Trine M. Olberg Eide

Thoracoabdominal aortic aneurysm repair – Operative technique, pathophysiology and results of treatment

Doctoral thesis
for the degree of philosophiae doctor

Trondheim, May 2006

Norwegian University of Science and Technology
Faculty of Social Sciences and Technology Management
and Faculty of Medicine
PhD Programme in Health Science

NTNU
Innovation and Creativity

NTNU
Norwegian University of Science and Technology

Doctoral thesis
for the degree of philosophiae doctor

Faculty of Social Sciences and Technology Management
and Faculty of Medicine
PhD Programme in Health Science

ISBN 82-471-7951-2 (printed version)
ISBN 82-471-7950-4 (electronic version)
ISSN 1503-8181

Doctoral theses at NTNU, 2006:98

Printed by NTNU-trykk

Contents

1. Aknowledgements

This study was carried out during the years 2003-2005 at the Department of Surgery, University Hospital of Trondheim.

I would like to express my sincere gratitude to my supervisor Professor Hans O. Myhre for introducing me to the field of vascular research. I feel deeply thankful for friendship, confidence, enthusiasm and impressive knowledge.

I also wish to thank the following:

My assistant supervisor Pål Romundstad, PhD, for valuable help and contribution in the field of statistics.

My assistant supervisor Professor Petter Aadahl, for his ideas and broad knowledge in the field of anaesthesiology.

Ann Mari Østraat for her kind help with the writing process and other practical matters.

Chief of the Intensive Care Unit, assistant Professor Pål Klepstad, for his central role in Paper V.

I also want to thank my other co-authors: Roar Stenseth, Ola D. Sæther and Jenny Aasland.

My dear husband Eivind for patient support and expert help in medicine. My precious children Anna, Katarina and Eivind jr. for loving existence.

This work was supported by grants from St. Olavs Hospital, University Hospital of Trondheim (no 1401 1023 4630), The Ministry of Health and Care Services and The Medical Faculty, The Norwegian University of Science and Technology.

2. List of papers

This thesis consists of the following publications, which will be referred to by roman numerals.

I. *T. O. Eide, H. O. Myhre, O. D. Sæther and P. Aadahl* . Shunting of the coeliac and superior mesenteric arteries during thoracoabdominal aneurysm repair. Eur J Vasc Endovasc Surg, 2003; 26: 602 – 606.

II. *T. O. Eide, P. Romundstad, O. D. Sæther, H. O. Myhre and Aadahl P.* A strategy for treatment of type III and IV thoracoabdominal aortic aneurysms. Ann Vasc Surg, 2004; 18: 408 – 413.

III. *T. O. Eide, J Aasland, P Romundstad, R Stenseth, OD Sæther, P Aadahl, H. O. Myhre.* Changes in haemodynamics and acid base – balance during cross-clamping of the descending thoracic aorta. A study in patients operated on for thoracic- and thoracoabdominal aortic aneurysm. Eur Surg Res 2005; 37: 330-334.

IV. *T. O. Eide, P. Romundstad, R. Stenseth, P. Aadahl and H. O. Myhre.* Spinal fluid dynamics during resection and graft replacement for descending thoracic – and thoracoabdominal aortic aneurysms. Int Angiol 2006; 25: 46-51.

V. *T. O. Eide, P. Romundstad, P. Klepstad, H. O. Myhre.* Health – related quality of life in long – term survivors of thoracoabdominal aortic aneurysm repair. J Vasc Nurs 2005; 23: 88-94.

3. Abbreviations

AAA	Abdominal aortic aneurysm
b/min	beats per minute
CA	Coeliac artery
CO	Cardiac output
COPD	Chronic obstructive pulmonary disease
CSFD	Cerebrospinal fluid drainage
CSFP	Cerebrospinal fluid pressure
CVP	Central venous pressure
DC	Declamping of the aorta
HRQOL	Health-related quality of life
ICU	Intensive care unit
l/min	Litres per minute
pre-XC	prior to aortic cross-clamping
SF-36	Short-form 36
SMA	Superior mesenteric artery
TAA	Thoracic aortic aneurysm
TAAA	Thoracoabdominal aortic aneurysm
XC	Cross-clamping
X-corp	Extracorporeal circulation

4. Introduction and background

A thoracoabdominal aortic aneurysm is an aneurysm of the aorta that includes the orifices to the visceral arteries; the celiac artery (CA), the superior mesenteric artery (SMA) and the renal arteries (Crawford 1974). Most of these aneurysms include both the thoracic and abdominal aorta. According to the classification of Crawford, who was a pioneer in modern surgical treatment of these aneurysms, they are divided into four types on the basis of the extent of the aneurysm (Crawford et al 1986). Type I involves most of the descending thoracic and upper abdominal aorta, type II involves most of the descending thoracic aorta and most of the abdominal aorta. Type III involves the distal descending thoracic aorta and varying segments of the abdominal aorta and finally type IV aneurysms, which are actually abdominal aneurysms, involve most or the entire abdominal aorta although including the arteries mentioned above (Crawford et al 1986) (Fig.1). In recent years a Type V aneurysm has been identified, starting at the level of the sixth intercostal space, tapering to just above the renal arteries (Safi et al 1998).

The aneurysm dilatation is usually caused by atherosclerosis leading to degeneration of the aortic wall, which makes the aortic diameter progressively increase. The etiology may also be conditions like Marfan syndrome, aortic dissection, arteritis, infection, complications following previous aortic surgery and trauma (Crawford & Crawford 1984, Coselli & Poli de Figueiredo 1997). Atherosclerotic aneurysms usually occur in the older age groups, with an increasing proportion of the population in the industrialized countries. The gender ratio of TAAA is similar to infrarenal abdominal aortic aneurysms with both groups showing a moderate male predominance. Aortic dissection, connective tissue disorders and aortitis seem to be more common causes of TAAA when compared to AAA (Webb & Williams 1999). The true incidence of TAAA is unknown (Svensjö et al 1996). However an estimated incidence has been reported to be 2.2 cases per 100,000 inhabitants per year in the U.S. (Webb & Williams 1999).

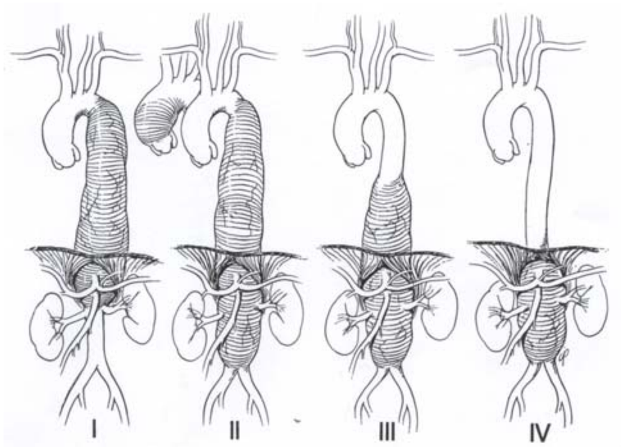

Fig. 1 Crawford's classification of thoracoabdominal aortic aneurysms into four types.

The natural history of descending thoracic- and thoracoabdominal aortic aneurysms is described in rather few studies (Crawford et al 1986, Cambria et al 1995, Coselli & Poli de Figueiredo 1997, Griepp et al 1999). The prognosis is significantly influenced by size, location, the occurrence of symptoms and etiology. Independent from the different mechanisms of injury and degeneration affecting the structural integrity of the aortic wall, the biological fate of most aneurysms is progressive enlargement, rupture and death, provided the patient is not dying from other causes (Coselli & Poli de Figueiredo 1997). Aneurysms developing in the thoracic or abdominal aorta following aortic dissection have a higher risk of rupture than atherosclerotic aneurysms, and thus portend a worse prognosis without intervention (Webb & Williams 1999). The 5-year survival of untreated patients with TAAA is significantly lower than age matched controls. Cambria and colleagues (1995) reported a 17%

repair-free 5-year survival rate of untreated TAAA. In their series aneurysm on the basis of dissection and ruptured aneurysms were excluded. In a study of Crawford et al (1986) the estimated 5-year survival rate of non-operated patients was less than 20% following diagnosis, and half of the deaths were due to rupture of the aneurysm.

Surgical treatment

The first successful repair of a thoracoabdominal aortic aneurysm was reported in 1955 by Etheredge (Etheredge et al 1955). Later, DeBakey and coworkers (DeBakey et al 1965) demonstrated that a Dacron graft could function as a temporary bypass during thoracoabdominal repair and then serve as a permanent vascular replacement. Stepwise grafting using 8 mm Dacron sidelimbs to the celiac, superior mesenteric and renal arteries decreased the organ ischaemia time. Crawford commenced using and developing the graft inclusion technique for repair of TAAA in the 1960's and a clinical series was reported in 1974 (Crawford 1974). By introducing a technique of incorporating the orifices of the visceral vessels as an inlay inclusion patch, the operative mortality was significantly reduced, and shortened clamp times led to improvement in overall results.

During the 1980's and 90's the results following thoracoabdominal aneurysm repair improved. 30-day mortality following elective operations varied from over 10% to around 7% depending upon the extent of the repair and the nature of the disease (Hollier et al 1988, Cambria et al 1989, Gilling Smith et al 1995, Sandmann et al 1995, Cowan et al 2003). In 1986 Crawford and colleagues reported a 91% early (30-day) survival rate in 605 patients treated surgically for TAAA. A few years later the

30-day survival rate in three series of type I and II TAAA repair showed improved and comparable results; around 96% (Crawford et al 1991, Svensson et al 1998, Coselli et al 2002). During the last decade distal aortic and visceral perfusion and cerebrospinal fluid drainage have been used successfully as adjuncts in an attempt to reduce end-organ ischemia in addition to various pharmacological treatment modalities (Safi et al 2003). Simpler methods have usually been preferred for type IV aneurysms (Crawford & Crawford 1984, Schwartz et al 1996, Walhgren & Walhberg 2005). As a method to demonstrate the effectiveness of surgical repair of descending thoracic aortic aneurysms and TAAA when compared to the natural history, Miller and colleagues (2004) found that the 5-year mortality in a cohort of unoperated patients was 87% vs. 39% in a population treated surgically for TAAA, giving a risk difference of 48%. These numbers indicate that two patients need to be treated to prevent one death within five years.

Complications

The surgical treatment of TAAA involves the vasculature of multiple organs, with the potential for complications. Renal insuffiency, symptomatic aneurysms, rupture and type II aneurysms were identified predictors of 30-day mortality in a study of LeMaire and colleagues (2003). Morbidity can be devastating and may prolong hospital stay and recovery. Postoperative quality of life can be negatively affected, especially for those experiencing complicated postoperative courses (Paper V). However, contrasting the 5-year survival rate of non-treated patients (Crawford et al 1986, Cambria et al 1995) the 5-year survival rate of patients treated surgically has been reported to be between 60 and 73.5% repectively (Svensson et al 1993, Webb &

Williams 1999, Coselli et al 2002). Comparing long-term survival in series from different time intervals should be performed with care. The life expectancy is steadily increasing, and better treatment of comorbidity may improve life expectancy over time.

Nevertheless, non-operative therapy may be selected in patients of high age, and in those with modest-sized aneurysms, or multiple comorbidities making the short-term risk of surgery prohibitive or limit the life expectancy to a degree that makes surgical treatment contraindicated (Gilling-Smith and Wolfe 1995). Non-operative management and close follow-up has been recommended for smaller TAAA if the annual growth rate does not exceed 5 mm over a 6-month period (Lobato and Puech-Leão1998). Otherwise, operative repair is considered the preferred method in patients with ruptured or symptomatic TAAA or whenever the diameter of the aneurysm exceeds 50-60 mm (Crawford et al 1991, Cambria et al 1995, Lobato and Puech-Leão1998).

Neurologic complications

Decreased blood perfusion to the spinal cord during cross-clamping of the descending thoracic aorta is probably the most important single mechanism of postoperative neurologic complications. In 1993 Svensson and colleagues reported a 16% incidence of paraplegia or paraparesis, of which 45% developed paraplegia and 55% paraparesis, in a study of 1509 patients following TAAA repair. Significant predictors of these devastating complications were aortic clamp time, extent of aortic repair, rupture, patient age, and a history of renal dysfunction. Several other risk factors for neurologic complications connected with aortic cross-clamping have been identified:

Firstly, cerebrospinal fluid pressure (CSFP) increases with anaesthetic manoeuvres during aortic surgery (Svensson et al 1990) and with aortic cross-clamping (Svensson et al 1990, Crawford et al 1991, Paper IV). Secondly, oxygenation of the spinal cord falls rapidly with aortic cross-clamping, even with the application of deep hypothermia and circulatory arrest (Svensson et al 1992). Thirdly, failure to reattach patent intercostal arteries is associated with an increased risk of paraplegia and paraparesis (Svensson et al 1991, Jacobs et al 1999). The need for reimplantation of intercostal and lumbar arteries can be assessed by recording motor evoked potentials during the operation (Svensson et al 1991, Jacobs et al 2000). The degree of ischemia is dependent on the number and diameter of available collateral arteries, including the anterior and posteriolateral spinal arteries, and on the extent of the aneurysm (Svensson et al 1993).

Protection of the spinal cord from ischemic and reperfusion injury has been the topic of several experimental research projects and clinical studies during the last two decades (Paper IV). The understanding of the pathophysiological changes of aortic cross-clamping in man has increased, but the means of preventing paraplegia or paraparesis is not yet fully understood (Jacobs et al 1999). Therefore there is need for further clinical and experimental investigations (Cochrane Review 2005). Prophylactic measures are usually based on the assumption that the problem is multifactorial (Myhre et al 1990). Several principles including mechanical methods like reimplantation of intercostal arteries, the use of bypass or shunts, and pharmacological methods or hypothermia have often been used in the combination with CSF drainage (Crawford et al 1991, Svensson et al 1998, Coselli et al 2002).

However, data supporting the role of CSFD in TAAA surgery for prevention of neurologic injury is still limited (Myhre et al 1996, Khan & Stansby 2003).

