Endovascular Treatment of a Life-threatening Blunt Thoracic Aortic Injury in Polytraumatized Patients – A Single Center Experience

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Abstract: A retrospective analysis of our group of patients, efficacy, safety and the results of endovascular treatment of descending thoracic aorta by using stentgraft implantation in polytraumatized patients. In the period between 6/2006 and 2/2020, in the processing of data, we analysed retrospectively patients with polytrauma diagnosed with thoracic aortic rupture or transection (TAT) and treated with multiple injuries. Clinical characteristics, complications, pathological features, and hospital follow-up data were retrieved from our group. In our group of 28 polytraumatized patients referred to our Trauma Centre with current TAT, all 28 patients with such a thoracic aortic injury were treated by using thoracic stentgraft implantation. In our group of patients, the average Injury Severity Score (ISS) was 22 for women (min 19, max 27) and 26 for men (min 17, max 41), respectively. We reached 100% technical implantation success rate with our patients. In our group, we had 30-day mortality of 10.7% (3 patients) and the in-hospital mortality was 17.8% (5 patients). Surviving patients had calculated ISS score of 25 (min 17, max 41); dead patients had an ISS score of 28 (min 19, max 34) – $p \leq 0.05$. Endovascular treatment of TAT, as a minimally invasive and effective procedure with rapid bleeding control, may increase survival chances for severely compromised polytraumatized patients in the context of multiple-organ damage and the need for a major cardio-vascular surgery.

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Introduction

The term polytrauma is defined in literature in different ways and according to different aspects. Polytrauma typically refers to severely injured patients with two or more significant traumatic injuries (Border et al., 1975). Various scoring systems are used worldwide for the clear objectification of injury severity, most commonly the Injury Severity Score (ISS) and the Abbreviated Injury Scale (AIS). An Injury Severity Score (ISS) ≥ 16 and an Abbreviated Injury Scale (AIS) ≥ 3 in at least two different body regions are in general the globally accepted values for the definition of "polytrauma" (Boyd et al., 1987; Butcher et al., 2014). The values are based on a description for the prediction of mortality of injured patients above 10% (Boyd et al., 1987). Polytrauma is the most common cause of death of patients younger than 40. The incidence of deaths associated with traumas in developed countries is 60–80/100,000 inhabitants. The main cause is traffic accidents. The most common cause of death in traffic accidents is brain injury and another fatal cause of death is a deceleration blunt aortic injury. Thoracic aortic rupture or transection (TAT) carries an overall mortality of 90% (Parmley et al., 1958). Approximately 15% of traffic accidents are associated with a thoracic aortic injury (Smith and Chang, 1986) and the injury ranks second as a cause of death in fatal traffic accidents. 85% of patients with a thoracic aortic injury die before being transported to the hospital and 15% have variable survival rates, of which about 2% of patients suffer from a chronic pseudoaneurysm (Smith and Chang, 1986; Reardon et al., 1997). More theories

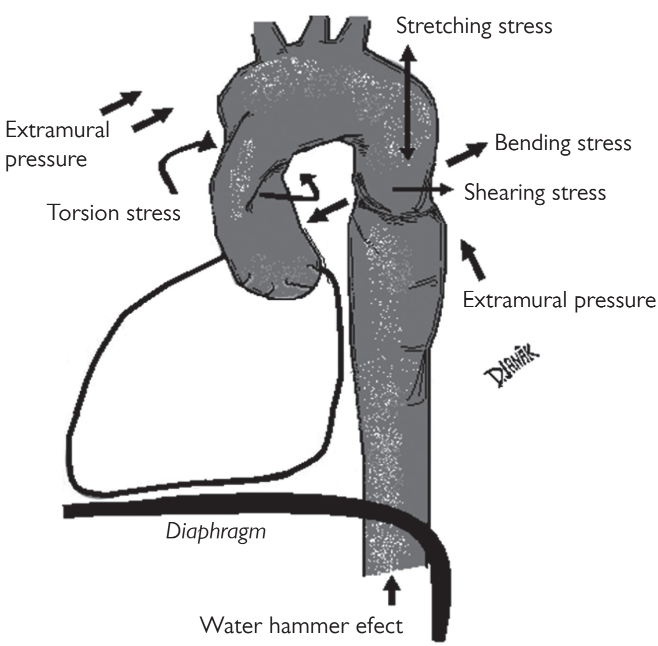

Figure 1 – Mechanism of TAT (thoracic aortic rupture or transection).

