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Open Repair Versus Thoracic Endovascular Aortic Repair in Multiple-Injured Patients: Observations From a Level-1 Trauma Center

Stephan Brand,[1,*] Ingo Breitenbach,[2] Philipp Bolzen,[3] Maximilian Petri,[1] Christian Krettek,[1] and Omke Teebken[4]

[1]Trauma Department, Hannover Medical School (MHH), Hannover, Germany
[2]Department of Cardiothoracic and Vascular Surgery, Public Hospital Braunschweig, Braunschweig, Germany
[3]Department of Diagnostic Radiology, Hannover Medical School, Hannover, Germany
[4]Division of Vascular Surgery, Department of Cardiothoracic, Transplantation and Vascular Surgery, Hannover Medical School, Hannover, Germany

*Corresponding author: Stephan Brand, Trauma Department, Hannover Medical School (MHH), Hannover, Germany. Tel: +49-5115322026, Fax: +49-5115325877, E-mail: brand.stephan@mh-hannover.de

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Abstract

Background: Blunt trauma of the thoracic aorta is a rare but potentially life-threatening entity. Intimal tears are a domain of non-operative management, whereas all other types of lesions should be repaired urgently. There is now a clear trend favoring minimally invasive stent grafting over open surgical repair.
Objectives: The aim of the present study was to retrospectively evaluate the mortality and morbidity with either treatment option. Therefore, a retrospective observational study was performed to compare two different treatment methods at two different time periods at one trauma center.
Patients and Methods: Between 1977 and 2012, all severely injured patients referred to our level 1 trauma center were screened for blunt aortic injuries. We compared baseline characteristics, 30-day and overall mortality, morbidity, duration of intensive care treatment, procedure time, and transfusion of packed red blood between patients who underwent open surgical or stent repair.
Results: During the observation period, 45 blunt aortic injuries were recorded. The average Injury Severity Score (ISS) was 41.8 (range 29 - 68). Twenty-five patients underwent Open Repair (OR), and another 20 patients were scheduled to emergency stent grafting. The 30-day mortality in the surgical and stent groups were 5/25 (20%) and 2/20 (10%), respectively. The average time for open surgery was 151 minutes; the mean time for stent grafting was 67 minutes (P = 0.001). Postoperative stay on the intensive care unit was between one and 59 days (median 10) in group one and between four and 50 days in group two (median 26)(P = 0.03). Patients undergoing OR required transfusion of 6.0 units of packed red cells in median; patients undergoing stent grafting required a median of 2.0 units of packed red cells (P < 0.001). In the stent grafting group, 30-day mortality was 10% (2/20).
Conclusions: Due to more sophisticated diagnostic tools and surgical approaches, mortality and morbidity of blunt aortic injuries were significantly reduced over the years compared to thoracic endovascular aortic repair and OR over two different time periods.

Keywords: Aortic Rupture, Traffic Accident, Injury Severity Score, In-Hospital Mortality, Multiple Injuries

1. Background

Ruptures and dissections of the thoracic and abdominal aorta caused by traffic crashes are rare but potentially life-threatening (1-3). Blunt injuries result from seat belt or dashboard injury, whereas penetrating injuries are more often associated with gunshot or stab wounds (4-6). Over the years, the treatment algorithm regarding traumatic aortic injuries has changed.

Therapy of blunt traumatic aortic injury mainly depends on the severity of the injury and the anatomical position (7-9). A classification scheme for grading the severity of aortic injury has been proposed (10) that are as follows: type I: Intimal tear; type II: Intramural hematoma; type III: Pseudoaneurysm; and type IV: Rupture.

In the guidelines of the Society for Vascular Surgery, the committee suggested expectant management with serial imaging and medical therapy (beta-blockers) for type I injuries (2C recommendation) (10). This consensus is based on the early experiences that most type I injuries healed spontaneously (11). Type II-IV injuries should be repaired urgently (< 24h). Delayed repair (at latest prior to hospital discharge) may be appropriate for patients who are hemodynamically stable, particularly if the patient has severe coexisting injuries. Blood pressure and heart rate should be controlled aggressively preoperatively (10).

The surgical strategy in type II-IV injuries depends on the anatomical position of the injury. A large majority (95%) of cases occur at the proximal descending aorta, just distal to the left subclavian artery origin (the isthmus), at the site of the Lig. arteriosum. The remaining 5% of cases involve the ascending aorta and the supradiaphragmatic aorta (12).

