Original Article

Selective Visceral Perfusion during Thoracoabdominal Aortic Aneurysm Repair

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Purpose: To evaluate the effectiveness of selective visceral perfusion during repair of an thoracoabdominal aortic aneurysm (TAAA), we compared the postoperative renal and hepatic functions (blood urea nitrogen, serum creatinine, total bilirubin, glutamate pyruvate transaminase) between the two groups with and without perfusion.

Patients and Methods: We operated on 52 patients with TAAA. Among them, the visceral vessels were reconstructed in 22 patients with selective visceral perfusion and in 12 patients without perfusion. The average selective perfusion time was 49.5±25.5 min. in the celiac and superior mesenteric arteries and 32.8±18.8 min. in the renal arteries. The average perfusion flow rate per each visceral vessel was 155.4±97.4 ml/min.

Results: There were five hospital deaths. There was no significant difference between the groups in the postoperative value of four factors. The selective perfusion time for vessel reconstruction in the selective visceral perfusion group was significantly longer than the arterial clamp time for vessel reconstruction in the non-perfusion group (49.5±25.5 min. vs. 25.6±13.4 min.).

Conclusion: Our selective visceral perfusion method is not only beneficial for organ protection, but also provides us with the necessary time to reimplant the visceral as well as intercostal or lumbar arteries. (Ann Thorac Cardiovasc Surg 2004; 10: 367–72)

Key words: selective visceral perfusion, thoracoabdominal aortic aneurysm, postoperative paraplegia

Introduction

Organ protection during surgery for thoracoabdominal aortic aneurysm (TAAA) is important for preventing postoperative complications. In particular, there are many reports regarding perioperative spinal cord protection for preventing postoperative paraplegia. Visceral organ protection is also important for successful operative results. The operative procedure for TAAA has followed the historical transition from Crawford[1)] to the recent operative procedure with organ perfusion. However, the views on the value of selective visceral perfusion for organ protection has been mixed, and is not definitive. In our hospital, selective visceral perfusion was introduced in 1994 in order to preserve visceral organ function and to ensure adequate time for the reconstruction of visceral as well as intercostal and lumbar arteries.[2-4)] In this study, we evaluated the role of selective visceral perfusion in TAAA surgery.

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Patients and Methods

Between July 1987 and December 2003, we surgically treated 52 patients with TAAA. The patient ages ranged from 22 to 82 years (average: 57.5±14.0 years). Seventeen patients were women and 35 were men. Aneurysm types consisted of 20 dissecting aneurysms and 32 non-dissecting aneurysms. According to Crawford classifica-

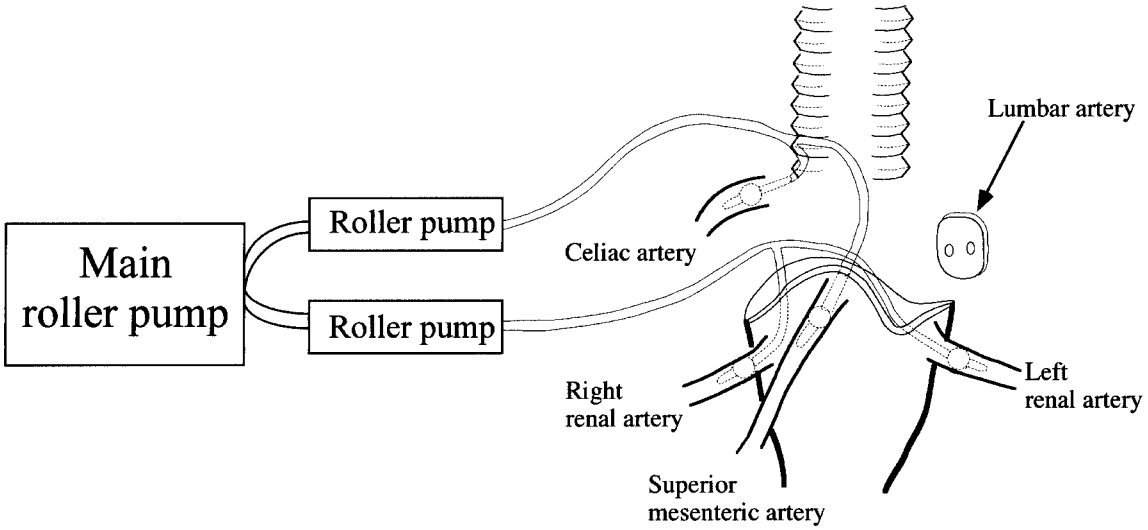

Fig. 1. Schema of selective perfusion of visceral organs.
With perfusion of the visceral arteries, the reconstruction of the lumbar arteries can be carried safely.