Intestinal ischemia

A number of approaches have been advocated for reducing intestinal ischemia which represents a risk of multiorgan failure following TAAA surgery (Christakis et al 1989, Jacobs et al 1997, Cambria et al 1998, Article I), which is an important source of morbidity during and after TAAA repair (Cohen et al 1988, Leijdekkers et al 1999). Intestinal ischemia is also implicated in the development of intraoperative coagulopathy (Gertler et al 1996, Harward et al 1996). Adjuncts like retrograde aortic perfusion as well as passive shunts have been applied (Paper I, Cambria et al 1998). During the last decade, the use of retrograde aortic perfusion by means of a left heart bypass combined with sequential aortic clamping and selective perfusion of the CA, SMA and both renal arteries, has in some centres become the preferred method for TAAA repair (Safi et al 2003, Jacobs et al 2004). Using centrifugal pump and heparin coated tubes has the advantage of reducing the need of heparinization, and gives the possibility to control distal blood flow. By this method visceral perfusion is maintained during the whole procedure, irrespective of the extent of the aneurysm and the time of aortic cross-clamping (Safi et al 2003). The method can be modified with perfusion of the kidneys with cold crystalloid solution, in an attempt to further reduce the risk of renal failure.

Renal failure

Acute renal failure is a common and potentially serious complication after TAAA surgery, affecting from 7-40 % (Svensson et al 1989, Safi et al 1996, Kashyap et al

1997). The severity of renal injury depends on the duration of renal ischemia time. Postoperative dialysis in required in 3-15% of all patients (Svensson et al 1989, Safi et al 1996, Widmann et al 1998). The optimal way of protecting the kidneys during TAAA surgery is controversial. Theoretically, blood perfusion of the kidneys should reduce renal injury by delivering oxygenated blood to the renal tissue (Svensson et al 1993). However, some reports have suggested that normothermic blood perfusion is not the optimal method for renal protection (Safi et al 1996). There are several possible causal explanations. In addition to sufficient flow, adequate arterial pressure seems to be essential in maintaining renal function (Jacobs et al 1998). It has been shown that perfusing the kidneys with cold crystalloid solution may be preferred to normothermic blood (Köksoy et al 2002). The aim of cold crystalloid renal artery perfusion is to produce local hypothermia and reduce the metabolic needs of the kidneys. This technique has been our preferred method for protection of the kidneys during TAAA operations.

Quality of life

The long-term consequences of TAAA repair have been described to a lesser extent, except for the mortality rates. Thus, the risk of non-operative management should be balanced against expected surgical mortality and the risk of spinal cord injury or other complications in most patients before proceeding with surgical treatment. In the discussion whether the patient should be operated or not, it is also of importance to know which quality of life the patient can expect in the years following surgery. To our knowledge there are no studies of HRQOL in patients operated for TAAA. However, Ohlson and co-workers have presented an investigation performed in patients who underwent surgery for descending thoracic aortic aneurysm (Ohlson and

Thelin1999). They found that the patients were satisfied with the operation, but reported a lower quality of life than the general population. Such information in addition to knowledge about medical risk factors could give a better background for evaluation of the best treatment modality in these patients (Higginson and Carr 2001).

5. Aims of the thesis

The aim of the present thesis was to study various technical aspects on resection and graft replacement for thoracoabdominal aortic aneurysm (I, II). In two of the papers descending thoracic aortic aneurysm repair was included in addition to TAAA repair (III, IV) since the problems regarding cardiac function and spinal fluid dynamics were similar in the two groups. In paper V postoperative quality of life was investigated in long-term survivors following TAAA surgery.

Paper I

The aim was to investigate the feasibility of applying a T-shunt supplying the celiac and superior mesenteric arteries with blood via a sidebranch of the main vascular graft following completion of the proximal anastomosis. The technique was used for type III and IV thoracoabdominal aortic aneurysms.

Paper II

To discuss the various technical strategies for surgical treatment of type III and IV thoracoabdominal aortic aneurysm.

Paper III

To study the haemodynamic, metabolic and blood gas response of proximal aortic cross-clamping, which occurred during thoracic – and thoracoabdominal aneurysm aortic repair. Only patients operated without extracorporeal circulatory support were included in the investigation.

Paper IV

The aim was to investigate cerebrospinal fluid pressure during and after thoracic – and thoracoabdominal aortic repair. We also wanted to investigate the volume of CSF removed during and after the operation. Finally, CSFP was correlated to the occurrence of postoperative neurologic complications.

Paper V

The aim was to investigate health-related quality of life in long-term survivors following TAAA repair, comparing with results obtained in age and gender adjusted data from the general population.

6. Patients and methods

Thoracoabdominal aortic aneurysm repair was started at St. Olavs Hospital, University Hospital of Trondheim, in the early 1980's and at the same time surgery for disease of the descending thoracic aortic aneurysm was started. The present investigations were based on patients operated during the period 1985 –2001 using direct cross-clamping of the aorta without extracorporeal circulation; the so-called "clamp and go" technique. Patients treated by stentgrafting were excluded from the study. Hybrid operations, which are a combination of open and endovascular repair, were also excluded from the investigation, with two patients as exceptions (Paper II and V). A follow-up of patients included in the present investigations was completed in August 2003.

Data recording

Patients' medical data were retrieved in medical records and all surviving patients were followed either at the outpatient clinic, by contact with the primary physician or by collecting information from the patient's local district hospital. Subsequently, all data were indicated into a form and plotted into SPSS version 13.0 (SPSS, Chicago, Illinois, USA) for statistical analysis. Physiological data were not available in all patients, partly due to the emergency nature of several of these operations. Furthermore, although monitored, some intraoperative data were not noted in the anaesthesia chart. Follow-up was also performed by checking patients against the Norwegian Registrar's Office of Births and Deaths. In Paper V patients' informed consent and permission to include a close relative was provided. Survey data were collected either by mail or phone using the Short-Form 36 and Disease-specific questions. All investigations were approved by the local ethics committee.

Statistical analysis

To describe the intra – and postoperative data following TAAA repair using a technique of shunting the coeliac and superior mesenteric arteries in Paper I, data were presented using medians and range.

To describe the distribution of preoperative risk factors, the mortality rate and postoperative problems in patients operated on for Crawford type III and IV aneurysm in Paper II, data were presented using numbers and percentages (%). Intraoperative data, need for artificial ventilation and hospital stay were described as median values and interquartile range. Long-term survival probability of nonruptured type III and IV aneurysms was plotted in a Kaplan-Meier curve.

In Paper III patient data and preoperative risk factors were presented in percent (%). Haemodynamic values and blood gases were given as mean values with standard deviations. A paired t-test was used to investigate the changes in haemodynamics and metabolic response induced by aortic cross-clamping in a group of patients operated without extracorporeal circulatory support. However, a complete set of data was not available for all time points during the operation mainly because of the emergency nature of several of these operations. The paired t-test analyses were therefore restricted to time points in which most of the patients were represented. Thus, the measure point 45 minutes during XC was excluded from the analysis.

In paper IV patient characteristics and comorbidities were presented as numbers of cases. Details of operation and spinal fluid drained intra – and postoperatively were given as median values with range. To estimate the correlation between CSFP, removed CSF and CVP, we used the Pearson correlation coefficient. To assess differences in CSFP before, during and after aortic cross-clamping we used repeated measures ANOVA, assuming a common underlying variance. Before XC, measurements performed after induction of anaesthesia and immediately prior to XC were combined. During XC, values immediately after XC and after 15, 30 and 45 minutes respectively, were recorded. Finally, during the DC phase the values at 5 and 15 minutes and at the end of surgery were combined. As for Paper III, a complete set of measurement data were not available for all time points during the operation

To assess health-related quality of life in long-term survivors after TAAA repair, SF-36 result scores were presented using the mean values with 95 % confidence intervals. When comparing with the general population, each patient score was matched on sex and age. Patient's scores were also compared with relative's scores, but in this part of the examination only individuals with relative's scores were included in the analysis. Paired samples t-test was performed when comparing mean scores of separate groups. The result scores of the disease-specific questions were illustrated in bars representing the number of patients.

Anaesthesia technique

In all patients anaesthesia was introduced by barbiturate, fentanyl and pancuronium. Continuation of the anaesthesia was obtained by isofluran and N2O/O2. Furthermore, fentanyl/pancuronium was supplemented with epidural bupivacain (5 mg/mL). In addition to a Swan-Ganz catheter, two large-bore intravenous lines were available. Prior to cross-clamping of the thoracic aorta, 25-40 g of mannitol was administered intravenously. Sodium bicarbonate was infused to counteract metabolic acidosis. To reduce blood pressure during cross-clamping of the thoracic aorta, nitroglycerine and sodium-nitroprusside were infused. These drugs were discontinued prior to declamping of the aorta. 3000 IU of heparin was given prior to cross-clamping of the aorta. Autotransfusion was used during most operations. The kidneys were irrigated with cold Ringer's acetated solution (4^oC) containing 1000 IU of heparin/L (Stenseth & Myhre 1988).

Paper I

In paper I data from eight patients operated on for either type III (5) or type IV (3) thoracoabdominal aortic aneurysm were induced. The feasibility of applying a T-shunt (Vascushunt 11F, Baxter Healthcare Corp. Erwin CA, USA) for perfusion of the CA and SMA following completion of the proximal anastomosis was investigated. This is a type of shunt originally designed for carotid artery surgery. The shunt was connected to a sidebranch of the main vascular prosthesis. It was used until the final anastomosis to the CA, SMA and both renal arteries had been almost completed. Immediately prior to termination of this anastomosis, the shunt was removed and the last couple of stitches were placed. Mortality, reoperations, as well as local and general complications were recorded. Furthermore, postoperative renal function, stay in hospital and in the ICU, as well as clamp-time until final restoration of blood flow to the CA and SMA were measured. A complete follow-up of the series was obtained.

Paper II

Twenty-seven patients operated for type III (10) or type IV (17) thoracoabdominal aortic aneurysms were investigated and the results following the application of different techniques were discussed. The “clamp and sew” technique was used in six cases. In 12 patients with type IV aneurysm the proximal part of the vascular graft was bevelled including the CA, the SMA and one or both renal arteries in the proximal anastomosis. Finally, the eight patients operated with shunting of SMA and CA referred to in paper I were included. A 100% follow-up was obtained. Early mortality (<30 days) was recorded and late survival calculated in patients with non-ruptured aneurysm by the Kaplan Meier method. The patients were categorized according the whether they had rupture, were symptomatic but without rupture or whether the operation was performed electively. Risk factors like hypertension, coronary heart disease, renal disease and chronic obstructive pulmonary disease were investigated. ASA classification was also recorded for evaluation of preoperative risk.

Paper III

Fifty-one patients treated for thoracoabdominal (31) or descending thoracic aortic aneurysm (20) were included in this investigation. They were operated on using direct aortic cross-clamping without circulatory support. The following parameters were measured: EKG, intraarterial pressure (right radial artery), central venous pressure and pulmonary arterial pressures. These parameters were measured continuously. The pulmonary capillary wedge pressure and cardiac output was measured intermittently as were blood gases and haemoglobin. Cardiac output was measured by the thermodilution technique. Haemodynamic variables and blood gases were measured before and during aortic cross-clamping. Urine output, serum potassium and body temperature were also recorded. Before XC measurements performed after induction of anaesthesia and immediately prior to XC were included. During XC we recorded values immediately after XC and after 15 and 30 minutes respectively. Only individuals with observation in both time spans were included in the analysis.

Paper IV

In 29 patients operated on for thoracic or thoracoabdominal aortic aneurysm we made an attempt of monitoring the cerebrospinal fluid pressure with the intention to keep it below 10 mm/Hg during and after the operation. For monitoring of CSFP and drainage of CSF, a 16G catheter was introduced via the L3-L4 interspace. The pressure was partly measured intermittently and partly by the use of an overflow system (Exacta external drainage and monitoring system, Medtronic Inc., MN, USA) where CSF was supposed to be drained whenever the pressure increased above 10 mm/Hg. The catheter was left in place and usually removed on the 2nd postoperative day. The CSFP was correlated to the central venous pressure as was drained volume of CSF. Length of stay in hospital and ICU were recorded as were operating time and the need for artificial ventilation. Postoperative complications with special attention to neurologic deficits were noted, and the occurrence of neurologic complications was related to the level of CSFP during the operation.

Paper V

Thirteen long-term survivors following thoracoabdominal aortic surgery were investigated, but two were lost to follow-up. Health related quality of life (HRQL) was measured by the short form 36 (SF-36) and questions specific for vascular disease. In addition, the patients' relatives received corresponding questions, responding on behalf of the patient. Patient's data scores were compared with age and gender adjusted data from the general population, and with the relatives' scores.

7. Summary of results

Paper I: In eight patients a technique of using a carotid T-shunt connected to a sidebranch of the main vascular prosthesis was applied for supplying blood to the coeliac and superior mesenteric arteries during repair of type III (5) and IV (3) TAAA. There was no early mortality in this group. One reoperation became necessary due to haemorrhage and another patient was reoperated with a Hartmann's procedure for gangrene of the sigmoid colon. One patient had postoperative paraparesis, but eventually recovered quite well, and was able to walk with splints. Two patients required dialysis for three days, but no permanent dialysis became necessary. The median clamp time until completion of the anastomosis to the CA, SMA and renal arteries was 47 min (range 35 - 82). However the actual ischemia time to the bowel was only 10-20 min, i.e. the time necessary to perform the proximal anastomosis. During follow-up one patient died of malignancy, one of renal insuffiency and two from myocardial infarction after 5, 5, 6.5 and 7.5 years respectively. The other patients were alive from 3 to 8 years after surgery. The shunting method seems feasible, but the flow capacity of the shunt needs to be explored more thoroughly.

Paper II: Twentyseven patients were operated on for type III (10) and IV (17) TAAA. The "clamp-and-sew" technique was applied in six cases, and one of these patients with a ruptured type III aneurysm died within 30 days from myocardial infarction. Of the 12 patients with type IV aneurysms who had the orifices of the visceral arteries included in one proximal anastomosis, three died within 30 days. All four patients (14.8%) who died within 30 days had ruptured aneurysm, giving a 45% mortality rate in this particular group. There were no early deaths in a group of eight patients where a shunt-technique to the CA and SMA had been applied, as described in Paper I. However, one patient in that group with a type III aneurysm developed postoperative paraparesis. An identical surgical technique was planned in one more patient who developed postoperative paraparesis. However due to technical problems during the operation the shunt could not be applied. Two additional patients had signs of moderate multiorgan failure, but lived for 5 and 6 years respectively, without sequelae. Reoperations for haemorrhage became necessary in two patients, and one patient underwent surgery for sigmoid necrosis. Four patients needed temporary dialysis.