The traditional definitive treatment for most patients with traumatic rupture of the descending aorta is the emergency surgical intervention with graft interposition (13). Surgery of the isthmus portion of the aorta is performed through a high left posterolateral thoracotomy under right single-lung ventilation, if necessary supported by extracorporeal circulation. Open Repair (OR) of traumatic aortic injuries has been associated with a mortality rate up to 28% and a 16% rate of paraplegia (14). These mortality and morbidity rates have spurred interest in endovascular techniques (15-21). Comparing these techniques with OR, mortality rates were significantly lower in patients who underwent endovascular therapy 9% vs. 19% (10). The risk of spinal cord ischemia, end stage renal disease and risk of graft infections were higher in OR compared with endovascular therapy while stroke rate showed no difference between the therapy options (11). Endovascular techniques require general anesthesia in most of the cases and due to lack of seal/landing zone, covering of the left subclavian artery with successive transposition of the artery is frequent (11). For the treatment of aortic injuries the stent grafts are regularly implanted via the femoral artery. Using intraoperative fluoroscopy, the optimal positioning of the stent can be verified.

Cases of uncommon anatomical aortic injuries (e.g. ascending aorta with innominate avulsion) require individual strategies and treatment options.

Differently to this, the management of intra-abdominal aortic injuries offers a widespread of possible treatments, starting with conservative treatment, the use of minimal invasive applied stents and surgery with suturing or replacement (22, 23).

Actual literature research shows limited numbers of survived blunt trauma to the thoracic aortic vessel, most of the patients died at accident scene and aortic ruptures were detected with autopsy later (6, 17, 24). The purpose of our retrospective study was to evaluate traumatic aortic injuries caused by blunt trauma. Evaluation goals were survival, 30-day mortality, length of postoperative intensive care unit (ICU) stay, packed red cell units, treatment (OR vs. stent graft), paraplegia and stroke. Due to the installation of a multi slice computed tomography (CT) scan (64 slices) in 2005, treatment algorithm turned to the use of minimally invasive applicable stent graft.

2. Objectives

This study was performed to evaluate the differences in mortality and morbidity in the treatment of traumatic aortic injuries over the years at one trauma center.

3. Patients and Methods

Medical data were obtained from our level-1 trauma center that provide a large history in the treatment of multiple injured patients with an ISS > 16 and in emergency and elective surgery of aortic injuries and diseases (25-29). A retrospective observational study was performed to compare two different treatment methods at two different time periods at one trauma center. Furthermore, biomechanics and outcome measures of traumatic aortic injuries have been a part of investigation in our institution since 1980 (30).

From 1977 to 2012, all severely injured patients transferred to our level-1 trauma center with air rescue unit were screened for blunt traumatic aortic injuries. Severely injured was determined with an ISS of 16 or higher (31). Two groups were formed depending on performed treatment of traumatic aortic injury. Group one was treated with OR between 1977 and 2005; group two was treated with stent graft from 2005 to 2012. Overall-mortality, 30-day mortality, ISS scores and demographic data of both groups were compared (Table 1).

All patients were seen immediately by trauma surgeons in the emergency unit and treatment algorithm was depending on overall medical situation of the patient and extends of accessory injuries (32).

Ultrasound of the abdominal cavity as well as of the pericardium was performed within minutes after arrival at the hospital. X-rays were taken from chest, pelvic ring and cervical spine as part of the ATLS®-based trauma algorithm (33) (ATLS: Advanced Trauma Life Support). Blood samples were taken and the patient was stabilized with arterial and venous catheters where possible.

Patients were then transferred to the CT-scan for whole body trauma scan; patients before 1987 were diagnosed using digital subtraction angiography (DSA).

Diagnosis of blunt aortic injury was done via multiple-slice CT scan (since 2005 64 slices CT, Figure 1).

Besides this, the patient monitoring includes demographic data, collision circumstances, injury pattern, abbreviated injury scale (AIS), maximum AIS, ISS, incidence of serious or severe multiple injuries. Data were obtained retrospectively from 1977 to 2004 and prospectively from 2005 on.

Statistical analysis was performed using GraphPad Prism 5.0 for mac. Where applicable a Wilcoxon-Mann-Whitney test as a nonparametric significance test was performed comparing whether one of two samples of independent observations tends to have larger values than the other. Furthermore, a student's t-test was used. A P value < 0.05 was considered statistically significant.

4. Results

From 1977 to 2012, a total of 45 blunt aortic injuries caused by high velocity traffic accidents transferred to our hospital were observed. All patients suffered blunt trauma to chest and abdominal wall, and all were involved in high-energy traffic accidents.

