Open versus endovascular repair of acute aortic transections —a non-randomized single-center analysis

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Abstract

Purpose To analyze early and midterm results after open and endovascular treatment of traumatic aortic transections (TAT).

Methods Between January 1990 and December 2007, a total of 28 patients were treated for TAT due to blunt deceleration trauma. Open repair (Group 1: OR) was performed in 14 patients (50%) and thoracic endovascular aortic repair (Group 2: TEVAR) in 14 (50%). A retrospective analysis of these patients was performed. For risk stratification, the Injury Severity Score (ISS), the Glascow Coma Scale, the Revised Trauma Score, and the Trauma Injury Severity Score were used. Mean follow-up was 52.0 months (range 0.1–187.2 months)

Results There was no difference regarding age and hemodynamic status in either group. Risk stratification with ISS was equal in either group (OR: median 50, range 22–66 versus TEVAR: median 45, range 29–75; p=0.354). The in-hospital mortality was 25%, with no statistical difference in either group (OR: 35.7% versus TEVAR 14.2%; p=0.117). Procedure-related complications occurred in one patient in the OR group (bleeding) and in one patient in the TEVAR group (limb ischemia). There was no procedure-associated neurological complication in either group. One patient showed a proximal type I endoleak which is under surveillance. Early conversion due to stent graft infection was necessary in one patient. The actuarial survival estimates were 82% at 1 year and 72.5% at 3 and 5 years, with no statistical difference in both groups (p=0.077).

Conclusions Endovascular treatment of acute aortic transections is associated with a reduced perioperative mortality compared to conventional surgery with no difference regarding midterm survival. Long-term data are still required to define the definite role of TEVAR in TAT.

Keywords Traumatic aortic transection · Thoracic aorta · Endovascular · Stent graft · TEVAR

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Introduction

Traumatic aortic transections (TAT) are a frequent cause of trauma-related death, especially in young, car-vehicle-accident victims, and cause approximately 8,000 deaths per year in the USA [1, 2]. Due to complete circumferential aortic transection, up to 90% of the patients do not reach the hospital alive, with another 50% of the survivors dying within 24 h [3]. Conventional open surgical repair (OR) including thoracotomy and one-lung ventilation is associated with a relevant mortality (approximately 15%) and neurological (stroke and paraplegia) complication rate (approximately 10%) in these frequently unstable patients [4].

Thus, besides conservative treatment, thoracic endovascular aortic repair (TEVAR) emerged as an alternative treatment modality in these patients [5–8]. TEVAR is minimal invasive, avoids one-lung ventilation, aortic cross-clamping, and systemic heparinization, which should potentially result in reduced mortality and morbidity [4]. Besides the aortic pathology, many patients face severe multiple-organ injuries, especially intracranial and intraabdominal, which contribute to their poor prognosis. It therefore remains debatable whether a patient's prognosis is more related to co-injuries or to the operative treatment modality of the aortic lesion.

The aim of this retrospective study was to review our experience in patients with TAT and compare operative early and midterm outcome in patients after open and endovascular aortic repair.

Materials and methods

Patient population

Between January 1990 and December 2007, a total of 28 patients were treated for acute TAT (Fig. 1) due to blunt deceleration trauma, 14 (50%) with open repair (Group1: OR) and 14 (50%) with stent graft placement (Group 2: TEVAR). This represents all patients presenting to our emergency room with TAT. One patient showed an additional aortic dissection type Stanford B. Until March 2000, patients with acute aortic tears were treated by conventional open surgery. Since March 2000, our treatment concept for TAT includes delayed TEVAR in hemodynamic stable patients and patients without aortic bleeding. These patients are monitored with a permissive hypotension (<120 mmHg) and surgical repair of trauma or visceral injuries is performed in first line. Emergency TEVAR is performed in unstable patients with a bleeding aortic lesion. The exact Heidelberg algorithm for the management of traumatic aortic tear has been published previously [1, 2]. In the present series, 12 patients underwent delayed surgery and 16 had immediate surgery, equally distributed in OR and TEVAR. Until today (8/2008), a total of 207 patients with various aortic pathologies were treated with thoracic stent graft repair in our institution.