Excluding patients who were admitted with rupture, the 5-year survival rate was 65%. There were no significant differences in median clamp time between the various groups. However, the actual ischemia time to the bowel was lowest in the shunt group because SMA and CA were perfused with blood from the T-shunt after about 10-20 min. The median hospital stay was similar in all groups; 16.8 days (range 12 to 35).

Paper III: In 51 patients operated on for TAAA or TAA using direct cross-clamping of the aorta without circulatory support, mean cardiac output rose significantly during XC (from 4.7 l/min to 6.0 l/min, $p<0.01$). A similar percentual increase in heart rate (from 70 b/min to 88 b/min) and proximal systemic blood pressure was observed during XC, even if an attempt had been made to keep the blood pressure at near-normal levels using vasodilating agents. Diastolic pulmonary arterial pressure as well as pulmonary capillary wedge pressure increased, whereas central venous pressure remained unchanged. The systemic vascular resistance remained unchanged during the XC-phase. Base-excess decreased significantly during XC. A highly significant increase in S_vO_2 ($p < 0.001$) during aortic cross-clamping indicated an increased perfusion of the upper part of the body during this phase of the operation.

Paper IV: In 29 patients with TAA or TAAA, operated without shunting or extracorporeal circulation, monitoring and drainage of CSFP was performed intraoperatively and until the second postoperative day. Twentysix patients had no postoperative neurologic deficits. In contrast, three suffered from postoperative neurologic sequele detected in the immediate postoperative period. The survival time until follow-up in the groups with and without paraplegia/paraparesis averaged 10 (7-15) and 5 (0-16) years respectively.

The patients who developed neurologic sequelae had a higher intraoperative CSFP compared to those without neurologic symptoms (p=0.04). Median CSFP before cross-clamping of the thoracic aorta, at cross-clamping, 15 min after cross-clamping and 15 min after declamping of the aorta were 18, 19, 17 and 19 mm/Hg respectively in patients with neurologic sequelae. In asymptomatic patients these pressures were 8, 13, 9 and 12 mm/Hg respectively.
During the operation a median of 41 ml (0-65) of CSF was removed in the three patients with neurologic sequelae. For comparison 43 ml (0-143) was removed in the asymptomatic group. On the day of operation the total removed volumes were 210 and 85 ml respectively, whereas the volumes from start of the operation until removal of the catheter were 600 and 251 ml respectively.

There was a statistically significant positive correlation between CVP and CSFP when including all intervals of measurement ($r=0.8$, $p=0.02$). The correlation between CVP and the drained volume of CSF, however, did not reach statistical significance.

Paper V: Assessing health-related quality of life in 11 long-term survivors following TAAA repair showed that the patient's SF-36 scores were generally poorer than that of the normal population in both physical and mental dimensions. Patients who had a complicated postoperative course generally scored lowest in all physical dimensions. Comparing with the relatives' scores, there were no significant differences. According to the disease specific questions, impotence and pain were reported as major long-term postoperative problems. Compared to the preoperative status, patients with uncomplicated postoperative courses all reported improved health status (n =6) while five patients with complicated postoperative courses reported poorer health status. 9 out of 11 patients experienced the same or improved health-related quality of life and two reported reduced health-related quality of life following surgery. 10 out of 11 patients evaluated the operation as successful.

8. General discussion

The papers in this thesis have focused on operative technique, pathophysiology and long-term results of patients treated surgically for TAAA and to some extent for TAA. Ischemia to the spinal cord, the bowel and the kidneys represent an immediate threat to a successful result following these operations, owing to both the technical difficulties of aortic reconstruction and the organ stress suffered in patients who are often elderly and afflicted by multiple comorbidities. Complications may also occur in other organ systems (Svensson et al 1991). However, it was found to be outside the scope of this thesis to include all possible complications in the discussion. Postoperative complications will not only threaten the patients' life expectancy, but also their physical and mental health status which could have major effect on their experienced quality of life.

There are several limitations with the present investigations, primarily caused by its retrospective nature. The data registrations were often insufficient and originally not recorded for research purposes. However, retrospectively describing and controlling practice is of importance for establishing a baseline for comparison with new treatment modalities.

Paper I

In paper I we observed that the method of shunting the celiac and superior mesenteric arteries with blood after completion of the proximal anastomosis was feasible during repair of type III and type IV aneurysms. A prerequisite is that the proximal anastomosis is performed end to end to the aorta. The shunt is connected to a sidebranch of the main prosthesis and this connection should be rather close to the proximal anastomosis not to interfere with the anastomosis to the CA and SMA. In one patient where it was located more distally, we were unable to apply this method.

The idea of using the shunting technique to minimize intestinal ischemia was presented in experimental investigations by Cohen and co-workers (1988), as a method to reduce the extent of intravascular coagulation which occurs with proximal aortic cross-clamping of more than one hours duration (Gertler et al 1996). The possibility of cooling the small bowel for the protection against ischemia has also been suggested (Hennesy et al 1991) and perfusion of the SMA with cold crystalloid solution has been used in the clinical situation (Line PD, personal communication). By the shunting technique the ischemia time to the bowel and liver can be reduced to the time necessary to perform the proximal anastomosis, which will usually be in the order of 10-20 min. As in other operations for TAAA we used perfusion of the kidneys with cold acetated Ringer’s solution containing heparin.

Although we avoid a prolonged ischemia time to the bowel by the described technique, there is still distal ischemia to muscular tissue and perhaps also a decreased perfusion to the spinal cord as long as the aorta is cross-clamped. In contrast, using extracorporeal circulation and double clamping of the aorta allows perfusion of the lower part of the body including the kidneys and the bowel while the proximal anastomosis is performed.

In the present investigation we did not measure blood flow during shunting of the SMA and the CA, which would have been advantageous to observe the actual blood flow to the liver and bowel. The volume of blood flow necessary to avoid intestinal ischaemia is largely unknown (Leijdekkers et al 1999). However, the described principle of shunting has been applied by others (Cambria et al 1998) for type I and type II aneurysms with excellent results. After the shunt is removed, the sidebranch can be used for revascularisation of arteries, which orifice cannot be included in one single sidehole of the main graft. An example is the left renal artery, which is often located far from the right renal artery in large aneurysms.

Paper II

In paper II the presented method of shunting was included since it was used for both type III and IV TAAA. In patients with type IV aneurysms it has been recommended to include the CA, SMA and the renal arteries in one proximal anastomosis (Crawford & Crawford 1984, Schwartz et al 1996, Wahlgren & Wahlberg 2005). This represents a simplification of the operative technique. In these cases it is difficult to perform shunting of the CA and SMA, and the time of visceral ischemia in our series was somewhat longer (median 39 min) than whenever the proximal anastomosis is made end to end as described in paper I. Irrigation of the kidneys with cold crystalloid solution was applied, and renal insufficiency did not represent a major problem in any of these operations.

Initially we used the so-called “clamp and sew” technique with the modification that the kidneys were perfused with cold crystalloid solution. Nevertheless, the time needed for perform the proximal anastomosis and the anastomoses to the visceral arteries should preferably be kept below 30-40 min. Expedient surgery is therefore necessary and the surgeon has limited time to perform the procedure without inducing ischaemia to the bowel and the spinal cord. Should complications occur, there is little time for additional correcting procedures which includes XC of the aorta. The selection of the preferred surgical technique must be based on personal preferences and results. Therefore, during recent years we have to a greater extent applied extracorporeal circulation especially for type I, II and III thoracoabdominal aneurysms. Previously this technique was regarded as a disadvantage because of the necessity of heparinization and the risk of haemorrhage (Crawford & Rubio 1973). However, during recent years, using modern techniques for extracorporeal circulation including a left heart bypass, centrifugal pump and heparin coated tubes (Coselli et al 2002, Safi et al 2003, Coady & Mitchell 2003), the risk of haemorrhage has been significantly decreased. Other methods to avoid organ ischaemia have been the application of a separate graft anastomosed to the visceral arteries prior to replacement of the aneurysm (Ballard 1999, Ballard et al 2002). Another method is to apply a temporary right axillofemoral bypass prior to thoracolaparotomy and repair of the thoracoabdominal aneurysm (Camerota and White 1995). A combination of open surgery with extraanatomic bypass to the visceral arteries and stentgrafting of the aneurysmal lesion has been described as an option, which is less traumatic to the patient (Quiñones-Baldrich et al 1999, Lundbom et al 2004, Rubin 2005). Recently endovascular repair using stentgrafts with sidebranches to the visceral arteries have been presented (Bleyn et al 2002, Anderson et al 2005).

For type IV aneurysms we still think that the described technique of bevelling the proximal part of the graft and including the orifices of the visceral arteries into the proximal anastomosis is a viable method. The presented results are in accordance with those obtained by other authors taking into consideration that the majority of our patients were emergencies with 33% having rupture (Crawford et al 1991, Bradbury et al 1999, Lewis et al 2002, Cowan et al 2003). The long-term survival seems acceptable for patients having symptoms or being treated electively. However, the material is too small to draw any final conclusions

Paper III

The haemodynamic response of thoracic aortic cross-clamping in the clinical situation has remained controversial. In 51 patients operated on for thoracoabdominal or descending thoracic aortic aneurysm using cross-clamping of the aorta, we observed the same pattern as in experimental investigations (Aadahl et al 1995). A significant increase in cardiac output was observed during cross-clamping of the thoracic aorta. We also observed a proximal hypertension and a tachycardia with decreased systolic volume of the left ventricle (Aakhus et al 1995). Further, there was an acidosis which was most pronounced after removal of the aortic clamp (data not shown). The reason for the increased cardiac output is probably displacement of blood from the splanchnic circulation to the relatively non-compliant upper part of the body, increasing preload and thereby activating the Frank Starling mechanism (Gelman et al 1994). In addition, there might be a stimulation of the sympathetic nervous system due to ischaemia distal to the aortic clamp (Strømholm et al 1999). This mechanism could also explain the tachycardia.

The technique of anaesthesia and especially the application of vasodilating agents during aortic cross-clamping are probably of importance for the haemodynamic response described in this work (Gelman 1995, Aadahl et al 1995). In general, the described changes in cardiac function seemed to be well tolerated by most patients. However, whenever the clinical situation permits, we treat coronary heart disease prior to elective thoracoabdominal aortic surgery. For emergencies, and especially patients with ruptured aneurysm, there is insufficient time for evaluation and treatment of cardiac function.

When using extracorporeal circulation we have not observed any increase in cardiac output and the acidosis was also absent (data are not shown). Thus, the negative effects of aortic XC may thereby be eliminated. The present results and the risk of inducing organ ischaemia by applying the “clamp and go” technique has lead to a re-evaluation of the operative strategy for thoracic- and thoracoabdominal aortic reconstruction. Recent reports indicate that maintenance of distal perfusion during the aortic reconstruction may improve the results (Coselli and LeMaire 1999, Safi et al 2003). Thus, for type I, II an III TAAA left heart bypass and selective perfusion of the CA and SMA combined with perfusion of the kidneys with cold crystalloid solution is used to a greater extent at our institution.

Paper IV

In the clinical situation there are few possibilities of monitoring the circulation of the spinal cord. From experimental investigations using laser Doppler technique (Aadahl et al 1990) one can observe that the microcirculation of the cord is first decreased to a level of 9% of baseline following aortic cross-clamping, and then stabilizing at about 40% of baseline values. However, we do not know the arterial blood pressure of the cord, but suppose that it is significantly decreased during XC. Furthermore, the pressure of the veins which are draining the cord, has so far not been measured. Nevertheless, it is suggested that an increase in CSFP during cross-clamping of the aorta will decrease the perfusion pressure of the cord (Hollier 1987).

For a long time it has been debated whether drainage of CSFP could reduce the incidence of paraparesis and paraplegia following TAAA repair. We found a higher intraoperative CSFP in patients who had neurologic sequelae in the immediate postoperative period. Indirectly, this supports the view that CSF drainage is advantageous and this has also been shown by two prospective randomised studies (Svensson et al 1998, Coselli et al 2002). Removal of CSF has also been applied successfully in the treatment of late paraplegia both following open and endovascular treatment of thoracic- and thoracoabdominal aneurysms (Tiesenhausen et al 2000, Azzizadeh et al 2000, Fleck 2002 et al, Aadahl et al 2003). A slightly higher volume of CSF was drained during and after operation in patients with neurologic sequele (600 vs. 251 ml). However, this difference did not reach statistical significance and may have been caused by chance. Malfunction of the catheter was the reason for the increased CSFP in the three patients who developed neurologic sequelae. An overflow system seems to be a good solution provided it is supervised continuously during the operation. In case of malfunction the catheter should be slightly withdrawn, or if necessary be replaced.

Paper V

Traditionally, the value and effect of all surgical treatment is measured by immediate and long-term morbidity and mortality. In Paper V we showed that measuring health-related quality of life of long-term survivors after TAAA repair could provide knowledge about the long-term effects of surgery. We used proxies to provide information about quality of life in the study, based on an assumption that they can attribute supplementary information and that the patient is the primary source of information who should be regarded as the gold standard (Sneeuw et al 1998, Addington-Hall & Kalra 2001). There was high agreement between individual patients and their proxies on the disease-specific questions, although lower levels of agreement were found in the SF-36 scores. As a group, proxies tend to rate the patient's quality of life as more impaired than the patient. However the magnitude of this bias tends to be limited (Sneeuw et al 1998, Addington-Hall & Kalra 2001).

Most patients experienced an impaired physical functioning after TAAA repair, reporting impotence and bodily pain as major problems several years after surgery. Mostly the sensation of pain was located in the field of the surgical incision. The patient's perception of impaired physical function after TAAA surgery also becomes evident when comparing the patient's physical dimensions scores of the SF-36 with that of a general population. The postoperative pain problem may be minimized provided endovascular repair is used to a greater extent for TAAA (Bleyn et al 2002, Anderson et al 2005).

