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Descending thoracic and thoracoabdominal aortic aneurysm repair: 15-year results using a uniform approach

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Descending Thoracic and Thoracoabdominal Aortic Aneurysm Repair: 15-year results using a uniform approach.

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Abstract

Objective: This review presents the results of surgical repair of descending thoracic (DT) and thoracoabdominal (TAA) aortic aneurysms, using spinal drainage, distal aortic perfusion, and other adjuncts intended to reduce complications.

Methods: Records of patients undergoing repair of DT and TAA between 1986 and 2002 were reviewed. Elective operations were performed using single lung ventilation, invasive monitoring, spinal drainage (SD), modest anticoagulation, permissive hypothermia (≥ 33° F), liberal use of transaortic endarterectomy, and complete repair. Intercostal arteries were reimplanted when possible and distal aortic perfusion (DAP) used in DT and TAA types I, II, III. Exceptions to this approach were noted. Some of these adjuncts were used in emergency cases. Actuarial survival was calculated.

Results: Fifty consecutive patients with DT (3), or TAA (47), type I (4), type II (16), type III (18), type IV (9), received elective (36) or emergency (14) repair between 1986 and 2002. Mortality was 2/36 (5.5%) in the elective group. In the emergency group, there were 2 intraoperative deaths and mortality was 4/14 (28.5%, p<.07). Overall survivor morbidity was 6/34 (17.6%) in elective and 7/10 (70%, p<.02) in emergency cases. Paraplegia occurred in one patient in the elective group (2.7%) with dissecting type II TAA aneurysm in whom the intercostal patch was sacrificed. Two of 12 initial survivors developed paraplegia in the emergency group (16.7%); one had SD but neither had DAP or intercostal reimplantation. Serious complications were associated with avoidable deviations from the approach. Five and 10 year survival for the entire series was 64.8% and 46.4%, respectively.

Conclusions: These results parallel those in contemporary reports from centers where repair of descending and thoracoabdominal aortic aneurysm is frequently performed. Good long-term results can be achieved using spinal drainage and distal aortic perfusion, combined with other adjuncts as a means of reducing complications. When possible, the same approach should be used in emergency cases.

Introduction

Repair of descending thoracic (DT) or thoracoabdominal aortic (TAA) aneurysms presents a significant technical and physiologic challenge. Reports from centers with a large experience with DT and TAA aneurysm repair have documented improved results when distal aortic perfusion and spinal catheter drainage are used.[1-4] These adjuncts attempt to address issues of organ dysfunction secondary to hypoperfusion.

Additional maneuvers have been suggested which may help reduce the risk of postoperative complications. Single lung anesthesia aids in exposure. Reimplantation of intercostal arteries has been associated with decreased risk of paraplegia.[5] Hypothermia, either regional [6,7]or systemic, [8] has been reported to improve outcome. Given these complex issues, the frequency with which the operation is performed may also influence overall results.

In 1986, the author started using spinal catheter drainage and distal aortic perfusion during repair of DT and TAA aneurysms. Reimplantation of intercostal arteries was performed when technically possible and according to aneurysm type. The procedures were done with invasive monitoring, single lung anesthesia, modest anticoagulation and permissive hypothermia. There was an attempt to accomplish complete repair including treatment of visceral artery stenosis. These were considered key elements. The objective of this review was to evaluate the results of this approach as performed over a period of 15 years.

Methods

All patients treated for DT or TAA since 1986 are included. Patients were managed as part of an individual and varied vascular practice within a major academic medical center (UCLA Medical Center, Los Angeles, California). In all cases there was assistance from surgical and medical colleagues. Surgical residents and vascular fellows provided continuous monitoring and care during hospitalization.

Medical records were reviewed retrospectively and information abstracted, including the patient's age, sex, risk factors and clinical presentation. Patients were considered to have significant COPD if they were receiving oral medications or nebulizers for this process. Preoperative renal insufficiency was considered as a serum creatinine greater than 2.0 Details of the operative procedure and postoperative course were recorded.