Those who survived the immediate impact and resuscitation sustained multiple injuries with an average ISS of 41.8 (range 29 - 68). Some 25 patients underwent OR of thoracic aortic injuries (3 women; 22 men; mean age 27, range 18 - 69).

These patients were involved in traffic accidents as car drivers and motorcycle riders. The mean ISS in this group was 41.25 (range 29 - 68) (Table 1).

The second group consisted of 20 patients undergoing emergency stent grafting of intrathoracic aortic injuries (18 men; 2 woman; mean age 41.3, range 17 - 78); the mean ISS was 42.5 (range 29 - 48). Patients were involved in traffic accidents as car drivers, motorcycle riders and pedestrians.

Surgery was performed within the first 24 hours in the TEVAR group and within 72 hours in the OR group (Figure 1).

In group one, OR via left lateral thoracotomy was performed using gelatin coated woven Dacron tube grafts with or without extracorporeal circulation (left heart bypass or femora-femoral cannulation). The TEVAR thoracic stent grafts were implanted via femoral artery (Medtronic Vascular, Santa Rosa, CA, USA or W.L. Gore and Associates, Flagstaff, AZ, USA, Figure 2).

The preferred surgical strategy was the OR procedure between 1977 and 2005; from then on, the surgical approach switched to the stent grafting as the preferred procedure for blunt aortic lesions.

Overall-mortality in both groups was 8/45 (18%) and 30-day mortality was 7/45 (16%). Mortality of those undergoing OR of aortic injury was 6/25 (24%), 30-day mortality 20% (5/25). The mean follow-up in the OR group was 101 months after surgery (1 - 382).

The average time for open surgery was 151 minutes; the mean time for stent grafting was 67 minutes (P = 0.001). Postoperative stay on the ICU was between one and 59 days (median 10 days) in group one and between four and 50 days (median 26 days) in group two (P = 0.03). Patients undergoing OR required transfusion of 6.0 units of packed red cells in median; patients undergoing TEVAR required a median of 2.0 units of packed red cells (P < 0.001).

With those undergoing immediate minimal invasive stent grafting, 30-day mortality was 10% (2/20). The 30-day mortality decreased significantly (P = 0.013, the Mann-Whitney-test). The overall mortality in the TEVAR group was 10% (2/20) (Table 1).

Neurological deficits were observed with three patients in the OR group with persistent paraplegia and unilateral vocal cord paralysis in two cases. In the stent group, persistent paraplegia was observed. All but one stent were implanted via femoral artery, in one case a retrograde stent grafting of the thoracic aorta was performed with open heart massage. This patient died at day six due to multi-organ failure. The left subclavian artery was cross-stented in eight patients, none of these presented with additional neurological deficits.

In the OR group, 22 patients were treated within six hours of hospital admission (88%); all patients of this group received surgical treatment within the first 72 hours. In the stent group 18 patients were treated within six hours of admission (90%), and all patients were treated within the first 24 hours. The ISS scores were not significantly higher in the stent group compared to the OR group (ISS stent 42.5 vs. ISS open repair 41.25).

Table 1. Characteristics and Results of Open Repair and Thoracic Endovascular Aortic Repair Groups[a]

	Gender Distribution	Age, Mean Years	ISS	Surgery Time, min	ICU, Median Days	Red Blood Cells, Units	30-day Mortality, %	Overall Mortality, %
OR	25 (3 f ; 22 m)	27	41.25	151	10	6.0	20	24
TEVAR	20 (2 f ; 18 m)	41.3	42.5	67	26	2.0	10	10

[a]Abbreviations: f, female; ICU, intensive care unit; ISS, injury severity score; m, male; OR, open repair; TEVAR, thoracic endovascular aortic repair.

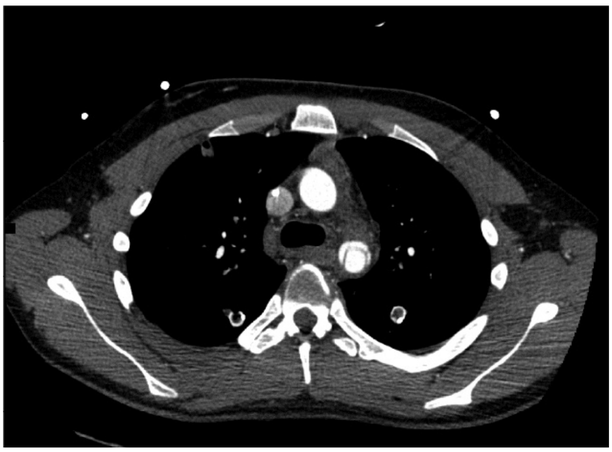

Figure 1. Traumatic Dissection of the Thoracic Aorta Distally to the Left Subclavian Artery

Figure 2. Successfully Performed Minimally Invasive Stent Grafting of the Lesion Above Thoracic Endovascular Aortic Repair

5. Discussion

This study was performed to evaluate the differences in mortality and morbidity in the treatment of traumatic aortic injuries over the years. Therefore, two different treatment methods were compared retrospectively at two different time periods. Special interest was focused on differences between surgical treatment with OR and minimal invasive applicable stents. Data were obtained from a level-1 trauma center between 1977 and 2012.