Our patients generally reported lower SF-36 mental function scores than a general population. However, most patients evaluated their HRQOL as improved compared to the preoperative situation. Accordingly, they evaluated the operation as successful and would have undergone the same procedure today. There seems to be no direct correspondence between objective functioning and an individual's quality of life (Rothwell et al 1997), because the patients rate their quality of life highly despite obvious physical problems. One could argue whether these findings are reflections of the individual's ability to adapt to a new situation, a phenomenon of internal adaptation called “response shift” (Addington-Hall & Kalra 2001, Higginson & Carr 2001).

9. Main Conclusions

- Shunting of blood to the superior mesenteric and coeliac arteries during TAAA repair is feasible and the results have been acceptable. Further investigation of the blood flow sufficient to avoid intestinal ischaemia is desirable.
- The “clamp and go” technique gives limited time for performing the necessary anastomosis during TAAA repair without inducing organ ischaemia. Inclusion of the orifices of the visceral arteries in the upper anastomosis is a feasible method during surgery for type IV aneurysms. Shunting of the CA and SMA might be an acceptable option, especially during surgery for type III and in selected cases with type IV aneurysms.
- Cardiac output was significantly increased during XC in patients operated on for thoracoabdominal and descending thoracic aortic aneurysms without circulatory support. Simultaneously, heart rate was increased and there was a hyperdynamic circulation proximal to the aortic clamp. Although these changes were well tolerated by most patients, the observations may influence the selection of operative strategy for some of these patients.
- Compared with asymptomatic patients, a higher intraoperative CSFP was observed in patients with neurologic sequele following thoracic- and thoracoabdominal aneurysm repair. Further, there was a tendency of higher volumes of CSF drained in this group of patients. Although the series is too small to allow firm conclusions, it supports the view that CSFP monitoring and drainage is beneficial in reducing the risk of neurologic complications during thoracic- and thoracoabdominal aneurysm repair.

- Long-term survivors who have experienced postoperative complications or a decreased physical function level following TAAA surgery report low HRQOL scores on the SF-36 form compared to a normal population. Bodily pain and impotence are most frequently reported problems. Despite physical constraints, most patients report an acceptable HRQOL when relating TAAA surgery to disease-specific questions.

10. Corrections

Summary:

Page 4, List of papers: References of paper III and IV have been added.

Paper II

Page 408, right column, Patients and methods, 1st line:

2000 should be replaced by 2001.

Page 410, right column, line 9 from above:

"141 ml of spinal fluid was removed at the day of operation" ("during the" should be replaced by "at the day of").

Table III

Clamp time until final revascularization --- 45 (36-55.3)

(45 within the parenthesis should be replaced by 36)

Paper III

Page 2, right column, line 9 from above:

N_2/O_2 should be replaced by N_2O/O_2

Table 3, line 4 from above:

PO_2 should be replaced by pO_2 (capital P should be replaced by p)

Paper IV

Page 2, left column, line 11 from above:

N_2O_2 should be replaced by N_2O/O_2

Page 3, right column, line 3 from below:

Table II should be replaced by Table III

Paper V

Page 88, right column, Patients and medical records:

1983 should be replaced by 1985

Page 89, left column, line 2 from above:

1.3 should be replaced by 2.0 in the parenthesis

Page 90, table I:

Patient no 10: 1.3 should be replaced by 2.0

Page 93, left column, para 4, line 1 from below:

Reference 5 should be excluded.

Line 5 from above: The references should be 13, 17, 18

11. References

Addington-Hall J, Kalra L. Measuring quality of life. Who should measure quality of life? BMJ 2001; 322: 1417-1420.

Anderson JL, Adam DJ, Berce M, Hartley DE. Repair of thoracoabdominal aortic aneurysm with fenestrated and branched endovascular stent grafts. J Vasc Surg 2005; 42: 600-607.

Azizzadeh A, Huynh TT, Miller CC, Safi HJ. Reversal of twize-delayed neurologic deficits with cerebrospinal fluid drainage after thoracoabdominal aneurysm repair: A case report and plea for a national database collection. J Vasc Surg 2000; 31: 592-598.

Ballard JL. Thoracoabdominal aortic aneurysm repair with sequential visceral perfusion: A technical note. Ann Vasc Surg 1999; 13: 216-221.

Ballard JL, Abou-Zamzam AM jr., Teruya TH. Type III and IV thoracoabdominal aortic aneurysm repair: Results of a trifurcated/two-graft technique. J Vasc Surg 2002; 36: 211-216.

Bleyn J, Schol F, Vanhandenhove I, Vercaeren P. Side-branched endograft system for thoracoabdominal aortic aneurysm repair. J Endovasc Ther 2002; 9: 838-841.

Bradbury AW, Bulstrode NW, Gilling-Smith G, Stansby G, Mansfield AO, Wolfe JHN et al. Repair of ruptured thoracoabdominal aortic aneurysm is worthwhile in selected cases. Eur J Vasc Endovasc Surg 1999; 17: 160-165.

Cambria RA, Brewster DC, Moncure AC, Ivarsson B, Darling RC, Davison JK. Recent experience with thoracoabdominal aneurysm repair. Arch Surg 1989; 124: 620-624.

Cambria RA, Gloviczki P, Stanson AW, Cherry jr. KJ, Bower TC, Hallett JW et al. Outcome and expansion rate of 57 thoracoabdominal aortic aneurysms managed nonoperatively. Am J Surg 1995; 170: 213-217.

Cambria RP, Davidson JK, Giglia JS, Gertler JP. Mesenteric shunting decreases visceral ischemia during thoracoabdominal aneurysm repair. J Vasc Surg 1998; 27: 745-749.

Camerota AJ, White JV. Reducing morbidity of thoracoabdominal aneurysm repair by preliminary axillofemoral bypass. Am J Surg 1995; 170: 218-222.

Christakis GT, Panos AP, Peniston CM, Lichtenstein SV, Salerno TA. Visceral and limb perfusion during thoracoabdominal aortic aneurysm repair. Ann Thorac Surg 1989; 48: 592-4.

Coady MA, Mitchell RS. Femoro-femoral partial bypass in the treatment of thoracoabdominal aneurysms. Sem Thorac Cardiovasc Surg 2003; 4: 340-344.

Cochrane Peripheral Vascular Diseases Group on Peripheral Vascular Diseases: Review Abstracts. Eur J Vasc Endovasc Surg 2005; 30: 457-460.

Cohen JR, Schroder W, Leal J, Wise L. Mesenteric shunting during thoracoabdominal aortic clamping to prevent disseminated intravascular coagulation in dogs. Ann Vasc Surg 1988; 2: 261-267.

Coselli JS, Poli de Figueiredo LF. Natural history of descending and thoracoabdominal aortic aneurysms. J Card Surg 1997; 12: 285-91.

Coselli JS, LeMaire SA. Left heart bypass reduces paraplegia rates after thoracoabdominal aortic aneurysm repair. Ann Thorac Surg 1999; 67: 1931-4.

Coselli JS, Lemaire SA, Köksoy C, Schmittling ZC, Curling PE. Cerebrospinal fluid drainage reduces paraplegia after thoracoabdominal aortic aneurysm repair: results of a randomized clinical trial. J Vasc Surg 2002; 35: 631-9.

Coselli JS, Conklin LD, LeMaire SA. Thoracoabdominal aortic aneurysm repair: Review and update of current strategies. Ann Thorac Surg 2002; 74: S1881-4.

Cowan JA, Dimick JB, Henke PK, Huber TS, Stanley JC, Upchurch GR. Surgical treatment of intact thoracoabdominal aortic aneurysms in the United States: Hospital and surgeon volume-related outcomes. J Vasc Surg 2003; 37: 1169-74.

Cowan JA, Dimick JB, Wainess RM, Henke PK, Stanley JC, Upchurch GR. Ruptured thoracoabdominal aortic aneurysm treatment in the United States: 1988 to 1998. J Vasc Surg 2003; 38: 319-22.

Crawford ES, Rubio AR. Reappraisal of adjuncts to avoid ischemia in the treatment of aneurysms of descending thoracic aorta. J Thorac Cardiovasc Surg 1973; 66: 693-704.

Crawford ES. Thoraco-abdominal and abdominal aortic aneurysms involving renal, superior mesenteric, and celiac arteries. Ann Surg 1974;179: 763-72.

Crawford ES, Crawford JL. Diseases of the aorta including an atlas of angiographic pathology and surgical technique. Baltimore; Williams and Wilkins 1984.

Crawford ES, Crawford JL, Safi HJ, Coselli JS, Hess KR, Brooks B et al. Thoracoabdominal aortic aneurysms: Preoperative and intraoperative factors determining immediate and long-term results of operations in 605 patients. J Vasc Surg 1986; 3: 389-404.

Crawford ES, DeNatale RW. Thoracoabdominal aortic aneurysm: Observations regarding the natural course of the disease. J Vasc Surg 1986; 3: 578-82.

Crawford ES, Hess KR, Cohen ES, Coselli JS, Safi HJl. Ruptured aneurysms of the descending thoracic and thoracoabdominal aorta: analysis according to size and treatment. Ann Surg 1991; 213: 417-425.

Crawford ES, Svensson LG, Hess KR, Shenaq SS, Coselli JS, Safi HJ. A prospective randomized study of cerebrospinal fluid drainage to prevent paraplegia after high-risk surgery on the thoracoabdominal aorta. J Vasc Surg 1991; 13: 36-46.

DeBakey ME, Crawford ES, Garrett HE, Beall AC, Howell JF. Surgical considerations in the treatment of aneurysms of the thoraco-abdominal aorta. Ann Surg 1965; 162; 650-662.

Etheredge SN, Yee J, Smith JV, Schonberger S, Goldman MJ. Successful resection of a large aneurysm of the upper abdominal aorta and replacement with homograft. Surgery 1955; 38: 1071-81.

Fleck T, Hutschala D, Weissl M, Wolner E, Grabenwögner M. Cerebrospinal fluid drainage as a useful treatment option to relieve paraplegia after stent-graft implantation for acute aortic dissection type B. J Thorac Cardiovasc Surg 2002; 123: 1003-1005.

Gelman S, Khazaeli MB, Orr R, Henderson T. Blood volume redistribution during cross-clamping of the descending aorta. Anesth Analg 1994; 78; 219-224.

Gelmann S. The pathophysiology of aortic cross-clamping and unclamping. Anesthesiology 1995; 82: 1026-1057.

Gertler JP, Cambria RP, Brewster DC, Davison JK, Purcell P, Zannetti S et al. Coagulation changes during thoracoabdominal aneurysm repair. J Vasc Surg 1996; 24: 936-43.

Gilling-Smith GL, Worswick L, Knight PF, Wolfe JHN, Mansfield AO. Surgical repair of thoracoabdominal aortic aneurysm: 10 years' experience. Brit J Surg 1995; 82: 624-629.

Gilling-Smith GL, Wolfe JHN. Thoracoabdominal Aneurysms: Which Patients Should We Operate On? Perspect Vasc Surg 1995; 8: 29-43.

Griepp RB, Ergin MA, Galla JD, Lansman SL, McCullough JN, Nguyen KH et al. Natural history of descending thoracic and thoracoabdominal aneurysms. Ann Thorac Surg 1999; 67: 1927-30.

Harward TRS, Welborn MB, Martin TD, Flynn TC, Huber TS, Moldawer LL et al. Visceral ischemia and organ dysfunction after thoracoabdominal aortic aneurysm repair: A clinical and cost analysis. Ann Surg 1996; 223: 729-736.

Hennesy A, Grace P, Leader M, Bouchier-Hayes D. Local hypothermia protects the small bowel from ischaemia. Gastroenterology 1991; 100 (suppl 5): A218.

Higginson IJ, Carr AJ. Measuring quality of life. Using quality of life measures in the clinical setting. BMJ 2001; 322: 1297-1300.

Hollier LH. Protecting the brain and spinal cord. J Vasc Surg 1987; 5: 524-528.

Hollier LH, Symmonds JB, Pairolero PC, Cherry KJ, Hallett JW, Gloviczki P. Thoracoabdominal aortic aneurysm repair. Analysis of postoperative morbidity. Arch Surg 1988; 123: 871-875.

Jacobs MJ, de Mol BA, Legemate DA, Veldman DJ, de Haan P, Kalkman CJ. Retorgrade aortic and selective organ perfusion during thoracoabdominal aortic aneurysm repair. Eur J Vasc Endovasc Surg 1997; 14: 360-66.

Jacobs MJ, Eijsman L, Meylaerts SA, Balm R, Legemate DA, deHaan P. Reduced renal failure following thoracoabdominal aortic aneurysm repair by selective perfusion. Eur J Cardio Thorac Surg 1998; 14: 201-205.

Jacobs MJ, Myhre HO, Norgren L. Thoracoabdominal Aortic Surgery With Special Reference to Spinal Cord Protection and Perfusion Techniques. Eur J Vasc Endovasc Surg 1999; 17: 253-256.

Jacobs JHM, Meylaerts SA, de Haan P, de Mol B, Kalkman CJ. Assessment of Spinal Cord Ischemia by Means of Evoked Potential Monitoring During Thoracoabdominal Aortic Surgery. Sem Vasc Surg 2000; 13: 299-307.

Jacobs MJ, van Eps RG, de Jong DS, Schurink GW, Mochtar B. Prevention of renal failure in patients undergoing thoracoabdominal aortic aneurysm repair. J Vasc Surg 2004; 40: 1067-73.

Kashyap VS, Cambria RP, Davison JK, L'Italien GJ. Renal failure after thoracoabdominal aortic surgery. J Vasc Surg 1997; 26: 949-57.

Khan SN, Stansby G. Cerebrospinal fluid drainage for thoracic and thoracoabdominal aortic aneurysm surgery (Review). The Cochrane Database of Systematic Reviews 2003, Issue 4. Art. No.: CD003635.pub2. DOI: 10.1002/14651858.CD003635.pub2.

Köksoy C, LeMaire SA, Curling PE, Raskin SA, Schmittling ZC, Conklin LD. Renal perfusion during thoracoabdominal aortic operations : Cold crystalliod is superior to normothermic blood. Ann Thorac Surg 2002; 73: 730-8.

