Selective visceral and renal perfusion in thoracoabdominal aneurysm repair

Kiyofumi Morishita*, Hideo Yokoyama, Satomi Inoue, Tokuo Koshino, Yukihiko Tamiya, Tomio Abe

Department of Thoracic and Cardiovascular Surgery, Sapporo Medical University School of Medicine, South 1 West 16, Chuo-ku, Sapporo 060-8556, Japan

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Abstract

Objective: Whether or not selective visceral and renal perfusion during thoracoabdominal aortic aneurysm (TAAA) repair has a protective effect on visceral and renal function remains unknown. The aim of this study was to clarify if selective perfusion has such an effect. Methods: From May 1982 to December 1997, 82 consecutive patients underwent TAAA repair. Patients receiving hypothermic circulatory arrest or cooling of the kidney using Ringer’s lactate solution were excluded, thus 73 patients were enrolled into this study. They were divided into three groups: those in whom selective visceral and renal perfusion was performed using a roller pump (n = 41), those in whom it was performed using a centrifugal pump with a reduced heparin regimen (n = 22) and those who underwent simple aortic clamping alone (n = 10). Results: Serum creatinine, total bilirubin and alanine aminotransferase levels were elevated postoperatively in patients undergoing simple cross-clamp repair, but remained almost within normal limits in patients undergoing TAAA repair with selective visceral and renal perfusion. Urine output was more in selective perfused patients than in non-perfused patients. Renal dysfunction, defined by requirement of hemodialysis or by a serum level of creatinine above 3 mg/dl, occurred in four patients (10%) of the roller pump group and in two patients (9%) of the centrifugal pump group, while in four patients (40%) of the simple cross-clamping group. Conclusion: Our experience suggests that selective visceral and renal perfusion has a protective effect on hepato-renal function during TAAA repair. © 1999 Elsevier Science B.V. All rights reserved.

Keywords: Thoracoabdominal aortic aneurysm; Selective visceral and renal perfusion; Visceral ischemia-reperfusion; Hepato-renal function

1. Introduction

Thoracoabdominal aortic aneurysm repair is still associated with significant morbidity and mortality. Even in the hands of experienced surgeons, the overall mortality is as high as 35% [1], and up to one-third of patients suffer from neurologic injury, pulmonary complications and renal failure [2,3]. Various factors contribute to such high morbidity and mortality. Recently, visceral ischemia-reperfusion has gained interest as one such factor. Unfortunately, animal studies have demonstrated that ischemia-reperfusion injures local and/or distant organs [4,5], but it remains unknown whether the findings of these studies apply to humans. Some authors have emphasized the impact of selective visceral and renal perfusion during graft replacement of extensive thoracoabdominal aortic aneurysms [6,7]. However, there has been little information on the effect of selective visceral and renal perfusion. Since 1982, we have used selective visceral and renal perfusion during thoracoabdominal aortic aneurysm repair. This experience provides the opportunity to retrospectively examine the effects of selective visceral and renal perfusion on overall outcomes, including hepato-renal function.

2. Materials and methods

2.1. Patients

Between May 1982 and December 1997, 82 consecutive
patients underwent thoracoabdominal aortic aneurysm repair. Patients undergoing hypothermic circulatory arrest or cooling of the kidney using Ringer’s lactate solution were excluded from this study. Seventy-three patients were divided into three groups: those in whom selective visceral and renal perfusion was performed using a roller pump (group I), those in whom it was performed using a centrifugal pump with a reduced heparin regimen (group II) and those who underwent simple aortic clamping alone (group III).

Group I included 41 patients; 31 were male and 10 were female. The median age was 57 ± 12 years. According to Crawford’s classification based on the extent of the disease [8], a type I aneurysm was replaced in five patients, a type II in seven patients, a type III in 22 patients, and a type IV aneurysm in seven patients. Twenty-six patients had an arteriosclerotic aneurysm, 14 patients had an aortic dissection, and one patient Behçet’s disease. Three patients had a ruptured aneurysm. Twelve patients had previously undergone a surgical aortic reconstruction in a total of 15 operations: three had undergone an aortic root replacement, two a combined ascending aorta and arch replacement, seven a descending aorta replacement and three had undergone an infrarenal aorta replacement.

Group II included 22 patients, their mean age of patients was 59 ± 16 years and 14 (64%) were male. Three patients had a type I aneurysm, six type II, nine type III, and 4 had a type IV aneurysm. The cause of the aneurysm was dissection in 16 and arteriosclerosis in six patients. Emergency operation was performed in three patients due to a ruptured aneurysm. The previous operations were aortic root replacement (four patients), combined aortic root and arch replacement (two patients), descending aorta replacement (six patients), infrarenal aorta replacement (five patients), and repeat thoracoabdominal repair (three patients). Five patients had been operated on two or more times (two patients having had three).