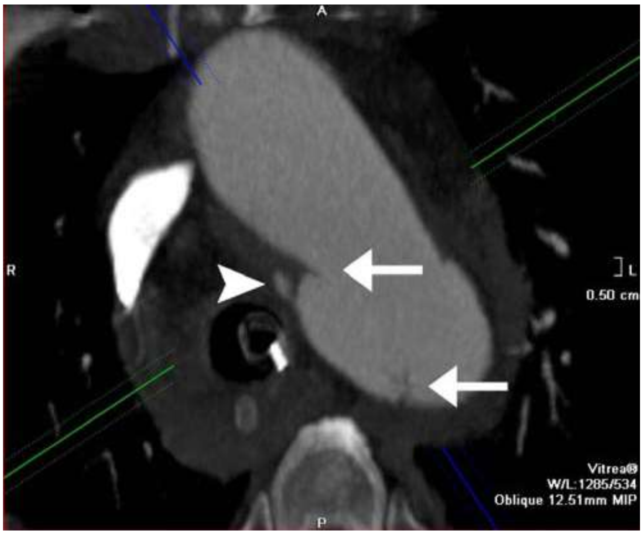

Fig. 1 Preoperative CTA of a contained aortic rupture. Double oblique paracoronary maximum-intensity projection through the aortic arch showing traumatic transection (*arrows*) and contained rupture (*arrowhead*) of the distal aortic arch

For risk stratification, the Injury Severity Score (ISS) was used [9]. Additionally, we retrospectively ranked the patients according to the Glascow Coma Scale (GSC), the Revised Trauma Score (RTS), and the blunt Trauma ISS (TRISS) [9–11]. To determine and compare the preoperative hemodynamic status of the patients, lowest preoperative hemoglobin level (mg/dl) and positive shock index (systolic blood pressure/heart rate<1) were used and patients showed no difference regarding preoperative hemodynamic status in both groups.

The preoperative baseline characteristics and risk stratification scores of our patients are given in Table 1 and showed no difference regarding ISS scores in both groups. TEVAR patients had a lower survival probability according to the TRISS score, though this did not reach statistical significance (p=0.053).

The associated injuries of all patients are listed in detail in Table 2. Patients undergoing OR had more relevant head injuries and thus a significantly lower GSC. All patients with head injuries or postoperative neurological complications were seen by a neurosurgeon and/or neurologist.

Abdominal and cardiopulmonary co-injuries as well as fractures were almost equally distributed in both groups.

The following concomitant/metachronous surgical procedures were performed: craniotomy (OR, 1; TEVAR, 1), fixateur interne for vertebral fracture (OR, 3; TEVAR, 0), splenectomy (OR, 3; TEVAR, 4), bladder repair (OR, 0; TEVAR, 2), liver resection/repair (OR, 2; TEVAR, 4), fixation of pelvic fractures (OR, 1; TEVAR, 1), upper extremity trauma surgery (OR, 1; TEVAR, 2), and lower extremity trauma surgery (OR, 6; TEVAR, 4).

Preinterventional imaging

Endograft sizing was based on centerline diameter measurements from preoperative contrast-enhanced multislice CT angiography (CTA) and three-dimensional image reconstructions. For device selection, 10% oversizing and stent grafts without proximal bare stents to avoid perforation of the aorta were applied.

Procedure

Conventional surgical treatment

After surgical access via left thoracotomy and aortic cross-clamping, a conventional Dacron (Vascutek®; Renfrew-

Table 1 Baseline characteristics and preoperative risk stratification of all patients (n=28)

Parameter and scores	Group I, open repair (n=14)	Group II, TEVAR (n=14)	P value <0.05
Age	24 (16–69)	30 (19–77)	0.945
Lowest Hb preoperative (mg/dl)	7.6 (5.1–10.7)	7.8 (4.1–12.4)	0.678
Shock index[a] <1	3 (21)	4 (28)	0.663
ISS	50 (22–66)	45 (29–75)	0.354
GCS	4 (3–14)	14 (3–15)	0.021
TRISS blunt	57 (4.5–99)	24 (1.7–91)	0.053
RTS	5 (1.7–7.8)	7.8 (3.6–7.8)	0.129