propose that TAT results from a combination of mechanisms including shear, torsion, bending and stretching stress (Figure 1). The compression force on the sternum and abdomen cause the mediastinum to displace upwards, often termed a "shovelling effect". As the chest is compressed, the heart is squeezed between the sternum and the spine forcing blood from the heart into the aorta and creating a dramatic rise in the blood pressure of the aorta and pulmonary trunk. In addition, it is anticipated that at the level where the aorta passes through the diaphragm, it can kink and occlude the blood flow through the aorta and contribute to the rise in aortic blood pressure. This sudden occlusion of the blood flow can lead to high-pressure waves in the aorta due to a "water-hammer" effect. The "shovelling effect" displaces the heart and aortic arch upwards, while the descending aorta, which is tethered to the spine via the lungs remains fixed (Richens et al., 2002).

Methods

In the period between 6/2006 and 2/2020, in the processing of data, we analysed retrospectively patients with polytrauma diagnosed with thoracic aortic rupture or transection (TAT) and treated with multiple injuries. These polytraumatized patients were transported to our Trauma Centre, which, together with two other trauma centres, provides the catchment area of the whole Prague and its vicinity comprising 2600,000 inhabitants. During this period, we dealt with 28 polytraumatized patients diagnosed with TAT who were referred to us primarily or who were referred from lower trauma centres. All patients were admitted through the emergency department; diagnosis and life-saving procedures (life-threatening to small lesions) were performed in cooperation with traumatologists and general surgeons, when using Advanced Trauma Life Support (ATLS) protocol, and all patients were treated with a full-body CT (computed tomography) scan with contrast media based on a trauma protocol. A CTA (computed tomography angiography) examination in these patients confirmed multiple injuries and TAT, and the simultaneous computer reconstruction of images helped to plan endovascular and surgical procedures, if any. All 28 patients in our group were treated by using thoracic endovascular stentgraft implantation. The procedures were performed by interventional radiologists in the radiological room with cardiovascular surgeons and anesthesiologists. In our Trauma Centre, the team of vascular surgeons and interventional radiologists has a 24-hour duty. Stentgrafting was performed through the femoral arteries. The device was inserted by either a puncture or surgical technique (we used during surgical technic low dose mini-heparinization). The procedure was conducted under DSA (digital subtraction angiography) control and the stentgrafts had 10% oversizing. The implantation was performed without the administration of heparin and with antibiotic prophylaxis. In our group of patients there was no anatomical contraindication from the point of view of insufficient proximal landing zone for stentgraft implantation. A follow-up CTA examination of the thoracic aorta is conducted immediately after thoracic aortic stentgraft implantation during hospitalization, then after 1 year and after 2–3 years. In addition to CTA examinations, we also perform contrast-enhanced ultrasound (CEUS) examinations 3 months after stentgraft implantation. In our group of patients with implanted stentgraft who were treated in a broad time period (between 6/2006 and 2/2020) we have patients with a wide variety of examinations, with 1-year, 2-year, 3-year intervals but also patients with more than 10-year intervals after implantation; the longest period is 13 years. Some patients are foreign nationals and are no longer kept in our records. All our patients registered during long-term follow-up examinations did not show any complication due to the implanted thoracic stentgraft. As of January 2020, we do not have any living patients with the evidence of stentgraft migration, endoleak or significant aortic dilatation in the thoracic region of the aorta (one patient with endoleak Ia after re-intervention, recently without endoleak).