Group III comprised of 10 patients (six men and four women) treated surgically without any adjuncts. Their mean age was 58 ± 17 years. There was one patient with type I aneurysm, three with type III, and six with a type IV aneurysm. Seven patients had an arteriosclerotic aneurysm and three patients had an aortic dissection. One patient underwent emergency repair for a ruptured aneurysm. Three additional aortic segments were replaced before the thoracoabdominal operation in two patients (two descending aorta and one infrarenal aorta).

Blood samples were drawn before the operation, and on postoperative days 1, 3, 7, 14 and 30. The laboratory parameters examined included serum creatinine, total bilirubin and alanine aminotransferase. Urine output during vessel reconstruction was also measured. Postoperative complications were defined as proposed by Svensson et al. [2]. Multi-system organ failure was defined as the failure of two or more organs.

2.2. Surgical procedure

In group I, patients were treated following a procedure previously reported [9]. Briefly, under double-lumen endotracheal-tube anesthesia, a left thoracoabdominal incision was made with circumferential division of the left hemidiaphragm. Dissection was performed along the extraperitoneal plane. After dissection was completed, femoro-femoral bypass was started with full heparinization. We maintained the lower body blood pressure at more than 50 mmHg. A clamp was placed proximal to the aneurysm. The aorta was transected above the aneurysm and anastomosed proximally in an end-to-end fashion to a woven Dacron graft. While the proximal end was being anastomosed, segmental, visceral and renal arteries were perfused by placing a distal clamp at the mid-thoracic level. Next, the distal clamp was moved to the supraclavicular level, and patent intercostal arteries at the T4 to T8 level were oversewn and segmental arteries below the T9 level, if patent, were reconstructed using the inclusion button technique. After implantation of the segmental arteries, the proximal clamp was moved below those, allowing perfusion of the lower intercostal and lumbar arteries. Visceral and renal arteries were also reimplemented as a large Carrel patch or preserved in a beveled distal aortic anastomosis. During reconstruction, selective visceral and renal perfusion with 10–12 F balloon cannulas was performed by clamping the outflow tubing to the lower extremities (Fig. 1A). Each artery was perfused at a flow rate of 200–300 ml/min. After completion of the anastomosis of the visceral and renal arteries, the balloon cannulas were removed from the origins of those arteries, the clamp was placed across the graft distal to the reimplemented arteries, thereby restoring flow to the reimplemented arteries. The distal end of the graft was sutured to the aortic bifurcation or the common iliac arteries.

For 15 years we had been operating on patients, following the above described surgical procedure. However, we could not reduce the occurrence of spinal cord ischemia to levels lower than 10%. In an effort to reduce the occurrence of postoperative neurologic complications, we have modified the surgical procedure [10]. A prosthesis was prepared by suturing 8-mm grafts to an aortic graft. The small tubular grafts were used as interposition grafts for reattachment of individual intercostal or lumbar arteries. The proximal anastomosis was performed in the usual fashion. After completion of this anastomosis, the proximal clamp was positioned on the graft and the distal clamp was placed at a level between T8 and T9. Before T8 arteries were reattached to the side-arm grafts, the intercostal arteries above T7 level were oversewn. After the reconstruction of T8 arteries, the proximal clamp was moved caudally below the reconstructed side-arm graft, while maintaining perfusion to the reimplemented arteries. The distal clamp was then moved to a level between T9 and T10. In the same fashion, patent segmental arteries were reconstructed seg-
ment by segment from the T9 level to the L1 level. The reason for reimplanting all patent arteries between T8 and L1 was that, in 91% of the cases, the blood supply to the spinal cord is provided by some arteries from T8 through L1 and the arteria radicularis magna does not always originate from the larger segmental arteries [11]. The segment-by-segment reattachment technique was used to shorten the ischemic time as much as possible. The mean time required for the reconstruction of the individual arteries was less than 10 min. The non-used side-arm grafts were occluded and sutured. When the diameter or quality of the aorta did not allow the segment-by-segment reattachment technique, we applied hypothermic circulatory arrest. The femoro-femoral bypass was performed using a heparin-coated perfusion equipment that included a centrifugal pump (Carmeda Closed Chest Support System; Medtronic, Anaheim, CA). This heparin-coated cardiopulmonary bypass equipment allowed us to reduce the dose of heparin [12]. Flow rates were adjusted to keep the mean distal aortic pressure above 50 mmHg. Visceral and renal perfusion was carried out in conjunction with distal aortic perfusion (Fig. 1B). Each flow depended upon visceral or renal vessel resistance, and ranged from 80 to 220 ml/min (mean flow was 155 ml/min). Blood flow was considered appropriate when the patient’s urine output was 0.5 ml/min [13].