There was an increase in patients diagnosed with traumatic aortic injury per year observed since 1995. This could be due to an increase in the quality of prehospital trauma car as well as improvements in diagnostic tools.

The most important finding of our study was a decrease of in-hospital mortality following the introduction of endovascular aortic repair. From 1977 to 2005, the treatment algorithm consisted of OR when a traumatic thoracic aortic injury was diagnosed. With the improvement of diagnostic tools (since 2005 64 slices CT scan) and improvements in the use of minimally invasive stent graft, the in-hospital mortality was significantly decreased ($P = 0.013$ Mann-Whitney-test). Furthermore, significantly less packed red cell units were transfused and time required for surgery was significantly reduced with stent grafting.

Surprisingly, in contrast to our expectations, a significant increase in postoperative ICU stay in the stent group was observed. This could be due to changes in treatment algorithms from early total care orthopedics to damage control surgery (32, 34-36) as well as changes in treatment algorithms of severely injured patients (e.g. continuous lateral rotational kinetic therapy in patients with major thoracic trauma and lung contusion).

Furthermore, especially regarding multiple injured patients not only the improvements in diagnostic and treatment of aortic injuries but also improvements in general management of orthopedic injuries and intensive care management seem to be responsible for the decrease of mortality and morbidity.

Previous investigations showed similar results with a significant lower mortality rate with patients undergoing endovascular repair (6, 10, 15, 16, 37). Complications described were type-1 endoleaks (16) and partially recovered paraplegia (6).

However, Azizzadeh et al. did not find any significant differences in their initial experience of blunt traumatic aortic injuries (11).

Compared to recently published studies our results of overall-mortality of endovascular repair of traumatic aortic lesions seem to be reasonable (38, 39).

Today, initial diagnostic of thoracic trauma should be fast, accurate with a high reliability and minimal- or non-invasive. It should fit in a standardized diagnostic chain without interrupting necessary constant life-saving treatment.

The frequent use of stents may lead to a decrease in time of operations, decrease in blood loss and substitution of packed red cells as well as a reduction of manpower (40).

With the infrastructure around, the use of stents in the treatment of aortic injuries distal to the left subclavian artery seems to be superior to the traditional approach with OR surgery.

The design of the study, partly retrospective, partly prospective, could be a limitation but observations from a single center could be seen as a strength. Thus, a prospective, multicenter study would be desirable in the future or even setting up a registry.

With the change and improvement in diagnostic tools and surgical approaches, mortality and morbidity of blunt aortic injuries were significantly reduced over the years in our retrospective analysis comparing two different methods at two different time periods. However, in an immediate life-threatening injury, early diagnosis through multiple-slice CT scans and surgical repair with minimally invasive stents showed excellent short-time results for selected patients.

Due to the fact that the proposed classification was released in 2009 by Prof. A. Azizzadeh and adopted by the society for vascular surgery (2011), we are not able to present subclassifications of our patients' observations including patients from 1977 - 2012.

Footnote

Authors' Contribution: Study concept and design: Stephan Brand, Christian Krettek, and Omke Teebken; Acquisition of data: Stephan Brand, Ingo Breitenbach, Philipp Bolzen, and Maximilian Petri; Analysis and interpretation of data: Stephan Brand, Ingo Breitenbach, Philipp Bolzen, Maximilian Petri, Christian Krettek, and Omke Teebken; Drafting of the manuscript: Stephan Brand, Ingo Breitenbach, Philipp Bolzen, and Maximilian Petri; Critical revision of the manuscript for important intellectual content: Stephan Brand, Ingo Breitenbach, Philipp Bolzen, Maximilian Petri, Christian Krettek, and Omke Teebken; Statistical analysis: Stephan Brand, Ingo Breitenbach, and Philipp Bolzen; Administrative, technical, and material support: Maximilian Petri, Christian Krettek, and Omke Teebken; Study supervision: Christian Krettek, and Omke Teebken.

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