Leijdekkers VJ, Wirds JW, Vahl AC, van Genderingen HR, Siebenga JS, Westerhof N. The visceral perfusion system and distal bypass during thoracoabdominal aneurysm surgery: an alternative for physiological blood flow? Cardiovasc Surg 1999; 7: 219-24.

LeMaire SA, Miller CC III, Conklin LD, Schmittling ZC, Coselli JS. Estimating group mortality and paraplegia rates after thoracoabdominal aortic aneurysm repair. Ann Thorac Surg 2003; 75: 508-13.

Lewis ME, Ranasinghe AM, Revell PP, Bonser RS et al. Surgical repair of ruptured thoracic and thoracoabdominal aortic aneurysms. Brit J Surg 2002; 89: 442-445.

Lobato AC, Puech-Leão P. Predictive factors for rupture of thoracoabdominal aortic aneurysm. J Vasc Surg 1998; 27: 446-453.

Lundbom J, Hatlinghus S, Ødegård A, Eide TO, Lange C, Aasland J et al. Combined open and endovascular treatment of complex aortic disease. Vascular 2004; 12: 93-98.

Miller CC, Porat EE, Estrera AL, Winnerkvist AN, Huynh TTT, Safi HJ. Numbers needed to treat: Analyzing the effectiveness of thoracoabdominal aortic repair. Eur J Vasc Endovasc Surg 2004; 28: 154-157.

Myhre HO, Sæther OD, Stenseth R, Aadahl P. Attempts to reduce paraplegia risk in aortic surgery. PP 373-385 In Greenhalgh RM, Mannick JA, Powell JT. The cause and management of aneurysms. WB Saunders Co. Ltd. 1996.

Myhre HO, Strømholm T, Aadahl P, Sæther OD. Is there any evidence that CSF monitoring is worthwhile during thoracoabdominal aneurysm surgery? PP 171-181 In Greenhalgh RM, Fowkes FGR. Trials and tribulations of vascular surgery. Evidence-based vascular surgery. WB Saunders Co. Ltd. 1990.

Ohlson C, Thelin S. Quality of life in survivors of thoracic aortic surgery. Ann Thorac Surg 1999; 67: 1262-67

Quiñones-Baldrich WJ, Panetta TF, Vescera CL, Kashyap VS. Repair of type IV thoracoabdominal aneurysm with a combined endovascular and surgical approach. J Vasc Surg 1999; 30: 555-560.

Rothwell PM, McDowell Z, Wong CK, Dorman PJ. Doctors and patients don’t agree: cross sectional study of patients’ and doctors’ perceptions and assessments of disability in multiple sclerosis. BMJ 1997; 314: 1580-3.

Rubin BG. Extra-anatomic visceral revascularization and endovascular stent-grafting for complex thoracoabdominal aortic lesions. Perspect Vasc Surg Endovasc Ther 2005; 17: 227-236.

Safi HJ, Harlin SA, Miller CC, Iliopoulus DC, Joshi A, Mohasci TG. Predictive factors for acute renal failure in thoracic and thoracoabdominal aortic aneurysm surgery. J Vasc Surg 1996; 24: 338-45.

Safi HJ, Winnerkvist A, Miller CC III, Illiopoulos DC, Reardon MJ, Espada R et al. Effect of extended cross-clamp time during thoracoabdominal aortic aneurysm repair. Ann Thorac Surg 1998; 66: 1204-9.

Safi HJ, Miller CC III, Huynh TTT, Estrera AL, Porat EEP, Winnerkvist AN et al. Distal aortic perfusion and cerebrospinal fluid drainage for thoracoabdominal and descending thoracic aortic repair. Ten years of organ protection. Ann Surg 2003; 238: 372-381.

Sandmann W, Grabitz K, Torsello G, Kniemeyer HW, Stuhmeier K, Mainzer B. Surgical treatment of thoraco-abdominal aneurysm. Indications and results. Chirurg 1995; 66: 845-56.

Schwartz LB, Belkin M, Donaldson MC, Mannick JA, Whittemore AD. Improvement in results of repair of type IV thoracoabdominal aortic aneurysms. J Vasc Surg 1996; 24: 74-81.

Sneeuw KCA, Aaronsen NK, Sprangers MAG, Detmar SBD, Wever LDV, Schornagel JH. Comparison of patient and proxy EORTC QLQ-C30 ratings in assessing the quality of life in cancer patients. J Clin Epidemiol 1998; 51: 617-631.

Stenseth R, Myhre HO. Anaesthesia in surgery for aneurysm of the descending thoracic or thoracoabdominal aorta. Acta Chir Scand 1988; 154: 147-150.

Strømholm T, Aadahl P, Sæther OD, Myking OD, Myhre HO. Excessive increase in circulating cathecolamines during cross-clamping of the descending thoracic aorta in pigs. Internat J Angiol, 1999; 8: 91-94.

Svensjö S, Bengtsson H, Bergqvist D. Thoracic and thoracoabdominal aortic aneurysm and dissections: an investigation based on autopsy. Br J Surg 1996; 83: 68-71.

Svensson LG, Coselli JS, Safi HJ, Hess KR, Crawford ES. Appraisal of adjuncts to prevent acute renal failure after surgery on the thoracic or thoracoabdominal aorta. J Vasc Surg 1989; 10: 230-9.

Svensson LG, Grum DF, Bednarski M, Cosgrove DM, Loop FD. Appraisal of cerebrospinal fluid alterations during aortic surgery with intrathecal papaverine administration and cerebrospinal fluid drainage. J Vasc Surg 1990; 11: 423-9.

Svensson LG, Patel V, Robinson MF, Ueda T, Roehm JO, Crawford ES. Influence of preservation or perfusion of intraoperatively identified spinal cord supply on spinal motor evoked potentials and paraplegia after aortic surgery. J Vasc Surg 1991; 13: 355-65.

Svensson LG, Hess KR, Coselli JS, Safi HJ, Crawford ES. A prosepective study of respiratory failure after high-risk surgery on the thoracoabdominal aorta. J Vasc Surg 1991; 14: 271-82.

Svensson LG, Crawford ES, Patel V, Jones JW, DeBakey ME. Spinal cord oxygenation, intraoperative blood supply localization, cooling and function with aortic cross-clamping. Ann Thorac Surg 1992; 54: 74-9.

Svensson LG, Crawford ES, Hess KR, Coselli JS, Safi HJ. Experience with 1509 patients undergoing thoracoabdominal aortic operations. J Vasc Surg 1993; 17: 357-70.

Svensson LG, Hess KR, D’Agostino RS, Entrup MH, Hreib K, Kimmel WA, et al. Reduction of neurologic injury after high-risk thoracoabdominal aortic operation. Ann Thorac Surg 1998; 66: 132-8.

Tiesenhausen K, Asmann W, Koch G, Hausegger KA, Oberwalder P, Rigler B. Cerebrospinal fluid drainage to reverse paraplegia after endovascular thoracic aortic aneurysm repair. J Endovasc Ther 2000; 7: 132-5.

Wahlgren C–M, Wahlberg E. Management of thoracoabdominal aneurysm type IV. Eur J Vasc Endovasc Surg 2005; 29: 116-123.

Webb TH, Williams GM. Thoracoabdominal aneurysm repair. Cardiovasc surg 1999; 7: 573-585.

Widmann MD, DeLucia A, Sharp J, Richenbacher WE. Reversal of renal failure and paraplegia after thoracoabdominal aneurysm repair. Ann Thorac Surg 1998; 65: 1153-5.

Aadahl P, Sæther OD, Stenseth R, Myhre HO. Microcirculation of the spinal cord during proximal aortic cross-clamping. Eur J Vasc Surg 1990; 4: 5-10.

Aadahl P, Sæther OD, Stenseth R, Myhre HO. Haemodynamic effects of thoracic epidural anaesthesia during proximal aortic cross-clamping in pigs. Acta Anaesthesiol Scand 1995; 39: 23-27.

Aadahl P, Aakhus S, Strømholm T, Sæther OD, Myhre HO. Effect of Sodium Nitroprusside on Cardiac Output during Cross-clamping of the Descending Thoracic Aorta in Pigs. Eur Surg Res 1995; 27: 323-331.

Aadahl P, Sæther OD, Lundbom J, Stenseth R, Dragsund S, Karevold A et al.. Delayed-onset paraplegia after thoracic and thoracoabdominal aortic aneurysm repair: Reversal with cerebrospinal fluid drainage. Eur J Vasc Endovasc Surg 2003; extra 6: 39-42.

Aakhus S, Aadahl P, Strømholm T, Myhre HO. Increased left ventricular contractility during cross-clamping of the descending thoracic aorta. J Cardio Thorac Vasc Anest 1995; 9: 497-502.

Paper I

Eur J Vasc Endovasc Surg **26**, 602–606 (2003)
doi: 10.1016/S1078-5884(03)00355-1, available online at http://www.sciencedirect.com on SCIENCE DIRECT

Shunting of the Coeliac and Superior Mesenteric Arteries during Thoracoabdominal Aneurysm Repair

T. O. Eide,[1] H. O. Myhre,[1*] O. D. Saether[1] and P. Aadahl[2]

Departments of [1]Surgery, and [2]Anaesthesiology, University Hospital of Trondheim, Trondheim, Norway

Objectives. *To describe our experience with shunting of the coeliac and superior mesenteric arteries during thoracoabdominal aneurysm repair.*
Design. *Retrospective study.*
Material. *Eight patients undergoing resection and graft replacement of Crawford type III (5) and type IV (3) thoracoabdominal aortic aneurysms were included in this series. One patient had rupture, four were symptomatic and three were operated on electively.*
Methods. *A vascular graft with a sidearm was applied for the reconstructions. A T-shunt was connected to the sidearm. Following completion of the proximal anastomosis the shunt was inserted into the coeliac and superior mesenteric arteries. The anastomoses to these arteries and the renal arteries were then completed. Finally the distal anastomosis was performed.*
Results. *There was no early mortality (30 days). One patient had postoperative paraparesis, but recovered quite well. Reoperation became necessary due to sigmoid necrosis in one patient and due to haemorrhage in another. During the follow-up period four patients died but the other patients are alive between 3 and 8 years after surgery.*
Conclusion. *The application of shunting of the superior mesenteric and coeliac arteries during thoracoabdominal aortic surgery is feasible and the results have been acceptable. Further investigation of the optimal blood flow needed to avoid intestinal ischaemia in a larger series of patients is desirable.*

Key Words: Thoracoabdominal repair; Shunting; Coeliac artery; Superior mesenteric artery.

Introduction

During treatment of thoracoabdominal aortic aneurysms, ischaemia to the spinal cord, bowel and kidneys represent a threat to a successful result. Several adjuncts have been introduced to reduce the risk of organ ischaemia.[1,2] Thus, extracorporeal circulation either as a femorofemoral or atriofemoral bypass is preferred by several surgeons.[3] To avoid visceral ischaemia, separate perfusion of these arteries via a sidearm from the arterial line could be advantageous. In January 1994 we introduced a technique for shunting of the coeliac axis (CA) and the superior mesenteric artery (SMA) during operations for type III and IV thoracoabdominal aortic aneurysms.[4,5] This adjunct had previously been suggested following animal experiments by Cohen and co-workers[6] and a similar technique has previously been described for clinical use.[7] The purpose of this paper is to describe the technique and to discuss alternatives to minimise visceral ischaemia during thoracoabdominal aortic surgery.

*Corresponding author. Hans O. Myhre, Department of Surgery, University Hospital of Trondheim, Olav Kyrres gt. 17, N-7006 Trondheim, Norway.

Material and Methods

Prior to induction of anaesthesia an 18G thoracic epidural catheter was applied at the th6-7 level and a 16G intrathecal catheter was inserted at the L3–L4 level for cerebrospinal fluid drainage. The intrathecal catheter was removed on the third postoperative day. Anaesthesia was induced by barbiturate, fentanyl and pancuronium. Continuation of the anaesthesia was obtained by isofluran and N_2O/O_2. Furthermore, fentanyl/pancuronium was supplemented with epidural bupivacain (5 mg/ml). A double lumen tube was applied in six patients. In addition to a Swan-Ganz catheter, two large-bore intravenous lines were available. Two hundred and fifty millilitre (37.5 g) of mannitol was administered intravenously prior to cross-clamping of the thoracic aorta. An infusion of sodium bicarbonate was given to counteract metabolic acidosis. To reduce the blood pressure during aortic cross-clamping, nitroglycerine and

1078–5884/03/060602 + 05 $35.00/0

sodium nitroprusside was infused, but the infusion was terminated prior to declamping of the aorta.[8] 3000 IU of heparin was given prior to cross-clamping of the aorta. Autotransfusion was used during all operations. A regular thoracolaparotomy was performed and the 7th intercostal space was entered. Vascular clamps were applied on the thoracic aorta proximal to the aneurysmal dilatation and distally on the abdominal aorta or the iliac arteries. The aneurysmal sac was then opened and a vowen, gelatine impregnated vascular prosthesis with a presutured 8 mm sidearm (Gelweave®, Vascutek Ltd., Inchinnan, Scotland) was used. Into the sidearm an 11F carotid T-shunt (Vascushunt 11F, Baxter Healthcare Corp, Erwin CA, USA) had been placed in advance and secured by a suture. (Fig. 1). The kidneys were perfused with cold (4 °C) Ringer's acetated solution containing 1000 IU of heparin per litre. The proximal anastomosis was sutured in an end-to-end fashion. After completion of the proximal anastomosis the vascular clamp was applied distal to the sidearm and the limbs of the T-shunt were then placed into the CA and the SMA where they were kept in place by inflatable balloons. Thus, blood flow to these arteries was reestablished immediately after completion of the proximal anastomosis. The lumbar and intercostal arteries were oversewn with the exception of those included in the proximal anastomosis. Through a sidehole in the main graft the CA, the SMA and one or both renal arteries were anastomosed to the prosthesis. Immediately prior to completion of this second anastomosis, the T-shunt and the catheters to the renal arteries were removed. After completion of the anastomosis blood flow was reestablished to these arteries and the distal anastomosis was then completed.