tion of TAAA,[1] the aneurysms were classified as being type I in 19, type II in 8, type III in 12 and type IV in 13 patients. Nine patients underwent emergency operations due to rupture, and 1 patient had a mycotic aneurysm with impending rupture. As adjuncts, a normothermic partial femoro-femoral bypass was used in 46 patients and a pulmonary artery-femoral artery bypass was employed in 6. Rectal temperatures were maintained in the range of 32.0 to 36.5 degrees C; average: 35.3±1.0. The aortic clamp time ranged from 29 to 211 min. (average: 124.0±47.9 min.; specifically, 95.7±35.2 min. in non-dissecting aneurysms and 154.8±40.4 min. in dissecting aneurysms). The average pump flow rate was 3.01±0.91 l/min., and the average arterial pressure of lower limb was maintained at 87.5±18.3 mmHg. The ratio of the lower limb arterial pressure to the upper limb arterial pressure was 0.85±0.26. As the level of aortic clamping was sequentially moved distally, the pump flow rate was reduced gradually according to the decreasing perfusion area. In the majority of cases, our multi-segmental cross-clamp technique[3,4] was applied with an average of 2.83±1.19 times per patient. In 45 (86.5%) out of 52 patients, patent segmental arteries were reimplanted or preserved by beveled anastomoses. The total number of reconstructed segmental arteries was 127, 92 (72.4%) of which were between the TH9 and L2 levels (where the Adams-kiewicz artery is generally located.). Since 1994, selective visceral perfusion was introduced in our hospital. Perfusion is maintained by inserting small cannulas to each arterial orifice, with a maximum of 4 cannulas perfused by two independent pumps as is illustrated in Fig. 1. After anastomosis between the aortic grafts and each visceral artery, the clamp is moved distal to the reconstructed branch and visceral perfusion from the aortic graft was reinitiated immediately. Finally, the main graft is anastomosed to the terminal aorta or bilateral iliac arteries using a straight or Y-graft.

In 34 patients, the major visceral vessels (celiac artery (CA), superior mesenteric artery (SMA), and renal arteries (RAs)) were involved in the aneurysm. All four of the major vessels were reconstructed in 15 patients, the CA and SMA in 14 patients, the SMA and bilateral RAs in 1, the CA in 1, and the RA in 3. We divided the 34 patients into two groups; selective visceral perfusion group (n=22) and non-perfusion group (n=12). In the selective visceral perfusion group, the reconstruction of visceral vessels was carried out with selective visceral perfusion in 22 patients, in whom CA and SMA were perfused in 19 patients, and the RA was perfused in 17 patients (Fig. 2). The selective visceral perfusion time ranged from 10 to 105 min. (average: 49.5±25.5 min.) for the CA and SMA, and from 9 to 67 min. (average: 32.8±18.8 min.) for the RA. The perfusion flow rate through each cannula ranged from 119.9 to 166.7 ml/min. (average: 155.4±97.4 ml/min.). The flow rate of each cannula was adjusted by equalization to the blood pressure of the lower extremity. In the non-perfusion group, the CA and SMA were reconstructed in 12 patients, and the RA was reconstructed in 6 patients without organ perfusion. The visceral organ ischemic time by the arterial clamp was from 12 to 49 min. (average:

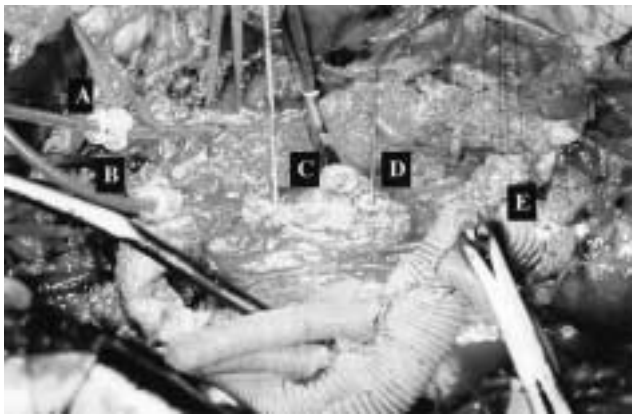

Fig. 2. Intraoperative photos.
The proximal anastomosis has been completed. The lumbar arteries, which are critical vessels for spinal cord ischemia, are prepared for reimplantation.
A, B: Perfusion of celiac artery and right renal artery with perfusion cannulas.
C, D: Lumbar arteries.
E: Main aortic graft with branches.