Values are presented as median (range) or n (%)

Hb hemoglobin, *ISS* Injury Severity Score, *GCS* Glascow Coma Scale, *TRISS* Trauma Injury Severity Score, *RTS* Revised Trauma Score

[a] Systolic blood pressure/heart rate)

shire, Scotland) tube interposition was performed. The median aortic clamping time was 42 min (range 23–57 min). Left heart bypass was used if necessary in an individual approach. The mean operation time was 171 min (range 90–240 min).

Endovascular treatment

All procedures were performed under general anesthesia in an operation theater equipped with fluoroscopic and angiographic capabilities (Series 9800; OEC Medical Systems, Inc., Salt Lake City, UT, USA) and a carbon fiber operating table. The procedure protocol has been published before [12]. Transfemoral surgical access could be achieved in 11 (78.5%) patients. Due to an insufficient diameter of the femoral access vessels, three patients received a Dacron prosthesis sutured to the common iliac artery as a conduit graft. Coverage of the left subclavian artery (LSA) for extension of the proximal landing zone was necessary in eight patients (58%). For exact positioning of the endograft in the aortic arch, adenosine-induced cardiac arrest was used in these eight patients.

A total of 14 endografts were implanted; all patients received a single stent graft. Median length and diameter were 100 mm (range, 100–150) and 26 mm (range, 24–37), respectively. Three types of endografts were implanted: ten

Table 2 Associated injuries of all patients (n=28) with acute aortic transection

Associated injuries	Total (n=28)	Group I, open repair (n=14)	Group II, TEVAR (n=14)
Head injuries	9	3 (21%)	6 (43%)
ICB		–	2
Subdural hematoma		2	1
Facial fracture		–	3
Hypoxic brain damage		1	–
Abdominal	17	9 (64%)	8 (57%)
Spleen		4	5
Liver		4	3
Renal		2	3
Bladder		–	2
Cardiopulmonary	27	13 (93%)	14 (100%)
Pulmonary contusion		3	6
Hemothorax		7	6
Pneumothorax		3	3
Fractures	28	14 (100%)	14 (100%)
Sternal		1	1
Rib		3	4
Upper extremity		2	3
Pelvic		5	7
Lower extremity		7	4
Vertebral		4	2

Values are presented as n (%)

ICB intracranial bleeding

TAG (W.L. Gore & Associates, Flagstaff, AZ, USA), three Talent/Valiant (Medtronic Vascular, Santa Rosa, CA, USA), and one Zenith (Cook Inc., Bloomington, IN, USA). Mean operation time was 86 min (range 60–190 min).

Follow-up

In endovascular-treated patients, follow-up included post-operative CTA before discharge, clinical examination, plain chest radiography, and CTA/magnetic resonance angiography (MRA) at 6 and 12 months postoperatively and annually thereafter. In the OR group, all patients received a yearly clinical examination and an actual CTA/MRA to complete follow-up. Mean follow-up was 52.0 months (range 0.1–187.2 months).

Definitions and statistical analysis

Technical and clinical success in TEVAR procedures were defined according to the reporting standards of endovascular procedures by Chaikof et al. [13]. Early endoleaks were defined as present on the first postoperative CTA control and late endoleaks as appearance during follow-up.

A retrospective analysis of the prospectively collected data was performed. Data are expressed as mean±standard deviation or median (range). Actuarial survival estimate was calculated using the Kaplan–Meier analysis. Log rank test was used for survival comparison. For subgroup analysis, Fisher's exact test and Mann–Whitney *U*-test was used for categorical and continuous variables, respectively. All statistical analyses were performed using XLSTAT (Version 7.5; Addinsoft SARL, NY). A p value$<$0.05 was defined as statistically significant.