Repair was considered elective when the patient underwent scheduled admission to the hospital for treatment of the aneurysmal process. Preoperative evaluation usually included cardiac stress testing and pulmonary studies. Emergency repair was attempted within 72 hours of urgent admission or transfer to our facility. All emergency cases were patients with either free or contained rupture.

Management was relatively standardized during the experience. Elective patients were prescribed mechanical bowel preparation before surgery. All cases were done with single lung ventilation and invasive monitoring (pulmonary artery catheter, radial artery line, right femoral artery line to record distal aortic pressure, and spinal pressure monitoring). Most cases were performed with cardiac anesthesiologists. Since 1998, transesophageal echocardiography (TEE) was used. Pulmonary catheters were examined with fluoroscopy or TEE to avoid placement in the left pulmonary artery where erroneous readings could occur during collapse of the left lung.

A spinal catheter was inserted by the anesthesiologist and connected to a gravity regulated drainage system. Pressure was maintained at 10 cm of water after induction of anesthesia. Distal aortic perfusion was used during repair of DT and TAA types I, II, and III aneurysm repair. The method of distal aortic perfusion included atrial or inferior pulmonary vein to femoral or iliac bypass using an extracorporeal centrifugal pump. In patients with DT aneurysm, the distal descending aorta was used for the outflow canula. When a previous axillofemoral bypass was present no additional method for DAP was used. Femoro –femoral perfusion with an extracorporeal oxygenator was used once. Cardiac surgeons assisted with DAP. Sequential clamping was used during the proximal anastomosis and intercostal reimplantation. With notable exceptions, patients received .5 mg/kg of heparin. Activated clotting time (ACT) was maintained around 200 seconds. Distal aortic pressure was monitored using a right femoral arterial line, and flow adjusted to maintain a mean distal pressure of 60 mm Hg. All patients received 12.5 to 25 grams of Manitol early during the operation and some elective patients were empirically given 500 to 1000mg of Solumedrol.

An attempt was made to maintain retroperitoneal aortic exposure in the abdominal area. The diaphragm was divided circumferentially in all TAA types II and III, and some types I and IV. In all patients with DT or TAA type I, II, or III, the proximal anastomosis was performed with a Teflon pledget strip and a continuous 3-0 polypropylene suture. Balloon catheters were used routinely to control back bleeding during the procedure.

Visceral and intercostals patches were reimplanted to a small opening in the graft using a continuous suture. Revascularization of the left renal artery often involved a separate patch or bypass. Intercostal artery reimplantation was attempted routinely in TAA types I, II, and III, but selectively in DT or TAA type IV. The aneurysm sac was closed over the completed repair, to the extent allowed by the anatomy.

Major postoperative complications were recorded. Bleeding was defined as postoperative blood loss requiring re-operation. Respiratory failure was defined as patients requiring respiratory support for longer than 7 days or requiring tracheostomy. Renal failure was defined as patients requiring temporary or permanent hemodialysis. Transient increases in creatinine or temporary hemofiltration for fluid management were not considered as organ failure. Paraplegia or paraparesis following surgery was defined as permanent lower extremity weakness or paralysis. Temporary elevations in serum amylase, cardiac or liver enzymes without clinical sequelae were not considered major complications. Postoperative death was defined as occurring within thirty days of surgery or prior to discharge.

The author provided care after hospital discharge, with the assistance of the referring physician. Patients not seen within a year of their surgery or the last year of this review were contacted by phone. If personal communication was not possible, the referring physician provided follow up information. The patient was considered lost to follow up beyond the time when information was available. Long-term survival was calculated by actuarial methods and includes postoperative deaths.

Proportions of patients with specified conditions were compared between the elective and emergency groups, and between the present study and results reported in the literature, using a chi-squared test with one degree of freedom. Mean blood loss was compared between the elective and emergency group using the Wilcoxon rank sum test. Differences were considered significant when p value was less than .05.

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Results

Between November1986 and January 2002, fifty consecutive patients underwent repair of DT or TAA. Thirty-six cases were elective and 14 patients presented with ruptured aneurysms. Twenty-one cases were done between 1986 and 1997 (10 elective, 11 emergency). Twenty-nine cases were performed between 1998 and 2002 (26 elective, 3 emergency).