25.6±13.4 min.) in the CA and SMA and from 8 to 30 min. (average: 16.2± 9.7 min.) in the RA. To shorten the ischemic time of RA, we placed the clamp forceps between the SMA and RA during reconstruction of CA and SMA.

To serve as a control to these two groups, patients whose aneurysms did not involve any of 4 major visceral vessels, and their circulation maintained by direct perfusion from the femoral artery were utilized (control group n=18).

The characteristics of each group were summarized in Table 1.

To evaluate postoperative organ function, the postoperative values of the serum blood urea nitrogen (BUN), serum creatinine (Cr) level, total bilirubin (T-Bil), and glutamate pyruvate transaminase (GPT) values were followed until the 4 th. week after operation, and were compared among the three groups described above.

Statistical analysis

The patients who died during hospitalization were excluded from statistical analysis. The data were analyzed by the Stat View 5.0 (SAS institute, Cary, NC) statistical software packages. The data are expressed as means±standard deviations (SD). The differences in data of four factors in the three groups were analyzed with repeated ANOVA.

Results

1) During hospitalization, five patients died of multiple organ failure (MOF) (n=2), low output syndrome (n=2) and lung bleeding (n=1), however, no patient died primarily from renal or hepatic failure. The overall hospital mortality rate was 9.6% (5 of 52 patients). Out of these 5 patients, 2 patients were in the non-perfusion group and 3 were in the selective visceral perfusion group. There was no patient with neurologic abnormalities, including postoperative paraplegia in the postoperative follow up period.

2) The course of postoperative BUN and Cr levels (Fig. 3):

In the three groups, the courses of postoperative BUN and Cr showed no significant differences. The peak values of Cr and BUN appeared on the 2nd and 7th postoperative day, respectively. These values almost returned to the preoperative levels by the 28th postoperative day. As shown in Fig. 3, the selective visceral perfusion group tended to normalize earlier than the other 2 groups, although there is no significant difference.

3) The course of postoperative T-Bil and GPT levels

Table 1. The conditions of organ perfusion or organ ischemia were summarized in each group

	Perfusion group	Non-perfusion group	Control group
No. of pts.	22	12	18
Perfusion method	Selective perfusion with perfusion cannula	(–)	Directly from main pump via femoral artery
Perfusion flow rate per each cannula (ml/min.)	119.9-166.7, avg. 155.4±97.4	0	Not measured
Perfusion time (min.)	CA/SMA (10-105, avg. 49.5±25.5), RA (9-67, avg. 32.8±18.8)	0	Not measured
Ischemic time (min.)	0	CA/SMA (12-49, avg. 25.6±13.4), RA (8-30, avg. 16.2±9.7)	0

No. of pts.: number of patients, CA/SMA: celiac artery and superior mesenteric artery, RA: renal artery, avg.: average