Results

Early outcomes

The operative results are presented in Table 3. Technical success rate was 100% in group I and 93% in group II. The overall in-hospital mortality was 25% (7/28), with no statistical difference in both groups (OR: n=5/14, 35.7% versus TEVAR: n=2/14, 14.3%; p=0.117). Causes of death in group I were multiorgan failure in three patients (day 1, 6, and 15 postoperatively), cardiopulmonary failure in one patient on the first postoperative day, and catheter-induced sepsis with consecutive cardiopulmonary failure in another patient on day 76 postoperatively.

In group II, one patient died intraoperatively due to an uncontrollable bleeding from a lung contusion. The second patient died as a result of an intracranial rebleeding 1 week postoperatively. In-hospital mortality was 37.5% in patients undergoing immediate repair and 8.3% for the delayed surgery group (p=0.091). The mean postoperative duration of mechanical ventilation was 12.7 days (range 0–74) in the OR group and 4.1 days (range 0–17) for TEVAR. There was no difference regarding intensive care and hospital stay in both groups.

Procedure-associated complications

In the OR group, one patient suffered from a postoperative bleeding of an intercostal artery after left thoracotomy which needed further operative revision. One patient in group II showed a limb ischemia due to an occlusion of the iliac conduit which was used as an interposition of the left common iliac artery. Reoperation with thrombectomy and distal extension of the Dacron graft was performed. Another patient presented with an asymptomatic proximal stent graft compression syndrome in routine CTA follow-up 8 months postoperatively and was treated by a stent (Palmaz XXL stent)-protected angioplasty. The complete case report has already been published [14].

Neurological complications

There was no procedure-related stroke in both groups. One TEVAR patient suffered from a transient ischemic attack with temporary aphasia and hemiparesis of the right arm on the first postoperative day. An immediately performed control CTA revealed the stent graft in the exact position with antegrade perfusion of all supraaortic branches and no ischemic brain lesion. Additionally, six patients showed neurological complications/symptoms due to preoperatively existing associated head injuries (two intracranial bleeding,

Table 3 Operative results of all patients (n=28) with acute aortic transection

	Group I, open repair (n=14)	Group II, TEVAR (n=14)	P value <0.05
In-hospital mortality	5 (35.7)	2 (14.2)	0.117
Stroke	–	–	–
Paraplegia	–	–	–
Endoleak	–	1 (type I)	–
ICU stay (day)	15 (1–76)	6 (1–30)	0.248
Hospital stay (day)	18 (8–76)	16 (7–31)	0.695

Values are presented as median (range) or n (%)

ICU intensive care unit

three subdural hematoma, and one hypoxic brain damage). No procedure-associated paraplegia was observed; one paraplegia in the OR group occurred as a result of a vertebral fracture at level Th5.

Early endoleaks

Postoperative CTA showed a minimal proximal type I endoleak with an additional endoleak type II via a retrograde perfused left subclavian artery in one patient (Fig. 2). Coverage of the left subclavian artery has already been initially performed in this highly comorbid 77-year-old patient. Additionally, the patient showed a bovine arch. Therefore, complete aortic debranching with proximal stent graft extension was denied and the patient is under close CTA surveillance.

Early conversion (1.5 months after initial surgery) was necessary in one patient who developed a hematogenic stent graft infection in sequel of a bacteremia caused by multiple-trauma surgery. The stent graft was explanted and a conventional silver Dacron prosthesis implanted. The patient is currently (4 years postoperatively) alive, showing no sign of graft infection.