Patient age, sex and risk factors are presented in table 1. Patients in the emergency group had a higher incidence of hypertension and COPD. One patient in the ruptured group had previously undergone cardiac transplantation. More females were present in the emergency group (57% vs. 33%). None of these differences were statistically significant

Signs and symptoms in elective patients are presented in table 2. Of 36 patients in this group, 19 patients had enlarging aneurysms noted during observation; 7 had symptoms and 12 were asymptomatic. Symptomatic patients included 17 patients with pain, 9 with renovascular hypertension and 3 with chronic mesenteric ischemia. Of the patients with rupture, 2 were free perforations and 12 were contained. Free rupture occurred during exposure of a contained process, resulting in significant hypotension.

Aneurysm size and type are summarized in table three. There were 3 DT and 47 TAA including 4 type I, 16 type II, 18 type III, and 9 type IV. Average size for elective aneurysms was 6.9cm, ranging for 3.9cm to 11cm. The patient with the 3.9cm aneurysm had a type III aneurysm with dissection and presented with severe renovascular hypertension and chronic mesenteric ischemia. Type III TAA aneurysms were the most frequently found in the emergency group whereas types II and III thoracoabdominal aneurysms were equally represented in the elective cases. All 3 DT aneurysms were in the elective group, likely due to referral patterns. Two patients in the elective group with TAA (types II, IV) had Marfan's syndrome. One patient with a DT aneurysm had a remote (20 year) history of automobile accident. All other patients in both groups were thought to have degenerative atherosclerotic aneurysms.

Amongst elective cases, there were six aneurysms with dissection and ten patients had prior abdominal aortic aneurysm repair (6) or thoracoabdominal aneurysm repair (4). The latter included two redo type III TAA repair, one type IV aneurysm after a type I TAA repair and one recurrent type IV TAA. Within the ruptured group, two had prior abdominal aortic aneurysm repair and two had prior TAA repair. One patient in this group presented with a type III TAA with dissection after a previous proximal interposition graft distal to the left subclavian artery.

In four elective patients (2 DT, 2 TAA types I, II), proximal aortic clamping was done between the left common carotid and the left subclavian artery because of involvement of the left subclavian artery in the aneurysm. In two of these patients (1 DT, 1 TAA type I), the left subclavian artery was reimplanted with the proximal anastomosis. In the other two, a preparatory left carotid subclavian transposition was performed during the same anesthetic. The origin of the left subclavian artery was occluded by the proximal suture line.

Mortality in the elective group occurred in 2/36 (5.5%) patients due to multisystem organ failure. One patient had a TAA type III aneurysm and was 1 of 2 aneurysms of this type repaired without distal aortic perfusion. The second death was related to hemorrhagic lung injury and an incomplete repair, both avoidable complications. This patient had a type I thoracoabdominal aneurysm and femoral vein to femoral artery extracorporeal bypass for distal perfusion. Because an oxygenator had to be used, this patient was heparinized with 15,000 units of intravenous heparin. This patient suffered hemorrhagic injury to the right lung, likely the result of some degree of pulmonary hypertension intraoperatively from single lung anesthesia combined with the large doses of heparin. In addition, he had multiple splenic and liver infarcts likely the result of distal embolization from an incomplete repair. In retrospect the distal anastomosis should have been performed at a more distal location. One death occurred in each time period (1986-97, 1998-02).

In the emergency group, 4/14 (28.5%) patients died. All deaths were associated with significant intraoperative hypotension and coagulopathy, two of them occurring in the operating room and two during the postoperative period. Two postoperative deaths were seen in patients with free rupture. One patient had significant postoperative bleeding and underwent reoperation with splenectomy. He died from multiorgan system failure. The second patient was hypothermic and suffered an intraoperative cardiac arrest. After resuscitation, the patient showed anoxic brain injury and supportive measures were withdrawn. Three deaths occurred within the first time period (1986-97). The difference in mortality between elective and emergency groups almost reached statistical significance (5.5% vs. 28.5%, $p < .07$).