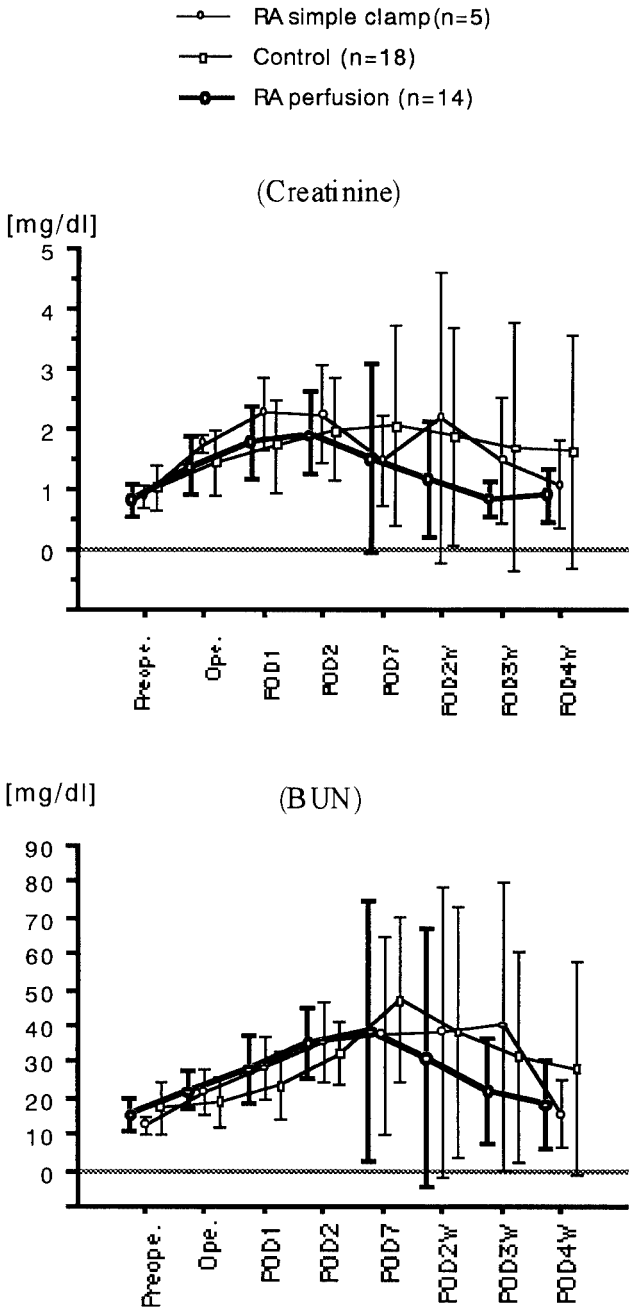

Fig. 3. The postoperative course of renal function related factors. There was no significant difference among the three groups. The creatinine and BUN in the selective visceral perfusion group remained lower than the remaining two groups after the 7th postoperative day.
RA: renal artery, BUN: blood urea nitrogen

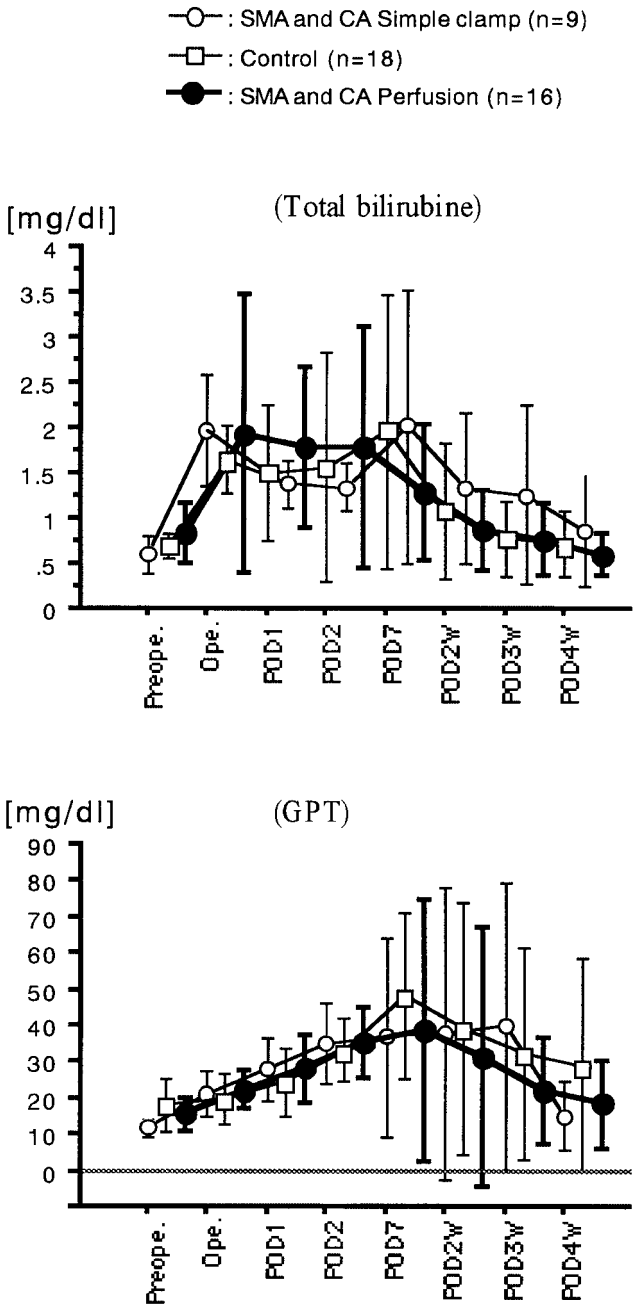

Fig. 4. The postoperative course of liver function related factors. There was no significant difference among the three groups. These two factors in the selective visceral perfusion group tend to be of lower value than the remaining two groups.
SMA: superior mesenteric artery, CA: celiac artery, GPT: glutamate pyruvate transaminase

(Fig. 4):

Two hepatic function related factors reached their maximal values on the 7th postoperative day. Thereafter, these values gradually decreased, and almost normalized by the 28th postoperative day. As for the postoperative course of these factors, there was no significant difference in the three groups. As shown in Fig. 4, the selective visceral perfusion group tended to normalize earlier than the other 2 groups.