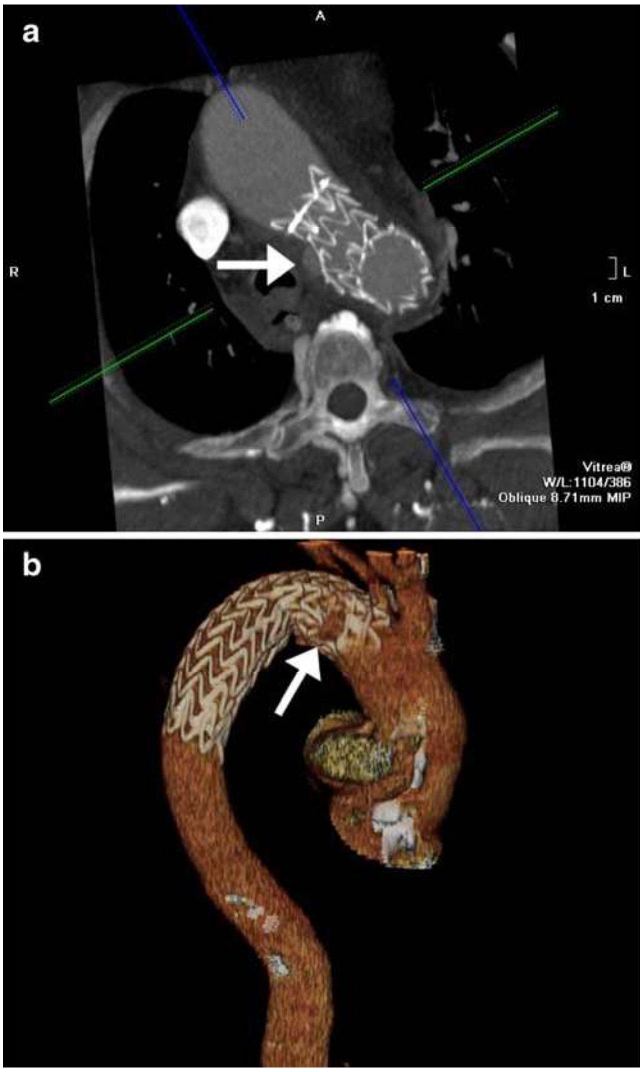

Fig. 2 Early postoperative CTA after endograft implantation. **a** Double oblique paracoronary maximum-intensity projection through the aortic arch indicating a small endoleak type I and II (*arrow*). **b** Volume rendering demonstrating correct deployment of the endograft distal to the patent left carotid and showing a retrograde perfusion of the left subclavian artery as well as a small endoleak (*arrow*)

Late outcomes

The actuarial survival estimates were 82% at 1 year and 72.5% at 3 and 5 years, with no statistical difference in both groups (p=0.077) (Fig. 3). One patient (TEVAR) died 8.5 months postoperatively from a major stroke. No late death in OR group during follow-up was observed. There was no aortic-related death during follow-up in both groups. No late endoleak but one asymptomatic stent graft collapsed was observed. Early or late reintervention was necessary in four patients (14.2%); these patients have already been discussed above.

Discussion

The present series underlines the technical feasibility of TEVAR in patients with acute aortic transections. Furthermore, it shows a reduced (although not statistically significant) in-hospital mortality of patients undergoing TEVAR versus OR. This is especially remarkable as TEVAR patients had a lower TRISS score predicting a rather worse outcome. This initial survival benefit is sustained during midterm follow-up although it did not reach statistical significance (log rank test, p=0.077) due to the relatively small number of patients in both groups.

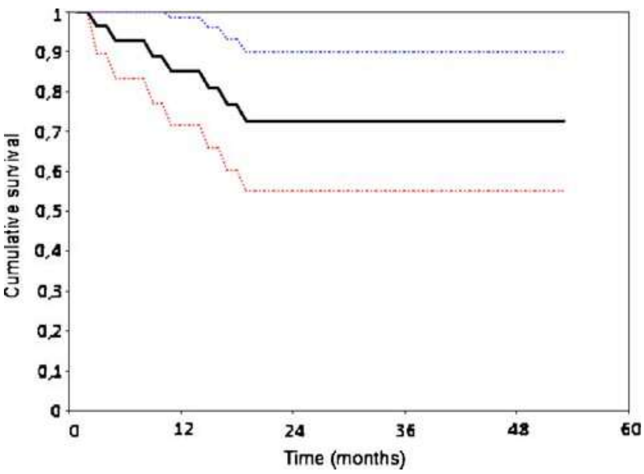

Fig. 3 Kaplan–Meier survival analysis of all patients (n=28) with acute aortic transections treated between 1/90 and 12/07