Details of the operation regarding blood loss, hypotension, use of spinal catheter drainage and distal aortic perfusion are presented in table 4. Mean blood loss (standard deviation) in elective cases was 2075 (1443) cc ranging from 600 to 6000 cc. Mean blood loss (standard deviation) in emergency cases was 3257 (4046), ($p < .69$).. Significant hypotension was more commonly seen in ruptured cases, occurring in 5 of 14 patients (36%); in elective cases it was seen in 6 of 36 patients (17%).

Spinal catheter drainage was used in 34 of 36 elective cases (94%). The two exceptions were TAA type IV. Spinal drainage was used in 10 of 14 cases (71%) in the emergency group.

Distal aortic perfusion was utilized in all DT and in 24 of 26 (92%) of elective TAA types I, II and III repairs. The exceptions were: Type III thoracoabdominal aneurysm that was thought preoperatively to be a type IV with operative findings dictating proximal clamping of the mid descending aorta and a patient with two prior coronary artery bypass surgeries presenting with a type III thoracoabdominal aortic aneurysm, significant renal insufficiency (creatinine 3.8) and chronic mesenteric ischemia. This patient suffered multiorgan system failure postoperatively and is one of the two deaths in the elective group. In the emergency group, distal aortic perfusion for TAA was performed in 5 of 12 patients including 2 TAA type IV redo repairs.

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The method of distal aortic perfusion in elective cases included 16 patients with atrial to femoral (12), or iliac (4) bypass with an extracorporeal centrifugal (Biomedicus) pump, and 5 patients with inferior pulmonary vein to iliac (2), or femoral (3) bypass with extracorporeal pump. Patients with DT aneurysm repair had distal aortic perfusion in the form of atrial to distal descending aortic extracorporeal pump bypass. No differences were noted between these options. Distal aortic pressure was maintained around 60 mm Hg and flow adjusted to avoid upper trunk hypotension. Three additional patients (including a TAA type IV) had prior axillofemoral reconstruction, which was maintained for distal aortic perfusion during aneurysm repair. There was one patient with femoral-femoral extracorporeal bypass using an oxygenator, as stated previously.

Excluding patients with free rupture, all patients received heparin. There were two exceptions to modest heparinization: one patient with femoral-femoral extracorporeal bypass in the elective group and one patient in the ruptured group who had a prior heart transplant, receiving 10,000 units (2mg/kg) of heparin. Both patients suffered hemorrhagic lung injury and respiratory failure.

Reimplantation of intercostal vessels was performed in 22 of 36 elective cases. In 7 cases, no intercostals arteries suitable for reimplantation were found. These included 4 patients with type III, 2 patients with type II, and one patient with type I TAA repair. Two of 7 patients with TAA type IV had reimplantation of intercostal arteries. In one patient with a TAA type II, the reimplanted patch of four intercostals arteries had to be sacrificed because of persistent bleeding. In patients with rupture, 3 had reimplantation of intercostals arteries (2 TAA type II and 1 TAA type III).

In the elective group a total of 17 transaortic endarterectomies in 11 patients were performed. This included unilateral renal endarterectomy in 6 and bilateral in 3. Endarterectomies were carried out in 3 celiac and 5 superior mesenteric arteries. In the ruptured group, unilateral renal endarterectomy was performed in 4 instances and bilateral in 1. There was 1 celiac endarterectomy, for a total of 6 transaortic endarterectomies in 5 patients. The left renal artery was managed with a Carrel patch in 9 elective cases, a bypass graft in 10 and included in the visceral patch in 6. In the emergency group the left renal artery was included in the visceral patch in 3 patients, reattached with a Carrel patch in 4 and with a bypass graft in 2 cases.