Table 1 – Basic patient information, mechanism of injury and type of injury

All patients	**n=28**
Stentgrafts	29
Sex – female	8 (28.5%)
Sex – male	20 (71.5%)
Sex – female – age	50.8 years (min 25, max 84)
Sex – male – age	32.8 years (min 19, max 73)
Injury Severity Score (ISS) – female	22 (min 19, max 27)
Injury Severity Score (ISS) – male	26 (min 17, max 41)
Mechanism of injury	numbers of patients (%)
Car accident	14 (50.0%)
Motorcycle accident	3 (10.7%)
Pedestrian	1 (3.5%)
Ski accident	1 (3.5%)
Train accident	1 (3.5%)
Fall from 5 m	1 (3.5%)
Fall from 10 m	6 (21.4%)
Fall from 20 m	1 (3.5%)
Associated injuries	numbers of patients (%)
Head	12 (42.8%)
Neck	3 (10.7%)
Chest	18 (62.4%)
Abdominal	8 (28.5%)
Retroperitoneal space	4 (14.2%)
Abdominal + retroperitoneal space	2 (7.1%)
Pelvis	10 (35.7%)
Limbs	18 (62.4%)
Pneumothorax	10 (35.7%)
Cervical spine fractures	3 (10.7%)
Thoracic spine fractures	3 (10.7%)
Lumbal spine fractures	6 (21.4%)

Result

Of the 28 patients (71.5% males with mean age 32.8 years [min 19, max 73 years] and 28.5% women with mean age 50.8 years [min 25, max 84 years]), the cause of TAT polytrauma in 14 patients was due to a traffic accident (vehicle occupants), in 3 patients it was due to a motorcycle accident, 1 – pedestrian, 1 – ski accident, 1 – fall from the height of 5 m, 6 – fall from the height of 10 m, and 1 – fall from the height of 20 m (Table 1). In our group of patients, the average ISS score was 22 for women (min 19, max 27) and 26 for men (min 17, max 41), respectively. In our group of 28 polytraumatized patients referred to our Trauma Centre with current TAT (Figure 2), all 28 patients with such a thoracic aortic injury were treated

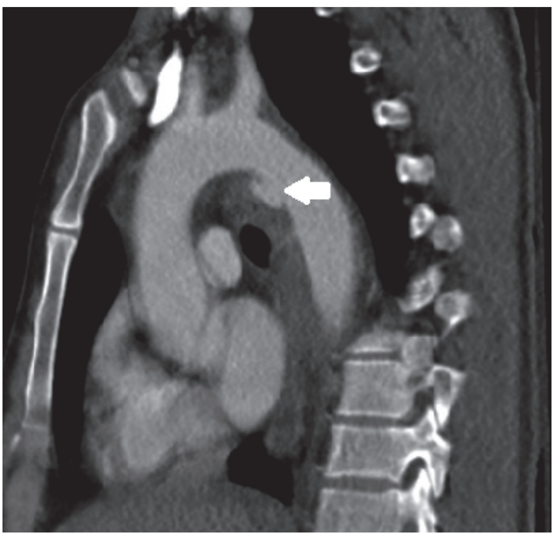

Figure 2 – Thoracic aortic rupture or transection (arrow) after car accident.

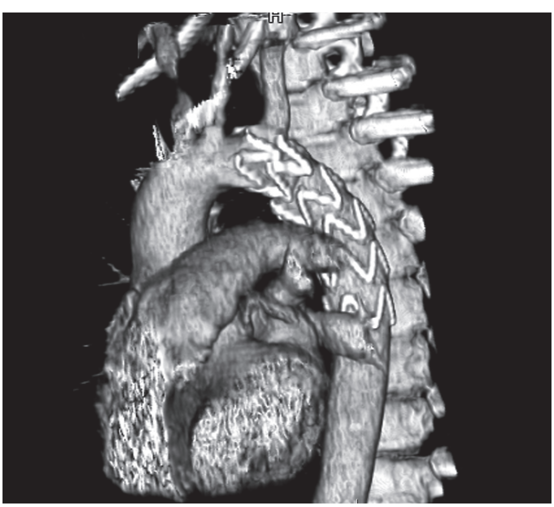

Figure 3 – TAT (thoracic aortic rupture or transection) after implantation of thoracic stentgraft.

by using thoracic stentgraft implantation (Figure 3). In 2 patients, simultaneous surgical reconstruction of the carotid bed and the left arteria subclavia was necessary (a hybrid procedure: stentgraft + aortal debranching). This approach is especially necessary for complex arch and descendent aortic lesions. In this case, the cooperation of cardiosurgeons and radiologists is necessary. The time period from the first contact of the patient in our Trauma Centre to the initiation of the thoracic stentgraft implantation was 126 min on average (in 2006, the average