In group III, aortic repair was carried out according to an inclusion technique [8]. Basically, this technique was employed only when we assumed an easy operation. The body temperature was kept in the range of 36 to 37°C, while passive cooling (33–34°C) was employed in patients undergoing selective visceral and renal perfusion.

### 2.3. Statistical analysis

All data were expressed as the mean ± SEM. Comparisons among groups were performed by one-way ANOVA with the Fisher’s PLSD post-hoc test for selected pairs. Changes in baseline and postoperative laboratory values of each group were compared by two-way repeated-measures ANOVA. Frequency tables were analyzed with χ² test. A P-value of less than 0.05 was considered to indicate a statistically significant difference.

### 3. Results

Aortic cross-clamp time was significantly longer in group I and group II than in group III (111 ± 51 min, group I; 143 ± 56 min, group II; 68 ± 41 min, group III; P < 0.01, group I vs. group III; P < 0.05, group II vs. group III). The number of reattached intercostal arteries was 4.4 ± 4.4 in group I, 6.6 ± 4.2 in group II and 2.8 ± 4.2 in group III (P < 0.05, group II vs. group III). Transfusion requirement of banked packed red blood cells averaged 3325 ± 2311 ml in group I, 3253 ± 1265 ml in
group II and 2660 ± 1892 ml in group III. There were no significant differences among them.

Mortality and morbidity are summarized in Table 1. Most patients (67%) died of multi-system organ failure. One patient in group I suffered a rupture of the superior mesenteric artery during selective visceral perfusion and died on postoperative day 2. This event was considered as a complication related to the roller-pump system. Spinal cord ischemia occurred in five patients of group I and one patient of group II. Four patients of group I had permanent paraplegia and the remaining patients had paraparesis. With regard to the incidence of kidney failure, there were significant differences among the three groups (P < 0.05). Two patients in each group required hemodialysis. One patient in group II required hemodialysis because of high creatinine levels (2.9 mg/dl). If this patient were excluded from the statistical analysis, the P-value would reach 0.01. Two patients in each group required hemodialysis. Hepatic failure, defined as the requirement of plasma exchange, occurred in two patients of group I and in one patient of group III.

Creatinine levels were higher in the non-perfused patients than in the perfused patients (Fig. 2). By the 7th postoperative day, the levels of creatinine had returned to baseline in group I and group II. In contrast, the values in group III remained elevated for 1 month after the operation. There were significant differences among the three groups (P < 0.0001). Urine output was 2.9 ± 1.6 ml/min in group I, 3.8 ± 1.7 ml/min in group II and 0.2 ± 0.1 ml/min in group III (P < 0.01, group I vs. group III; P < 0.005, group II vs. group III). Non-perfused patients also had higher serum levels of total bilirubin and alanine aminotransferase than perfused patients postoperatively. In the non-perfused group, serum transaminase rapidly rose to levels 10 times the normal level but they normalized within 7 days, while serum bilirubin rose marginally but sustained bilirubinemia developed. This response was identical to the course of serum transaminase and bilirubin in ischemic hepatitis [14]. The differences in bilirubin and alanine aminotransferase values among the three groups are shown in Fig. 3A,B (P < 0.001, P < 0.005, respectively).

4. Discussion

Selective visceral and renal perfusion during thoracoabdominal aortic aneurysm repair has greatly contributed to lower occurrence of kidney failure and to maintain hepato-renal function. Intuitively, it is reasonable to perfuse the visceral and renal arteries during ischemia. The results of the current study support this thought. According to Schepens et al. [15], renal failure after thoracoabdominal aortic aneurysm repair adversely affected both short-term and long-term survival. Kashyap et al., have demonstrated that postoperative renal failure is associated with prolonged aortic cross-clamp [16]. Therefore, one should minimize intraoperative ischemia with adjuncts.

Safi et al., also reported the effect of selective visceral and renal perfusion on organ function after thoracoabdominal aortic aneurysm repair. However, in their series, while selective perfusion contributed to protect liver function, renal function deteriorated [13,17]. Although the difference between our results and theirs is difficult to explain, the only possible explanation is imminent renal tear related to balloon insertion. Only one patient in our group had visceral occlusive disease leading to such a complication, whereas approximately 60–80% of their patients had visceral artery stenosis [17]. Anyhow, prospective studies will be needed to definitively answer the question whether selective renal perfusion contributes to protect renal function or not.