Postoperative morbidity is summarized in table 5. Overall morbidity amongst survivors was significantly lower in the elective group (6/34; 17.6%) than in the emergency group (7/10; 70%, $p<.02$). Major complications included renal insufficiency in 3 elective and 4 emergency repairs. Of the 4 patients with renal insufficiency in the latter group, two eventually died of multisystem organ failure. One survivor had pre-existing renal insufficiency and the other had significant intraoperative hypotension. Both eventually recovered adequate renal function. In the elective group, 2 patients with renal failure eventually died from multisystem organ failure. Both had significant intraoperative hypotension and one had a dissecting process that prevented distal aortic perfusion of one of the two kidneys. The remaining elective case complicated by renal failure was in a patient with pre-operative renal insufficiency (serum creatinine 3.2), who required chronic hemodialysis 3 weeks after hospital discharge. The difference in the incidence of renal failure in emergency and elective group did not reach statistical significance ($p < .11$)

Respiratory failure occurred in 4 elective and 7 emergency cases. Six patients (2 elective, 4 ruptured) eventually died of multisystem organ failure. Of the 2 survivors in the elective group, one patient had significant intraoperative hypotension, coagulopathy and cardiac arrest requiring cardiac massage. This patient also had the single case of paraplegia in the elective group. He required a tracheostomy. All three surviving patients in the ruptured group required tracheostomy. All patients except one (elective group) had preoperative COPD. Respiratory failure was significantly more common after emergency repair compared to elective cases ($p<.004$)

Paraplegia occurred in 1 patient in the elective group (2.7%) who had a dissecting type II TAA aneurysm. The patient had distal aortic perfusion, and spinal catheter drainage.

His intercostal patch reimplantation had to be sacrificed secondary to bleeding from coagulopathy and dissection in the area of the patch. In retrospect, coagulopathy may have been related to poor liver perfusion during repair due to the celiac artery originating from the false lumen. Bleeding and hypotension were contributing factors. Two patients in the emergency group suffered paraplegia (16.7%). One of these two patients had spinal catheter drainage but neither had distal aortic perfusion or intercostal reimplantation. The patient with spinal catheter drainage had intraoperative rupture of her contained aneurysm and significant hypotension. Both patients eventually became ambulatory with assistive devices. The difference between emergency and elective group was not significant ($p < .3$)

One patient in each group suffered a stroke. One occurred in an elective patient requiring control between the carotid and left subclavian arteries for distal arch repair. The patient recovered. The second case was likely related to significant hypotension. The patient had a prior stroke. The incidence of postoperative stroke between the two groups was not significant ($p<.43$).

Reoperation for postoperative bleeding occurred in one patient in the elective group. This was recognized within the first three hours after operation and successfully resolved. An elective case required reoperation due to multiple splenic and liver infarcts. There was reoperation in one patient requiring splenectomy (emergency group). Both patients died from multisystem organ failure. Splenectomy during repair was required in

3 elective and 1 emergency case. Based on past experience, splenectomy was performed for any minor splenic injury to reduce the risk of postoperative bleeding. Bleeding or reoperations as a complication was not significantly different between the emergency and the elective group ($p<.76$).

Lower extremity ischemia was recognized intraoperatively in two elective patients. Both had femoral popliteal bypass at the conclusion of the aneurysm repair. In the emergency group, one right femoral embolectomy was performed at the conclusion of the procedure. There were no amputations.

Key elements of the approach (DAP, SD, modest anticoagulation, permissive hypothermia, complete repair) were achieved in 32/36 (90%) elective cases. There were no deaths or paraplegia in this cohort. In 5/12 (40%) emergency repairs these key elements were accomplished. Two of these 5 patients died due to intraoperative cardiac arrest. There were no major complications in the 3 survivors.

Following discharge, 4 patients (3 elective, 1 emergency) died within the first year. Two had renal or respiratory failure as a complication of the aneurysm repair. Four patients were lost to follow up, 3 of them after 1 year and one after 2 years. Twenty-nine patients remain alive (24 elective, 5 emergency) as of June 2002. Cumulative survival for the entire series was 64.8% and 46.4% at 5 and 10 years respectively, with only 2 patients followed at the 10 year interval. Five-year survival was similar between elective and emergency patients (57% vs. 62%). No patient is alive beyond 12 years after the procedure.