Mortality rates after TEVAR for TAT vary between 0% and 14.2% and are thus in line with our reported results [7, 15–17]. Although retrospective series have shown a reduced mortality of TEVAR versus OR, most single-center studies, such as ours, failed to show a statistical significance due to the relatively small patient cohorts [6, 18–20]. Only recently, two meta-analyses could prove a statistically significant reduced perioperative mortality in endovascular-treated patients compared to open repair [4, 17]. Takagi et al. showed in their meta-analysis including 17 studies on 565 patients a 57% reduced mortality with TEVAR versus OR (8.1% versus 20.8%, OR 0.43, 95% CI 0.25–0.75, $p<0.01$) [17]. This survival benefit remained when only data of 11 studies with comparable preoperative variables (ISS score) in both groups were pooled. The second meta-analysis (TEVAR 370 patients versus OR 329 patients) by Tang et al. also revealed a significantly lower mortality rate in TEVAR patients (7.6% versus 15.2%, $p=0.0076$). Additionally, endovascular-treated patients showed a significantly reduced risk of paraplegia (0% versus 5.6%, $p<0.0001$) and a reduced perioperative stroke rate (0.85% versus 5.3%, $p=0.0028$) [4]. In our series, no procedure-related stroke/paraplegia was observed although one TEVAR patient showed transient hemiparesis. Neurological complications (stroke/paraplegia) can be expected in approximately 5–10% of all patients undergoing OR and we presumably did not encounter any neurological complication in this group due to the relatively small patient cohort [4]. Tang et al. report cranial nerve injuries in 41/329 (12.5%) patients undergoing OR, a neurological complication avoided by TEVAR as a result of the different (transfemoral) surgical approach [4].

Trauma victims with TAT are frequently young patients (median age 30 years in our series) and show relatively small maximum aortic diameters in the proximal landing zone. Therefore, small stent graft sizes (median 26 mm in this series) have to be implanted and thus need to be kept on stock for these emergency situations [4]. Furthermore, small diameters of access vessels and steep angulation of the aortic arch ("gothic arch"), especially in young patients, make TEVAR in patients with acute aortic transections frequently a technically challenging procedure. Technical success rates thus vary from 80% to 100% and are in line with our results [7, 20, 21].

Another problem of these special anatomic considerations (small aortic diameter, tight arch curvature) in younger-aged trauma patients is stent graft collapse, especially in traumatic transections [8, 22]. Hinchliffe et al. report in their retrospective multicenter study that four out of seven patients with stent graft collapse were treated for acute aortic transections [22]. Stent collapse was asymptomatic in 60% of the patients which underscores, besides the young age, the importance of correct sizing, rigorous intraoperative imaging, and lifelong surveillance. Furthermore, Orend et al. report in their series of 34 patients stent graft compression in 6% (2/34) [8]. To avoid stent collapse and proximal type I endoleaks, sufficient (>2 cm) proximal landing zone and sufficient radial force of the stent graft are recommended. As the predominant location (approximately 90%) of acute aortic transections is the aortic isthmus in the inner curve, just distal to the origin of the LSA, covering of the LSA is frequently unavoidable [1]. Whether primary revascularization or secondary transposition after the development of symptoms in order to avoid type II endoleaks and to reduce the risk of paraplegia is advocated remains debatable [23–26].

Our policy is to deliberately cover the subclavian artery (58% in this series) to achieve a sufficient sealing zone and perform staged revascularization if necessary (none in this series).

Limitations

The limitations of this study certainly include the relatively small number of patients and its retrospective and non-randomized design. However, few patients with an acute aortic injury reach the hospital alive and a multicenter randomized control trial seems ethically questionable. The large time frame (17 years) of this study with significant improvements in surgical and anesthesiological trauma management also warrants attention while interpreting our results as patients with OR were treated in the earlier period.

Conclusions

Endovascular treatment of acute aortic transections is technically feasible and is associated with a reduced perioperative mortality compared to conventional surgery in frequently polytraumatized patients. Midterm results could prove a sustained treatment success regarding survival and reintervention in open repair and endovascular stent graft placement. Nevertheless, long-term data are still required to define the definite roll of TEVAR in this young-patient cohort.

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