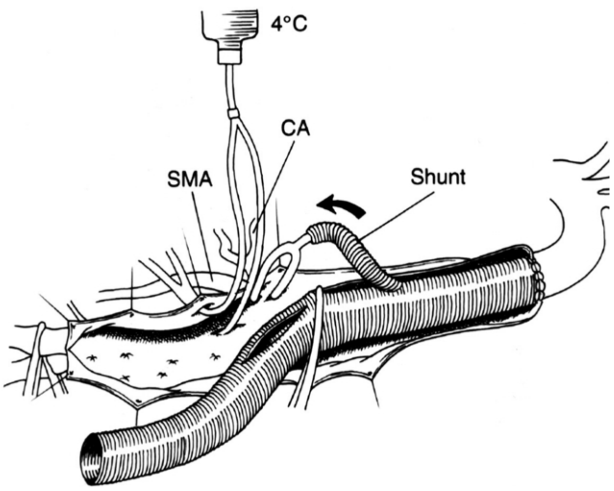

Fig. 1. The application of a T-shunt for perfusion of the superior mesenteric artery (SMA) and the coeliac artery (CA) during thoracoabdominal aneurysm repair. The kidneys are perfused with Ringer's acetated solution of 4 °C.

In four cases we used the sidearm of the main prosthesis as a separate bypass to the left renal artery because the distance between the two renal arteries was too wide to anastomose them to the sidehole of the main graft (Fig. 2). In the others the sidearm was oversewn and removed.

During the period 1994–1999 eight patients were operated on for thoracoabdominal aortic aneurysm using the described technique of shunting of the SMA and CA. The shunting technique was planned in one more patient. However, the sidearm was located too close to the sidehole of the main graft. It therefore became impossible to apply the shunt while doing the anastomosis to the visceral arteries and the operation was performed with aortic cross-clamping only. Five of the patients were women and three men with a median age of 69 years (range 58–79). Concomitant diseases included hypertension in five patients. Four had coronary heart disease defined as angina, previous myocardial infarction, previous PCI or aortocoronary bypass grafting, two had lower limb ischaemia and two had previously undergone surgery for infrarenal abdominal aortic aneurysm. Two patients had chronic obstructive pulmonary disease. One of the patients was operated on because of rupture while four were symptomatic and three patients were operated on electively. According to the ASA classification five belonged to the ASA class III and three to the ASA class IV. Five patients had aneurysms cathegorised as Crawford type III whereas three had a type IV aneurysm. The maximal aneurysmal diameter averaged 70 mm (range 60–96). The study was approved by the local ethics committee.

Results

There was no early mortality (less than 30 days). One reoperation became necessary due to haemorrhage and another was reoperated for gangrene of the sigmoid colon. A Hartmann's procedure was performed. One patient had postoperative paraparesis, but eventually recovered quite well. Two patients required dialysis for three days, but there was no need for permanent dialysis. In one case splenectomy was performed due to haemorrhage. The median operating time was 261 min (Table 1). The median clamp time until restoration of blood flow to the CA, SMA and renal arteries was 47 min (35–82) while the median need for blood transfusion was 1350 ml (900–2700). There was a significant increase in cardiac output during cross-clamping of the thoracic aorta from a median level of 4.4 l prior to cross-clamping to 6.9 l during thoracic aortic cross-clamping. The volume of

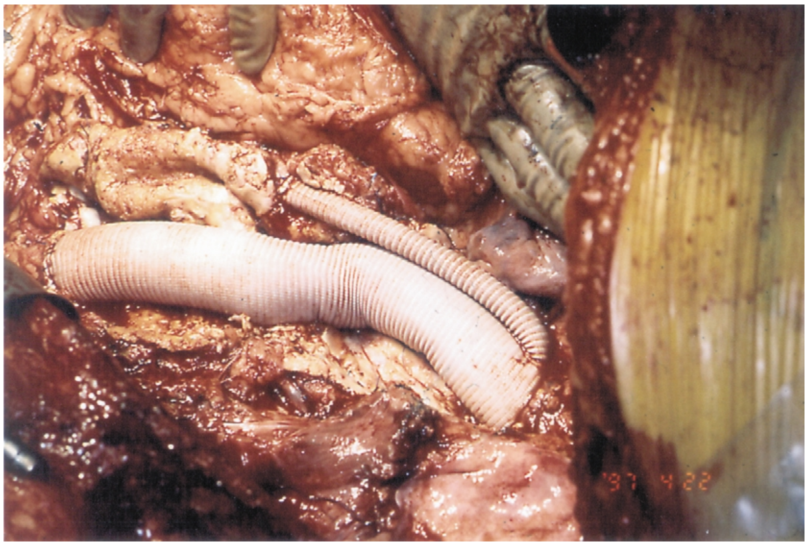

Fig. 2. Reconstruction of a thoracoabdominal type III aneurysm. The sidearm of the vascular prosthesis, which primarily was used for shunting of the superior mesenteric and the coeliac arteries, was in this case applied as a bypass to the left renal artery. Since the attachment of the sidearm to the main graft is relatively close to the proximal anastomosis there is little chance of kinking when the left kidney is rotated back to it's original site.

cerebrospinal fluid removed during the day of operation averaged 74 ml and the total removed volume was 142 ml. The median requirement for ventilatory support was 31 h and median stay in an intensive care unit or intermediate care unit was 8 days (4–33). All patients have been followed at the outpatient clinic. Four patients died during the follow-up period after 5, 5, 6.5 and 7.5 years respectively. One died of malignancy, one of renal insufficiency whereas two died from myocardial infarction. No autopsies were performed. The other four patients are alive between 3 and 8 years after surgery.

Discussion

Several techniques have been applied to reduce organ ischaemia following thoracoabdominal aortic aneurysm repair.[1,2] Whereas extracorporeal circulation is used to a great extent for type I and II aneurysms, other techniques have been suggested for the treatment of type III and IV aneurysms.[9,10] The reason is that extracorporeal circulation is not without complications in these patients, especially haemorrhage due to heparinisation. Sequential cross-clamping will not eliminate a period of ischaemia to the bowel and kidneys unless these organs are perfused via separate catheters from the arterial line.[11,12] Direct cross-clamping of the aorta without any special adjuncts has been used for several years.[13] We have also used this method and find it technically simple. However, the time until completion of the anastomosis to the visceral arteries was in the same range as in the presented series, which means that the actual visceral ischaemia time became significantly longer. This could lead to postoperative complications including multi-organ failure. In 12 patients operated on for type IV aneurysm not included in this series, we applied an alternative technique where the visceral arteries were conserved on a patch of aortic tissue. The proximal part of the graft was then cut in an oblique fashion thereby including the orifice of the visceral arteries in one single proximal anastomosis.[14] In the presented cases, however, the proximal extension of the aneurysm

Table 1. Data following thoracoabdominal aortic repair in eight patients using shunting of the coeliac and superior mesenteric arteries.

	Median	Range
Operating time (min)	261	(190–377)
Blood transfusion (ml SAG)	1350	(900–2700)
Time of aortic cross-clamping until completion of the anastomosis to the coeliac, superior mesenteric and renal arteries (min)	47	(35–82)
Median time of ventilatory support (h)	31	(10–256)
Total postoperative stay in hospital (d)	15	(10–90)
Stay in ICU/intermediate care unit (d)	8	(4–33)

was too high for the application of this technique and a separate proximal end-to-end anastomosis was therefore made. One disadvantage of the described shunting technique is that the proximal anastomosis has to be completed before blood flow can be restored to the CA and SMA. However, the time needed to perform the proximal anastomosis was in the range of 10–20 min, which actually represents the ischaemia time to the bowel. This ischaemia time is therefore reduced approximately 25 min compared to direct cross-clamping of the aorta, which is similar to the observations from other investigations.[7]

Measurement of blood flow would have been advantageous to observe the flow capacity of the shunt applied in this series.[15] It is possible that shunts with a higher flow capacity would have been advantageous. We did not measure any indicators of intestinal ischaemia in this series. However, parameters like early mortality and complication rate, need for postoperative ventilatory support and stay in hospital were reasonable, indicating that in general no severe or long lasting visceral ischaemia had taken place. The stay in the intensive care unit or intermediate care unit of 8 days seems long, but we often let the patient stay in the intermediate care unit for a longer time than actually needed, until the bowel function became normal and the patient was fully mobilised. An extra side-branch with a T-shunt could have been used to perfuse the kidneys with blood rather than Ringer's acetated solution. However, in a prospective randomised series it has been shown that cold crystalloid perfusion is superior to normothermic blood to conserve the renal function during thoracoabdominal aneurysm repair.[16]

Shunting of only one of the CA or SMA has been described by other surgeons with excellent results.[7] The results were fairly similar to ours, but the majority of their patients had type I and II aneurysms, which usually have a higher complication rate than type III and IV aneurysms. A comparison between the two series is therefore difficult. It might be beneficial to apply an extra shunt to avoid prolonged ischaemia of the lower extremities.[17] Further, the application of a Gott shunt or a similar device might actually have reduced the ischaemia time to the visceral organs to a minimum.

Spinal fluid drainage is now performed routinely during thoracoabdominal aortic repair. In some of our cases the spinal fluid pressure increased significantly during thoracic aortic cross-clamping. Spinal fluid was removed to keep the pressure below 10 mm/Hg, a level, which has been suggested to decrease the incidence of neurologic complications.[18,19] In spite of this adjunct one of our patients had postoperative paraparesis. He has recovered quite well and is now mobilised using crutches.

The reason for the increased cardiac output observed during cross-clamping of the thoracic aorta is unclear. It may be caused by a redistribution of the blood volume, the application of vasoactive agents or an increase in catecholamine levels, which we have observed in experimental investigations.[20] An increase in cardiac output is usually well tolerated but could represent a stress to the heart, especially in elderly patients with coronary heart disease. It is possible that more extensive shunting including both the CA, SMA and the arteries and to lower extremities might give better hemodynamic stability in these patients, but future investigations are necessary to explore this possibility further. It is possible that such a technique might also improve the intraoperative collateral circulation to the spinal cord and perhaps reduce the incidence of neurologic complications. From a theoretical point of view, perfusion of the CA or SMA with cold solutions could increase the tolerance of intestinal ischaemia. However, rather limited volumes of fluid can be used since a significant decrease in body temperature should be avoided. A solution to this problem might be external cooling of the bowel, which has only been tested in an experimental setting.[21]

In conclusion shunting of the CA and SMA during thoracoabdominal aortic surgery for type III and IV aneurysms is feasible and the results have so far been acceptable. A larger series of patients are required to investigate the volume of blood flow necessary to avoid visceral ischaemia.

Acknowledgements

This work was supported by grants from St Olavs Hospital, University Hospital of Trondheim (No. 1401 1023 4630) and the Norwegian Foundation for Health and Rehabilitation.

References

1 Svensson LG, Coselli JS, Safi HJ, Hess KR, Crawford ES. Appraisal of adjuncts to prevent acute renal failure after surgery on the thoracic or thoracoabdominal aorta. *J Vasc Surg* 1989; **10**: 230–239.
2 Svensson LG, Crawford ES, Hess KR, Coselli JS, Safi HJ. Experience with 1509 patients undergoing thoracoabdominal aortic operations. *J Vasc Surg* 1993; **17**: 357–370.
3 Ballard JL, Duensing A. Extracorporeal techniques in thoracoabdominal aortic surgery. *Semin Vasc Surg* 2000; **13**: 331–339.
4 Myhre HO, Saether OD. Shunting of the superior mesenteric and coeliac arteries during thoracoabdominal aortic aneurysm repair. Presented at the 2nd Nordic Workshop on Thoracoabdominal Aortic Repair, 12th of May, 1997.
5 Jacobs MJHM, Myhre HO, Norgren L, Second Nordic Workshop-group. Thoracoabdominal aortic surgery with

special reference to spinal cord protection and perfusion techniques. *Eur J Vasc Endovasc Surg* 1999; **17**: 253–256.
6 Cohen JR, Schroder W, Leal J, Wise L. Mesenteric shunting during thoracoabdominal aortic clamping to prevent disseminated intravascular coagulation in dogs. *Ann Vasc Surg* 1988; **2**: 261–267.
7 Cambria RP, Davison JK, Giglia JS, Gertler JP. Mesenteric shunting decreases visceral ischemia during thoracoabdominal aneurysm repair. *J Vasc Surg* 1998; **27**: 745–749.
8 Stenseth R, Myhre HO. Anaesthesia in surgery for aneurysm of the descending thoracic or thoracoabdominal aorta. *Acta Chir Scand* 1988; **154**: 147–150.
9 Ballard JL. Thoracoabdominal aortic aneurysm repair with sequential visceral perfusion: a technical note. *Ann Vasc Surg* 1999; **13**: 216–221.
10 Christakis GT, Panos A, Peniston CM, Lichtenstein SV, Salerno TA. Visceral and limb perfusion during thoracoabdominal aortic aneurysm repair. *Ann Thorac Surg* 1989; **48**: 592–594.
11 Safi HJ, Hess KR, Randel M, Iliopoulos DC, Baldwin JC, Mootha RI *et al.* Cerebrospinal fluid drainage and distal aortic perfusion: reducing neurologic complications in repair of thoracoabdominal aortic aneurysm types I and II. *J Vasc Surg* 1996; **23**: 223–229.
12 Jacobs MJ, deMol BA, Legemate DA, Veldman DJ, deHaan P, Kalkmann CJ *et al.* Retrograde and selective organ perfusion during thoracoabdominal aortic aneurysm repair. *Eur J Vasc Endovasc Surg* 1997; **14**: 360–366.
13 Crawford ES. Thoraco-abdominal and abdominal aortic aneurysms involving renal, superior mesenteric, and celiac arteries. *Ann Surg* 1974; **179**: 763–772.
14 Crawford ES, Crawford J. *Diseases of the Aorta*. Baltimore, MD: Wilkins & Williams, 1984.
15 Leijdekkers VJ, Wirds JW, Vahl AC, van Genderingen HR, Siebenga J, Westerhof N, Tangelder GJ, Bulder ER, Rauwerda JA. The visceral perfusion and distal bypass during thoracoabdominal aneurysm surgery: an alternative for physiological blood flow? *Cardiovasc Surg* 1999; **7**: 219–224.
16 Köksoy C, LeMaire SA, Curling PE, Raskin SA, Schmittling ZC, Conklin LD *et al.* Renal perfusion during thoracoabdominal aortic operations: cold crystalloid is superior to normothermic blood. *Ann Thorac Surg* 2002; **73**: 730–738.
17 Ouriel K. The use of an aortoiliac side-arm conduit to maintain distal perfusion during thoracoabdominal aortic aneurysm repair. *J Vasc Surg* 2003; **37**: 214–218.
18 Coselli JS, LeMaire SA, Köksoy C, Schmittling ZC, Curling PE. Cerebrospinal fluid drainage reduces paraplegia after thoracoabdominal aortic aneurysm repair: results of a randomized clinical trial. *J Vasc Surg* 2002; **35**: 631–639.
19 Svensson LG, Hess KR, D'Agostino RS, Entrup MH, Hreib K, Kimmel WA *et al.* Reduction of neurologic injury after high-risk thoracoabdominal aortic operation. *Ann Thorac Surg* 1998; **66**: 132–138.
20 Strømholm T, Aadahl P, Saether OD, Myking OD, Myhre HO. Excessive increase in circulating catecholamines during cross-clamping of the descending thoracic aorta in pigs. *Int J Angiol* 1999; **8**: 91–94.
21 Hennessy A, Grace P, Leader M, Bouchier-Hayes D. Local hypothermia protects the small bowel from ischaemia. *Gastroenterology* 1991; **100**(Suppl 5): A218.