Table 6 presents a comparison between results herein presented and those from Le Maire et al.[16] The latter report was selected as it is one of the largest series of TAA reported, represents contemporary results, analyzes both elective and emergency cases and provides necessary details to make meaningful comparisons. The column titled 95% CI (confidence interval) compares the two reports for each element, taking the difference as the proportion in Le Maire study minus the proportion in this study using a chi square test with one degree of freedom. In regards to the two patient populations, there were no significant differences in age, gender and hypertension. Patients in the elective group in this series had a higher incidence of coronary artery disease and diabetes. These differences were not present in the emergency group. The incidence of COPD in their series was higher almost reaching statistical significance. Results between these two experiences are remarkably similar with no statistically significant difference in mortality, paraplegia, renal failure, and stroke in both elective and emergency groups. Respiratory failure in the elective group in their series was significantly higher likely the result of larger number of patients with COPD and a more inclusive definition of this complication. Renal failure in our emergency group seems higher, almost reading statistical significance (33% vs. 9.8%, $p < .06$).

Discussion

Repair of descending thoracic (DT) or thoracoabdominal aortic (TAA) aneurysm is a complex procedure, which requires use of adjuncts that attempt to minimize postoperative organ dysfunction. Spinal catheter drainage as suggested by Hollier[9], has now been shown to reduce the incidence of paraplegia in some large clinical series.[2,3] Reduction of intra-spinal pressure is intended to improve blood flow at any given perfusion pressure. Reimplantation of intercostal arteries is also an effort to maintain circulation to the spinal cord. The author has adopted use of spinal drainage during management of patients undergoing DT or TAA aneurysm repair of all types since 1986. This decision was based on experimental studies, [10-12] limited clinical reports[13] and personal conversations with experienced surgeons. Although good results can be obtained without spinal catheter drainage in type IV thoracoabdominal aortic aneurysms, [14] it is notable that incidence of paraplegia can be as high as 10% for these more limited aneurysms.[15] Spinal catheter drainage is a low risk procedure that may help minimize this complication after repair of DT or TAA aneurysms, regardless of type.

Distal aortic perfusion was adopted as part of the approach in the absence of randomized clinical data to support its use. When utilized in DT or TAA types I, II, and III, distal aortic perfusion not only maintains blood flow to distal organs during proximal clamping, but also assists in management of the hemodynamic changes that result from clamping the thoracic aorta. Traditionally, this has been managed with intravenous antihypertensives in order to avoid upper truck hypertension, thus reducing strain to the heart. Artificially decreasing blood pressure in this fashion is likely to cause further loss of perfusion to the distal viscera. Distal aortic perfusion reduces some of the demands on the operating surgeon to expedite unnecessarily the performance of the procedure. Although axillofemoral bypass can accomplish similar objectives, it is a passive form of perfusion, thus flow and pressure (upper and lower trunk) cannot be controlled as with an extracorporeal pump. When already present, it can provide distal aortic perfusion. Otherwise, extracorporeal bypass seems preferable. There was no experience with catheter perfusion of visceral vessels. This is an attractive approach, which in combination with DAP, may further prevent postoperative organ dysfunction.

The overall results of this experience in elective (mortality 5.5%; paraplegia 2.7%; morbidity 17.6%; 5yr survival 57%) and emergency (mortality 28.5%; paraplegia 16.7%; morbidity 70%; 5 yr survival 62%) patients, compares well with centers that have a large experience with repair of DT and TAA aneurysms. This experience and that reported by other investigators support use of distal aortic perfusion and spinal catheter drainage in these complex repairs.[3, 4, 16]

The incidence of respiratory failure seems particularly high and the mortality associated with this complication was significant. Six of 11 patients having this complication eventually died. Although in 2 of these cases heparinization-related pulmonary hemorrhage led to respiratory failure, the contribution of routine division of the diaphragm cannot be ignored. Engle et al has reported on 397 descending and thoracoabdominal aortic aneurysm repairs, and concluded that maintaining the intact diaphragm during repair resulted in a higher probability of early extubation[17]. On the other hand, routine preservation of the diaphragm, particularly when experience is limited, may interfere with adequate exposure and expediency of the repair. With experience, modification and inclusion of this technique may be preferable.