Table 2 – Stentgrafts and procedures details and complications

Stentgrafts size	**Numbers**
22×100 mm	1
20×105 mm	2
22×105 mm	2
24×105 mm	4
24×115 mm	1
24×150 mm	1
26×105 mm	6
26×134 mm	2
28×140 mm	1
28×155 mm	2
32×140 mm	1
32×155 mm	2
32×160 mm	1
34×77 mm	1
34×161 mm	2
Femoral approach	28 (100%)
Percutaneous access	22 (78.5%)
Surgical access	6 (21.4%)
Left subclavian artery (LSA) coverage	10 (35%)
Revascularization of LSA	2 (7.1%)
Hybrid procedure (stentgraft + surgery)	2 (7.1%)
Emergency department (first contact) to implantation (min)	126 min (min 40, max 360)
Complications	**Numbers (%)**
Stentgrafts failure	1 (3.5%)
Endoleak	1 (3.5%)
Pseudoaneurysm following a. puncture	1 (3.5%)
Femoral wound complications	3 (10.7%)
Postimplantation mortality (<30 days)	3 (10.7%)
Postimplantation mortality (in hospital)	5 (17.8%)
Cause of death	**Numbers (%)**
MODS	3 (10.7%)
Brain injury	1 (3.5%)
Stentgrafts failure/bleeding/surgery	1 (3.5%)

MODS – multiple organ dysfunction syndrome time was 180 minutes and in 2019 75 minutes). During this time period, further life-saving procedures for concomitant life-threatening injuries and simultaneous post-examination and planning procedures for thoracic stentgraft implantation were carried out. No patients died before stentgraft implantation. The implantation was 100% from femoral artery (78.6% percutaneous vs. 21.4% surgical techniques). We used COOK-Zenith stentgrafts for patients (Table 2). We reached 100% technical implantation success rate with our patients. In one case, the stentgraft seal failed early with subsequent bleeding and the need for surgical replacement of the thoracic aorta (subsequently with early death of the patient). In one case (patient with very anatomically unfavourable finding), post-implantation Ia endoleak occurred with the necessity of reintervention by secondary stentgraft implantation. In one case we encountered femoral artery pseudoaneurysm after a percutaneous technique and in three cases we had an early complication in the groin area after the implantation surgery. In our group, we had 30-day mortality of 10.7% (3 patients) and the in-hospital mortality was 17.8% (5 patients). In 3 patients, the cause of death was multiple organ dysfunction syndrome (MODS), in 1 patient it was a brain injury and in 1 patient it was a haemorrhagic shock after a direct stentgraft failure followed by thoracic aortic rupture followed with subsequent aortic surgical replacement and organ failure (Table 2). Surviving patients had calculated ISS score of 25 (min 17, max 41); dead patients had an ISS score of 28 (min 19, max 34) – $p \leq 0.05$. The value of mortality is given by the severity of concomitant fatal injuries.