Accepted 23 June 2003

Paper II

Paper II is not included due to copyright.

Paper III

Paper III is not included due to copyright.

Paper IV

Paper IV is not included due to copyright.

Paper V

Health-related quality of life in long term-survivors of thoracoabdominal aortic aneurysm repair

Trine M. Olberg Eide, MA, RN, Pål Romundstad, MSc, PhD, Pål Klepstad, PhD, MD, and Hans O. Myhre, PhD, MD

The purpose was to assess health-related quality of life (HRQOL) in long-term survivors of thoracoabdominal aneurysm repair. Between 1983 and 2001, 43 patients underwent thoracoabdominal aneurysm repair. Long-term survivors (13) were investigated. Two were lost to follow-up. The mean follow-up period was 6.2 years. HRQOL was measured by Short Form (SF)-36, constructed of 36 items grouped into eight scales measuring physical functioning, role limitations caused by physical problems, bodily pain, general health perceptions, vitality, social functioning, role limitations caused by emotional problems, and mental health. Additional questions specific for vascular disease were ascribed. The patients' relatives received corresponding questions, responding on behalf of the patients. Patient data scores were compared with a selection of individuals from the general population. The patients' SF-36 scores were generally poorer than that of the healthy population in both physical and mental dimensions. Patients who had a complicated postoperative course generally scored lowest in physical dimensions. Comparing patients' scores with relatives scoring on behalf of the patients showed no statistical differences. According to disease-specific questions, impotence and pain were reported as major long-term postoperative problems. Patients with uncomplicated postoperative courses all reported improved health status (six) compared with the preoperative status, whereas five patients with complicated postoperative courses reported poorer health status. Nine of 11 patients experienced the same or improved HRQOL, and two patients reported reduced HRQOL after surgery. Ten of 11 patients evaluated the operation as successful. Although the sample size in this study is small, those who had postoperative complications or reported a decreased physical function in the years after surgery generally had low scores in almost all dimensions of the SF-36. When disease-specific questions were related to thoracoabdominal aneurysm surgery, most patients reported an acceptable HRQOL. (J Vasc Nurs 2005;23:88-94)

Although there has been significant improvement in surgical technique, anesthesia, and intensive care, surgical treatment of thoracoabdominal aortic aneurysm (TAAA) is still associated with significant mortality and morbidity. The risk is dependent on the extent of the aneurysm, nature of the disease, and urgency of the operation.[1] The early mortality is significantly lower when the patient is treated electively, compared with emergency operations, which are performed in patients with rupture or pain caused by aneurysm expansion.[2] Survival is the most used indicator of the quality of treatment. However, because serious complications such as renal failure or neurologic sequelae can occur after these operations,[1,3] it is also import to know the expected health-related quality of life (HRQOL) after surgery.[4] Such knowledge in addition to information about medical risk factors could be included in the decision process before the operations.

Trine M. Olberg and Hans O. Myhre are from the Department of Surgery and Pål Klepstad is from the Department of Anesthesiology, University Hospital of Trondheim; Pål Romundstad is from the Department of Community Medicine and General Practice, Medical Faculty, Norwegian University of Science and Technology, Trondheim, Norway.

This article was presented at the 23rd Annual National Convention, Society for Vascular Nursing, April 14 to 16, 2005, The Westin, Cincinnati, Ohio.

This work was supported by a grant from St. Olavs Hospital, University Hospital of Trondheim (No. 1401 1023 4630).

Address reprint requests to Trine M. Olberg Eide, MA, RN, Department of Surgery, University Hospital of Trondheim, N-7006 Trondheim, Norway, e-mail: trine.eide@ntnu.no

1062-0303/2005/$30.00

doi:10.1016/j.jvn.2005.06.002

Measurement of HRQOL has been performed in patients treated for thoracic and abdominal aortic aneurysms.[3,5,6] However, to our knowledge there are no investigations focusing on HRQOL after TAAA repair. Thus, the primary aim of the present investigation was to measure the postoperative HRQOL after TAAA repair and to compare the HRQOL results with those observed in a healthy population. Self-reported HRQOL scores were also compared with the relative's proxy scoring of patient HRQOL.

MATERIAL AND METHODS

Patients and medical records

Between 1983 and 2001, 43 patients underwent thoracoabdominal aneurysm repair at our institution. Thirteen patients were alive at the start of this study in October 2003. Two patients did not respond. Eleven patients agreed to participate in the study (three women and eight men). The mean interval from surgery until the investigation was 6.2 years (1.3-14.1 years), and the mean age at follow-up investigation was 67.4 years (44.4–78.3 years). The median aneurysm diameter was 70.0 mm. According to Crawford's classification for TAAA, four patients had type II, four patients had type III, and three patients had type IV. One patient had ruptured aneurysm, six patients had symptomatic nonruptured aneurysm, and four patients underwent operation electively.

Patients' data were retrieved in medical records and supplemented by a medical follow-up study. A majority of the patients had various comorbidities before surgery. The patient's primary physician and the local hospital were contacted to assess possible changes in the patient's general heath status in the years after surgery. Complications related to aortic surgery were identified. Patient data and results are summarized in Table I. The investigation was approved by the local ethics committee.

Disease-specific and health-related quality of life questionnaire

Thirteen long-time survivors received a Norwegian translation of the Short Form (SF)-36[7] and a disease-specific questionnaire[3] by mail. The SF-36 is a generic questionnaire that measures physical ability and quality of life and is recommended for application in vascular surgery.[8,9] It consists of 35 items in eight dimensions of health: physical functioning, social functioning, physical and mental role limitation, emotional well-being, energy/fatigue, pain, and general health perception.[10] The Norwegian version of SF-36 has been tested on a representative group of the general Norwegian population, according to the recommendations for converting the system developed by the International Quality of Life Assessment.[11] The SF-36 scores range from 0 to 100 (100 represents the best function level). Patient data scores were compared with age- and gender-adjusted data from the general population.[12,13]

A questionnaire specific for vascular diseases was added to evaluate the individual's HRQOL in relation to the operation for aneurysmal disease. The form contains seven questions evaluating health and QOL related to aneurysmal surgery. A similar questionnaire form has been applied in an investigation of HRQOL after thoracic aneurysm surgery.[3] We added one question to the questionnaire in our study; "Would you agree to undergo the same operation today?" The self-administered forms were sent to patients by mail, and they were given the opportunity of assistance from one of the researchers to complete the questionnaires, either by phone or personal contact. Nonresponders were contacted by phone after 1 month. Four patients responded by phone, six patients responded by mail, and one patient filled out the questionnaire during a personal interview.

To ascertain whether the patient's perception of health and HRQOL may have changed subsequent to surgery, we asked for the patient's permission to include one of their close relatives in the study. The purpose was to assess how relatives score HRQOL on behalf of the patient and thereafter to compare the patient's and the relatives' scores. We presupposed that this could provide more precise information required for detecting changes in the patient's perception of HRQOL in the years after surgery, and that the difference in scores would demonstrate this.[4] All but one patient agreed to include a relative in the study. One patient's relative did not respond. The remaining nine relatives returned the questionnaires by mail.

Statistical analysis

The analyses were performed with SPSS version 12.1 (SPSS Inc., Chicago, IL). The SF-36 result scores were presented using mean values and 95% confidence intervals. When compared with the general population, each patient score was matched on sex and age. Patients' scores were also compared with relatives' scores, but only individuals with a relative's score were included in that analysis. Paired-samples t tests were performed when comparing mean scores of separate groups. P values of less than .05 were considered statistically significant.

RESULTS

Surgical and late postoperative results

Thirteen patients were alive at the time of this follow-up study. Postoperative complications, medical condition registered at the time of medical follow-up study, and self-reported complications related to aneurysm surgery as recorded from the disease-specific questionnaire for the patients included in this study are described in detail in Table I. Six patients had impotence and/or sexual lust disturbance as a major problem. Two patients reported sexual problems as irrelevant for their situation. Seven patients reported pain as a major problem that they related to the aortic surgery. The pain was described as a stabbing and lasting ache in the areas of the surgical incision.

Short Form-36 scores

The results of the patients' HRQOL scores are presented in Table II. The patient scores are compared with expected mean scores of corresponding individuals in a general population. The patients' SF-36 scores were significantly lower than that of the healthy population in the bodily pain (41.4 vs. 68.8), physical functioning (41.8 vs. 77.3), and role physical dimensions (25.0 vs. 58.7). Scores for vitality (43.0 vs. 60.2), social functioning (62.5 vs. 84.2), general health (59.1 vs. 69.2), and mental health (66.8 vs. 80.3) were lower, but not statistically different from the expected scores of the healthy population. Patients who experienced a complicated postoperative course had low levels of function in all physical dimensions.

The results of the relative's proxy HRQOL scores are presented in Table III. The relatives' scores are compared with mean self-reported scores of the patients. The patient's relatives scored lower than the patients on bodily pain (35.4 vs. 46.8), general health (62.9 vs. 48.6), mental health (73.0 vs. 61.0), and role emotional (83.3 vs. 66.7), but the differences in scores were not statistically significant. The scores were similar in the role physical (28.1 vs. 31.1) and vitality (45.6 vs. 41.9) dimensions. Relatives had higher scores in the physical functioning (40.6 vs. 52.2) and social functioning (59.7 vs. 66.7), but these were not statistically significant.

Disease-specific scores

Six patients with uncomplicated postoperative courses reported improved health status compared with their preoperative

TABLE I

POSTOPERATIVE COMPLICATIONS AT THE PRIMARY HOSPITALIZATION IN THE TIME INTERVAL FROM SURGERY UNTIL INVESTIGATION (YEARS), MEDICAL CONDITION AT TIME OF FOLLOW-UP INVESTIGATION, AND SELF-REPORTED PROBLEMS RELATED TO SURGERY FOR ALL LONG-TERM SURVIVORS AFTER THORACOABDOMINAL AORTIC SURGERY

Patient No.	*Postoperative complications at time of hospitalization*	*Time from surgery until investigation (y)*	*Medical condition at time of follow-up*	*Self-reported problems related to surgery*
1		14.1	Polymyalgia rheumatica, hypertension, operation for renal carcinoma	
3		5.0	Atrial fibrillation, aneurysm of the aortic arch	Pain and sense of weakness at field of surgical incision
5	Superficial wound infection, renal failure (temporary dialysis), paraparesis	8.7	Paraparesis	Pain in field of surgical incision when walking, ISD
7	Reoperated for colon necrosis, multiorgan failure, wound infection, renal failure (temporary dialysis)	6.8	Cardiac insuffiency	Pain in the field of surgical incision, cannot stand-up for more than 10 min at a time, ISD
8		8.8		Retrograde ejaculation, reduced ISD
10	Reintervention for endoleak	1.3		ISD
12		3.1	Abdominal pain, drainage of pleural effusion	Chest and back pain ISD reported not relevant for patient
14		5.6	Chest pain, headache, shortness of breath during activity, incisional hernia	Chest pain limits activity to intervals of 10 min
16	Hypertension	5.0	Expansion of the descending thoracic aorta located near the upper anastomosis	Back pain and fatigue, ISD
18		6.8	Pain in the left flank, cardiac insuffiency, aneurysm of the descending thoracic aorta	Pain in left flank and genital area, but ISD reported not relevant for patient
19	Renal failure because of occluded left renal artery, colon necrosis, peritonitis, decubital ulcer, paraplegia	3.0	Paraplegia, dialysis 4 times every week	ISD, renal failure, nausea and general feeling of sickness

COPD, Chronic obstructive pulmonary disease; *ISD,* impotence or sexual lust disturbances.

TABLE II

IN THE TOTAL SERIES OF 11 PATIENTS WHO UNDERWENT OPERATION FOR THORACOABDOMINAL AORTIC ANEURYSMS THE MEAN SF-36 SCORES OF AN EXPECTED HEALTHY POPULATION AND PATIENTS ARE LISTED, USING A PAIRED-SAMPLES *T* TEST

Dimension of SF-36	*Numbers*	*Mean score (95% CI) expected healthy population*	*Mean score (95% CI) patients*	*Paired mean difference from healthy population (95% CI)*
Bodily pain (BP)	11	68.8 (66.5–70.5)	41.4 (17.9–64.9)	−27.4 (−49.7–−5.3) *P* = .03*
General health (GH)	9	69.2 (67.5–70.9)	59.1 (40.7–77.8)	−10.1 (−29.7–9.6) *P* = .27
Physical functioning (PF)	11	77.3 (75.9–78.7)	41.8 (14.5–69.2)	−35.5 (−11.0–−60.9) *P* = .02*
Role physical (RP)	10	58.7 (55.6–61.8)	25.0 (−1.7–51.6)	−33.7 (−56.5–−10.9) *P* = .02*
Mental health (MH)	10	80.3 (79.1–81.5)	66.8 (44.1–89.5)	−13.5 (−36.0–9.1) *P* = .21
Vitality (VT)	10	60.2 (58.6–61.8)	43.0 (24.3–61.7)	−17.2 (−36.9–2.5) *P* = .07
Social functioning (SF)	11	84.2 (82.5–85.9)	62.5 (36.5–88.5)	−21.7 (−48.0–4.6) *P* = .09
Role emotional (RE)	10	72.7 (70.3–75.1)	80.0 (54.4–105.6)	7.3 (−21.4–36.1) *P* = .54

CI, Confidence interval; *SF-36,* Short Form-36.