Renal failure was associated with an increase in mortality. Of 3 patients in the elective group, 2 eventually died of multisystem organ failure. In the emergency group 2 of 4 patients with renal failure eventually died of multisystem organ failure and the other two recovered and did not require chronic hemodialysis. Pre-existing renal insufficiency or intraoperative hypotension was present in all patients complicated by renal failure. The incidence of renal failure after elective repair in this series (3/36, 8.3%) is similar as that reported using regional hypothermia (3.5-11.5 %).[6] Routine control of back bleeding might have helped by preventing blood from following the path of least resistance and thus improving perfusion. Transaortic endarterectomy of occlusive lesions in the renal artery was not associated with an increase risk of renal failure and may have prevented this complication in some patients. An analysis of 271 patients by Svensson et al, found that endarterectomy or bypass of occlusive visceral vessel reduced the risk of renal failure after thoracoabdominal aneurysm repair and did not increase morbidity.[18]

The policy of permissive hypothermia has been used in the majority of these cases. Regional hypothermia with infusion catheters or systemic hypothermia has been advocated in some reports.[6, 8] Systemic hypothermia is also associated with risk of intraoperative arrhythmias and in some reports with increased mortality.[19] We made an effort to maintain temperature above thirty-three degrees. There was no experience with regional hypothermia. Anticoagulation was accomplished with heparin at a dose of .5 mg per kilogram. Major complications were seen after more aggressive anticoagulation.

Mortality and serious morbidity in this series were associated with deviations from the intended approach. This was observed particularly in the elective group. In the emergency group this was often done for expediency. Most patients presenting emergently with DT or TAA aneurysms have a contained rupture, which gives the treating surgeon time to consider use of these adjuncts. The purpose of this review was to evaluate results of a clinical approach to a surgical problem. A uniform method to repair these complex aneurysms should include spinal drainage, distal aortic perfusion, intercostal revascularization, permissive hypothermia, modest heparinization and complete repair. This approach is associated with excellent outcomes and is recommended in all elective and most emergency cases.

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Table 1

	Elective N = 36	Emergency N = 14	Total N = 50
Age (mean)	30 – 84 (69)	45 – 86 (70)	44 – 86 (69)
CAD*	22 (61%)	7 (50%) #	38 (76%)
Hypertension	26 (72%)	12 (86%)	38 (76%)
Diabetes	8 (22%)	1 (7%)	9 (18%)
COPD ^	8 (22%)	5 (36%)	13 (26%)
Smoking	28 (78%)	8 (57%)	13 (26%)
Gender Female	13 (33%)	8 (57%)	21 (42%)

Demographic information and risk factors

* CAD = Coronary Artery Disease

^ COPD = Chronic Obstructive Pulmonary Disease or Emphysema

One patient had a prior heart transplant

Table 2

Presenting Signs and Symptoms in 36 elective cases

Enlarging	19
Asymptomatic	12
Symptomatic	7
Pain	17
Renovascular Hypertension	9
Chronic Mesenteric Ischemia	3

Table 3
Aneurysm Size and Type

Aneurysm	Elective N=36	Emergency N=16	Total N=50
Size in cm (mean)	3.9 – 11 (6.9)	5 – 10 (7.4)	3.9 – 11 (7.0)
Dissection	6	1	7
Descending Thoracic	3	0	3
TAA Type I	2	2	4
Type II	12	4	16
Type III	12	6	18
Type IV	7	2	9
Prior Repair	10	4	14
AAA	6	2	8
TAA	4	2	6

Table IV
Operative Details

	Elective N=36	Emergency N= 16	Total N=50
Blood loss range in cc's (mean)	600 – 6000 (2075)	1000 – 13000 (3257)	600 – 13000 (2666)
Hypotension	6 (17%)	5 (36%)	11 (22%)
Spinal Drainage	34* (94%)	10 (71%)	44 (88%)
Distal Aortic Perfusion (DT; TAA Types I, II, III)	27/29+ (93%)	5/12 (42%)	32/41 (78%)

* Two patients with Type IV TAA did not have spinal drainage.

\+ One Type III TAA thought pre-operatively to be Type IV; one Type III TAA status post two coronary bypass surgeries.