or for suprarenal aortic aneurysms, kidney hypothermia is accomplished in situ by cyclic or continuous perfusion of renal arteries with cold solutions (Ringer’s lactate or saline). Ice slush can be applied on kidney surface to further ensure hypothermia, but this requires a retroperitoneal exposure. However, hypothermia of the renal parenchyma is less reproducible when the kidney remains in situ, and the results of this method are controversial in the prevention of post-operative renal failure.

Based on our research studies and preliminary clinical reports, we applied the short-term kidney arterial blood reperfusion when clamping ischaemia exceeded 30 min. The shunt is removed immediately from the surgical field after the reperfusion, in order to avoid technical failure during the vascular reconstruction.

The results of this study indicate that kidney STABR protect renal tissue from prolonged clamping ischaemia (up to 100 min). Short-term renal artery reperfusion is also effective in patients considered to be at higher risk to develop renal failure after surgery. Moreover, the short-term arterial blood reperfusion can be recommended because it is easy to perform and shows reproducible results. Kidney STABR can be applied during any step of the surgical procedure, proving to be useful also in unpredictable critical surgical situations.

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References

Kidney Short-term Arterial Blood Reperfusion


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