In addition to local organ injury, visceral ischemia-reperfusion is considered to lead to coagulopathy [18] and respiratory impairment [4]. Harward et al., suggested that these phenomena were probably mediated by proinflammatory cytokines [19]. If the occurrence of coagulopathic hemorrhage or pulmonary complications were, at least in part, related to a release of proinflammatory cytokines after reperfusion of the ischemic viscera, it might be of great advantage to avoid visceral ischemia. In this regard,
selective visceral and renal perfusion was expected to reduce the incidence of pulmonary, hematopoietic or multi-system organ failure after thoracoabdominal aortic aneurysm repair. However, our data failed to confirm that selective visceral and renal perfusion reduced such complications.

Our strategy for thoracoabdominal aortic aneurysm repair is that basically all types are repaired with sequential clamping using distal aortic perfusion including selective visceral and renal perfusion. Sometimes one might encounter a situation where the required clamping time is longer than expected due to the complexity of TAAA repair. Even under such a circumstance, our strategy ensures that repair is completed without increasing organ ischemic time. Despite the prolonged aortic cross-clamp times, our surgical results were similar to those of contemporary reports [2,3,20–22]. These have convinced us that adjuncts are useful in repairing thoracoabdominal aortic aneurysms.

There are some potential drawbacks to our selective perfusion technique: firstly, it involves the possibility of causing vessel trauma during insertion of balloons into the orifice; and secondly, non-pulsatile flow does not prevent organ failure. We experienced the case of a patient who suffered vessel trauma. Probably, blood flow, pumped by a roller pump, exerted an excessive pressure on the diseased artery, leading to the rupture. Since then, we have replaced roller pumps with centrifugal pumps because the latter are inherently safer than the former, in that centrifugal pumps limit extreme positive pressure. The effect of pulsatile flow remains controversial. In this study, despite non-pulsatile flow, selective perfusion showed to have a protective effect on organ function.

Besides selective visceral and renal perfusion, several perfusion techniques have been advocated. They include cold Ringer’s lactate solution and mesenteric shunting using a side-arm graft [7]. Many surgeons have used cold perfusion, but its beneficial effect remains unproven [2]. Mesenteric shunting has the advantage of eliminating bypass equipment. However, the technique requires epidural cooling for spinal cord protection and the epidural cooling technique seems complicated.

The major limitation of this study is that the present work was a retrospective analysis of a non-randomized group of patients. Therefore, comparability among the groups becomes crucial. Namely, in the non-perfused group, most patients had less extensive diseases, which meant a lower risk of having ischemic complications. Nonetheless, they suffered from kidney failure more often. These results suggest that our selective perfusion technique is effective in preventing kidney failure. Another limitation is that the distribution of groups was rather unbalanced. Early in the study period, selective perfusion did appear to have a protective effect on organ function. Therefore, random usage could not be performed ethically. This bias may limit the strength of the conclusions. The data, however, justify the clinical use of selective visceral and renal perfusion.

In summary, our experience suggests that selective visceral and renal perfusion has a protective effect on hepato–renal function during thoracoabdominal aortic aneurysm repair.

References


Fig. 3. The course of serum total bilirubin level (A) and alanine aminotransferase level (B) before and after operation in the groups. There were differences among them (P < 0.001, P < 0.005, respectively, by analysis of ANOVA).


Appendix A. Conference discussion

Dr J. Pirk (Prague, Czech Republic): Are your cannulas commercially available and where?

Dr Morishita: No. This cannula is made by us and not yet commercially available.

Dr U. von Oppell (Cape Town, South Africa): What was your incidence of paraplegia with your method and did you use any method of staged clamping during the long cross-clamp times required for thoracoabdominal reconstruction?

Dr Morishita: In the non-perfused group no patient had a paraparesis and a paraplegia and four patients of 63 perfused patients had a paraplegia. But we must take into consideration the non-perfused patient had less extensive disease, and half of the patients had type IV. Despite the longer cross-clamp time in our perfused group, our incidence of paraplegia was 7%, similar to that of contemporary reports.

Dr von Oppell: Are you still using this technique?

Dr Morishita: Our paraplegia rate is now so low. Recently we have applied the side graft arm technique. For example, a prosthesis was prepared by suturing many side arm grafts onto the aortic graft and the intercostal artery is almost 10 min, and I think that the technique in combination with perfusion will contribute to our result.