4) The time required for reconstructing the CA and SMA

was significantly longer in the selective visceral perfusion group compared to the non-perfusion group (49.5±25.5 min. vs. 25.6±13.4 min.) (P=0.0026).

Discussion

Thoracoabdominal organ protection, including the spinal cord during surgery for TAAA, is important for successful operative results. Among ischemic complications, postoperative paraplegia is still one of the most feared complications. Many clinical or experimental reports[2-9] have discussed the prevention of postoperative paraplegia in TAAA surgery, and there are some reports concerning visceral perfusion during TAAA surgery. Opinions are mixed. Safi et al.[10] reported the benefits of maintaining perfusion of the SMA, especially for postoperative hepatic function. On the other hand, Svensson et al.[11] reported that selective renal perfusion did not prevent postoperative renal dysfunction at all, conversely, non-pulsatile pump flow appeared to be deleterious to renal function due to activation of the renin-angiotensin system, and inducing spasms of the renal arterial sphincter, which causes postoperative renal failure. However, our study shows selective perfusion to the kidney did not produce any adverse effects on the recovery of postoperative renal function. There is also a report in which renal insufficiency does not occur when renal arterial clamping is kept within 60 min.[11] In our series, the average ischemic time for RA, CA and SMA was short, and was 16 min. and 26 min. respectively. In spite of such short organ ischemic time in the non-perfusion group, we have introduced selective visceral perfusion with the principle goal of eliminating the ischemic time. In addition, we employ this technique to allow the surgeon to have sufficient time for identifying and reimplanting the critical intercostal or lumbar arteries for the spinal cord. Generally, the critical artery for spinal cord circulation branches off the abdominal aorta from the near level and opposite side of the major visceral arteries. In the range from TH11 to L2, 25 patients in our series underwent reconstruction of intercostal and/or lumbar arteries associated with concomitant reconstruction of the visceral vessels. The reconstruction was carried out with selective visceral perfusion in 14 patients, and without perfusion in 11 patients. The time required for reconstructing the CA and SMA was significantly longer in the selective visceral perfusion group compared to the non-perfusion group. Although the organ perfusion time was prolonged compared to the ischemic time of the non-perfusion group for reconstruction of visceral vessels, the postoperative visceral functions were normalized in the same postoperative period. Therefore, it is obvious that our perfusion method during TAAA surgery is beneficial for visceral organ protection. Moreover, this time difference between the two groups is thought to be explained by the time necessary for identifying and reconstructing the critical arteries for spinal cord circulation. Therefore, with the adjunct of selective visceral perfusion, it is shown that visceral vessels or critical arteries for the spinal cord can be reconstructed without any concerns of visceral ischemia.

There are very few reports about the methodology of selective visceral perfusion with theoretical background in detail. As an index of optimal perfusion, we used the pressure measurement at the tip of cannula. The flow rate of each perfusion cannula was regulated as the pressure of the cannula tip was kept equal to the pressure distal to aortic clamp. We used a roller type pump, which is regulated by flow rate, not by pressure. As a consequence, the perfusion flow rate was 155.4±97.4 ml/min. in this study. Some researchers have recommended a flow rate of 200-300 ml/min.,[12] but we believe this flow rate is too high. They have used “urination” as an index of optimal perfusion flow rate to the RA, however that perfusion flow rate may become to be high for renal cell viability. We feel that an unnecessarily high flow rate for the purpose of obtaining urination should be avoided. The alternative method of selective visceral perfusion reported by Cina et al.[13] uses cooling perfusion fluid and is considered a reasonable method for visceral organ protection, however, may prolong cardiopulmonary bypass time due to the need for warming time of the systemic circulation.

Selective visceral perfusion can be especially useful in patients such as emergency patients with ruptured aneurysms, in whom the multisegmental aortic clamping method cannot be applied, and in patients with visceral organ dysfunction. In the patient with impaired visceral organ function, a fatal injury may be caused even by negligible visceral organ ischemia during surgery. However, there is no report showing utility of selective visceral perfusion in such poor conditioned patients. Its evaluation seems to be difficult to perform clinically but may be possible experimentally. Selective visceral perfusion also provides surgeons with enough time for protective procedures of the spinal cord and certainly improves the mental composure of the surgeon; nevertheless it is difficult to provide the facts objectively.

Conclusion

In this report, it is shown that our organ perfusion method is beneficial for organ protection during TAAA surgery, and also the most beneficial advantage of this technique is to provide surgeons enough time to identify and reimplant the critical intercostal or lumbar arteries, which can lead to preventing spinal cord ischemia consequently.

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