A paired mean differences from the healthy population for each separate dimension are also listed, using a paired-samples difference test (all survivors' scores are included).

*Statistical significance, $P<.05$

TABLE III

IN THE TOTAL SERIES OF 11 PATIENTS WHO UNDERWENT OPERATION FOR THORACOABDOMINAL AORTIC ANEURYSMS THE MEAN SF-36 SCORES OF THE PATIENTS AND THE RELATIVES' SCORES ARE LISTED, USING A PAIRED-SAMPLES *T* TEST

Dimension of SF-36	*Numbers*	*Means score (95% CI) patients*	*Mean score (95% CI) relatives*	*Paired mean difference from patients (95% CI)*
Bodily pain (BP)	9	46.8 (18.6–74.9)	35.4 (7.9–63.0)	−11.4 (−42.5–19.8) *P* = .43
General health (GH)	7	62.9 (42.4–83.3)	48.6 (21.5–75.6)	−14.3 (−29.3–0.7) *P* = .06
Physical functioning (PF)	9	40.6 (9.7–71.4)	52.2 (24.7–79.7)	11.6 (−10.2–33.6) *P* = .25
Role physical (RP)	8	28.1 (−6.2–62.4)	31.3 (−1.8–64.3)	3.2 (−37.8–44.1) *P* = .86
Mental health (MH)	8	73.0 (53.1–92.9)	61.0 (44.1–77.9)	−12 (−32.6–8.6) *P* = .21
Vitality (VT)	8	45.6 (24.7–66.5)	41.9 (20.8–62.9)	−3.7 (−26.9–19.4) *P* = .71
Social functioning (SF)	9	59.7 (28.3–91.1)	66.7 (37.1–96.3)	7.0 (−14.1–27.9) *P* = .47
Role emotional (RE)	8	83.3 (53.5–113.1)	66.7 (27.3–106.1)	−16.6 (−68.3–34.9) *P* = .47

CI, Confidence interval; *SF-36,* Short Form-36.

Paired mean differences from the patients' scores for each separate dimension are also listed using a paired-samples difference test (only scores of survivors that can be compared with relatives' scores are included).

status (Fig. 1A). Three of these patients had almost or completely resumed their activity level, whereas the others reported poor activity level after surgery. All five patients with complicated postoperative courses reported poorer health status (Fig. 1A). These patients had not, or to a smaller extent, resumed their level of activity after the operation.

Nine of 11 patients reported the same or improved HRQOL, and two reported reduced HRQOL after surgery compared with

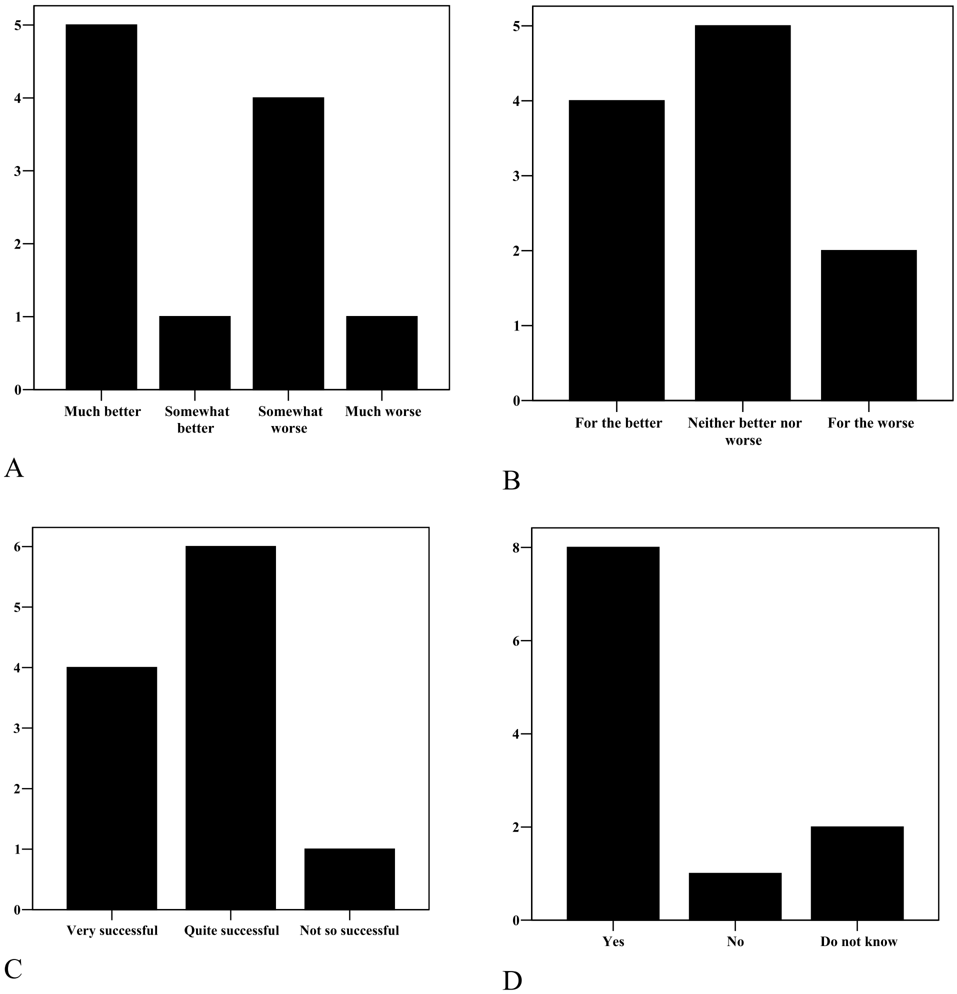

Figure 1. *Results from the disease-specific questions that were added to the Short Form (SF)-36 health questionnaire. (A) Answers regarding the question, compared with the preoperative situation, how do you judge your general health status now? (B) Answers regarding the question, how is your quality of life affected by the operation? (C) Answers regarding the question, how do you consider the operation today? (D) Answers regarding the question, would you agree to undergo the same operation today? The bars on the coordinate axis represents the numbers of patients.*

the preoperative status. Of the four patients who reported a higher HRQOL, three had resumed their activity level after surgery (Fig. 1B). Of the five who stated neither worse nor better HRQOL, all reported that they had not at all or to a small part resumed activity after surgery. The two patients reporting a reduced HRQOL both experienced great physical constraints after surgery and evaluated their general health as poorer than before the operation. Ten of 11 patients evaluated the operation as successful, and eight patients would agree to undergo the same operation again (Fig. 1C and D).

There was a high agreement between patients' responses and relatives' proxy responses on the disease-specific questions.

DISCUSSION

We observed that most patients experience an impaired physical functioning after thoracoabdominal aortic surgery. These findings are reflected in both the physical dimension of the SF-36 scores and the disease-specific questions. A complicated postoperative course had a negative impact on the patient's perception of health status at late follow-up. Impotence was a frequently reported problem among our patients. This is a well-documented problem after treated and untreated abdominal aortic aneurysms.[14,15] We observed that most patients indicated bodily pain as a major problem up to 9 years after surgery. In most patients pain was located in the field of the surgical incision. In a similar study of patients who had undergone thoracic surgery,[3] pain scores were similar to that of the healthy population. The differences in findings regarding pain as a postoperative problem between the two studies could perhaps be explained by the larger incisions used in thoracoabdominal aortic surgery.

The patients' SF-36 mental function scores were lower than that of the general population, except for the role emotional dimension. Still, most patients reported the operation as successful and would have undergone the same procedure today. It has been argued that the changes in HRQOL that occur in chronic and life-threatening diseases result in part from patients adapting to their situation; patients change their internal standards, values, or ideas of HRQOL. Therefore an HRQOL measure in different stages of a disease does not always change, and individuals with serious diseases are not consistently evaluating their own HRQOL as inferior to the HRQOL reported by healthy people.[16] This phenomenon is called "response shift." [4]

The scoring profile indicates that the patients do worse physically than mentally, and that there is a correspondence between self-reported functioning and an individual's HRQOL. Nevertheless, the disease-specific questions revealed that most patients experienced an acceptable quality of life after surgery despite physical constraint.

The observed differences in the HRQOL scores when comparing the patients' scores with the relatives' scores on behalf of the patient were varied within both physical and mental dimensions. The lowest relatives' scores were for the role emotional dimension. However, in the disease-specific questions both groups reported an impaired physical health status, but they were satisfied with respect to the global questions concerning life after TAAA surgery.

We recognize that this study has some limitations. The lack of statistically significant differences in the SF-36 scores are most likely explained by the low number of patients and relatives included in the study, and the large distribution of HRQOL data universally observed in HRQOL studies. It has been argued that differences in SF-36 scores more than 10 represent a clinically meaningful difference between patient groups. Thus, several of the nonsignificant differences observed in this study may represent clinically important differences, which would have reached statistical significance in a study including a larger number of patients. This limitation is a common feature of studies on patients presenting with infrequent diseases.[12,17,18] Similar investigations on abdominal aortic aneurysms show that after both elective and acute surgeries one can obtain an acceptable postoperative HRQOL when comparing with an age-adjusted healthy population.[5,6,17,19,20]

Methodologic and ethical considerations

Quality of life studies in patients undergoing operation for TAAA repair raise complex methodologic challenges. The impact of a specific condition on perceived health can be hidden and difficult to detect. Thus, it is a problem to identify to which extent the aneurysmal disease itself or the development of comorbidities in the years after surgery is influencing the patient's HRQOL. Patients may also have different expectations regarding quality of life, and they could be in different stages in the postoperative course including recovery from an operation. Second, there is a selection bias because several of these operations often are performed as emergency procedures. Also, handling of the patients is different in those who have ruptured aneurysm or pain compared with those who are asymptomatic and therefore undergoing operation electively. In the latter group there is sufficient time to explain the operation and discuss the postoperative course, risks, and potential complications with the patient. Such preparations are usually insufficient in patients who undergo emergency operations. The possibility of informing the patients satisfactorily is then limited, and often the patient is not prepared for a high risk of a complicated postoperative course including a prolonged stay in the intensive care unit.

HRQOL has been used extensively as a measure of results after vascular surgery. Extensive surgery, often prolonged intensive care treatment, and treatment costs should be balanced against the expected HRQOL after surgery.[17] In the discussion on whether to perform surgery in patients with TAAA, the expected postoperative HRQOL is one of several factors that should be taken into consideration.

REFERENCES

1. Svensson LG, Crawford ES, Hess KR, et al. Experience with 1509 patients undergoing thoracoabdominal aortic operations. J Vasc Surg 1993;17:357-70.
2. Lewis ME, Ranasinghe AM, Revell MP, et al. Surgical repair of ruptured thoracic and thoracoabdominal aortic aneurysms. Br J Surg 2002;89:442-5.
3. Ohlson C, Thelin S. Quality of life in survivors of thoracic aortic surgery. Ann Thorac Surg 1999;67:1262-7.
4. Addington-Hall J, Kalra L. Measuring quality of life. Who should measure quality of life? BMJ 2001:322:1417-20.
5. Hennesy A, Barry MC, McGee H, et al. Quality of life following repair of ruptured and elective abdominal aortic aneurysms. Eur J Surg 1998;164:673-7.
6. Korhonen SJ, Kantonen I, Pettilä V, et al. Long-term survival and health-related quality of life in patients with ruptured abdominal aortic aneurysm. Eur J Endovasc Surg 2003;25:350-3.
7. How to score the SF-36 health survey. Boston, MA: Medical Outcomes Trust; 1994.
8. Beattie DK, Golledge J, Greenhalgh RM, et al. Quality of life assessment in vascular disease: towards a consensus. Eur J Vasc Endovasc Surg 1997;13:9-13.
9. Mangione CM, Goldman L, Orav EJ, et al. Health-related quality of life after elective surgery: measurement of longitudinal changes. Gen Intern Med 1997;12:686-97.
10. Ware JE, Gandek B. Overview of the SF-36 health survey and the international quality of life assessment (IQOLA) project. J Clin Epidemiol 1998;51:903-12.
11. Ware JE. The SF-36 health survey. In: Spilker B, editor. Quality of life and pharmacoeconomics in clinical trials. Philadelphia: Lippincott-Raven; 1996.
12. Loge JH, Kaasa S, Hjermestad MJ, et al. Translation and performance of the Norwegian SF-36 health survey in patients with rheumatoid arthritis. I. Data quality, scaling assumptions, reliability and construct validity. J Clin Epidemiol 1998;51:1069-76.
13. Loge JH, Kaasa S. Short Form 36 (SF-36) health survey: normative data from the general Norwegian population. Scand J Soc Med 1998;26:250-8.
14. Lederle FA, Johnson GR, Wilson SE. Quality of life, impotence, and activity level in a randomized trial of immediate repair versus surveillance of small abdominal aortic aneurysm. J Vasc Surg 2003;4:745-52.
15. Prinssen M, Buskens E, Tutein Nolthenius RP, et al. Sexual dysfunction after conventional and endovascular AAA repair: results of the DREAM trial. J Endovasc Ther 2004;11: 613-20.

16. Higginson IJ, Carr AJ. Measuring quality of life: using quality of life measures in a clinical setting. BMJ 2001;322: 1297-300.
17. Bohmer RD, Fleischl J, Knight D. Quality of life after emergency abdominal aortic aneurysm repair. Aust N J Surg 1999;69:447-9.
18. Osoba D, Brada M, Yung WKA, et al. Health-related quality of life in patients treated with temozolomide versus procarbazine for recurrent glioblastoma multiforme. J Clin Oncol 2000;18:1481-91.
19. Rohrer MJ, Cutler BS, Wheeler HB. Long-term survival and quality of life following ruptured abdominal aortic aneurysm. Arch Surg 1988; 123:1213-7.
20. Joseph AY, Fisher JB, Toedter LJ, et al. Ruptured abdominal aortic aneurysms and quality of life. Eur J Vasc Endovasc Surg 2002;36:65-70.