Discussion

Polytraumatized patients are a very specific group of patients with a high mortality. The main cause of death in these patients in developed countries is road accidents. TAT is a significant negative factor affecting the patient condition. Around 80–90% of patients with TAT die at the scene of the accident and of those who do reach a hospital, 15–20% of patients survive (Dosios et al., 2000). The first surgical treatment for blunt traumatic rupture of the thoracic aorta was described by Passaro and Pace in 1959. Nowadays, thoracic stentgrafts (TEVAR) are used for clear diagnoses such as thoracic aneurysm and penetrating aortic ulcer. However, endovascular treatment is becoming an emergent option for highly compromised TAT patients with increasing numbers of polytraumatized patients. At present, some experts ask whether the surgical treatment of TAT is still the “gold standard” but based on available studies (Riesenman et al., 2007; Buz et al., 2008; Chung et al., 2008) and meta-analyses (Takagi et al., 2008; Tang et al., 2008; Xenos et al., 2009) predicting a lower mortality and shorter procedure time, the solution shifts significantly towards a primary endovascular TAT treatment. An analysis of the studies is difficult and limited due to a small number of patients with different characteristics and, for example, the time prior to the commencement of procedures. The evaluated meta-analyses have drawn conclusions in favour of endovascular treatment of TAT. However, it should be noted that meta-analyses evaluating unilaterally interpreted studies with a small number of different patient characteristics may lead to biased results compared to the actual condition. The basis for patient survival is early diagnosis, prompt pharmacological therapy (a pressure control) and urgent handling of findings. The treatment of this type of trauma is not routine in most trauma centres. Typically, approximately 3–4 cases per year are reported per trauma centre (Arthurs et al., 2009). Centres with experience in thoracic surgery, cardiac surgery and anesthesiologists are required to responsibly address polytraumatized patients with blunt aortic injuries. Experienced interventional radiologists are required in case of stentgraft implantation for TAT. Rapid and minimally invasive endovascular treatment of the aortic lesion improves the outcome of aortic injuries. Endovascular repair of traumatic aortic rupture minimizes hemodynamic instability and prevents the exacerbation of bleeding from the injured area. In young polytraumatized patients, a sharper angle and cross-section of the aortic arch than in older patients and possibly more difficult adherence of the stentgraft, should be expected. Older generations of the stentgrafts were sized for degenerative aortic diseases. These stentgrafts were more rigid and designed for larger aortic diameters. There was a threat of great instability, stentgraft migration and possible pseudocoarctation of the aorta (Azizzadeh et al., 2014; Mouawad et al., 2020). The new generation of stentgrafts is more flexible with better adherence and smaller cross-sections for smaller types of the aorta in young patients. The short- and medium-term results of endovascular treatment of thoracic aortic aneurysms are encouraging. Concerns about the subsequent complications resulting from stentgraft implantation such as stentgraft migration and collapse are relevant. Due to the development of new generations of stentgrafts with better adherence and compliance even for narrow aortas, there is an assumption of improving results of stentgraft implantation and minor complications associated with stentgraft implantation. Polytraumatized patients are a very specific group of patients with critical injuries to the CNS (central nervous system), chest, abdomen and extremities, where a fast mini-invasive TAT treatment minimally affects the patient's hemodynamic status. Patients need not undergo thoracotomy and no extracorporeal circulation is needed. Meta-analyses have shown the incidence of paraplegia after TEVAR below 1% as opposed to 7% after surgical treatment (Xenos et al., 2008; Jonker et al., 2010). Spinal cord ischemia (SCI) had always been a grievous complication of thoracic endovascular aortic repair. It often results in paraplegia, reversible or permanent. A number of patient and procedure-related factors have been shown in previous studies to be associated with the development of SCI after TEVAR, including extensive exclusion of the aorta by endografts (more than 15 cm of thoracic aorta), perioperative hypotension (mean arterial pressure) < 70 mm Hg (Chiesa et al., 2005), previous or concomitant thoracic aortic repair and coverage of the left subclavian artery (LSA). Arm ischemia after unprotected LSA occlusion occurred in 20%. To prevent or minimize this complication, widely employed prophylactic measures include cerebrospinal fluid (CSF) drainage, arterial pressure augmentation and LSA revascularization (Bobadilla et al., 2013). To prevent spinal cord ischemia, we used short stentgrafts (up to 15 cm in 22 patients – 78.5%), prevent LSA revascularization (2 patients – 7.1%), coverage of the left subclavian artery only in 10 patients – 35.7%, arterial pressure augmentation and corticosterois. Young patients have a lower incidence of atherosclerosis and a lower risk of spinal cord ischemia. Rizvi et al. (2009) performed a meta-analysis on 3,365 patients from 51 observational studies on TEVAR procedure with or without left subclavian coverage. Results from 8 studies showed a non-significant increase in the risk of SCI with LSA coverage (Rizvi et al., 2009). Recently, Patterson et al. (2014) conducted a meta-analysis on 1,002 TEVAR patients from the Medtronic Thoracic Endovascular Registry (MOTHER) data derived from five clinical trials and one institutional series and reported that subclavian coverage did not increase the risk of SCI (5%) compared to those without coverage (3%) (p=0.16). In our cohort, none of the patients with complete LSA coverage developed ischemic complaints of the left arm and no significant SCI. Planned coverage of LSA is an acceptable risk for arm ischemia and SCI in life-threatening injuries. Based on the results found in our population, we speculate that complete LSA coverage during TEVAR is relatively safe and did not lead to significant ischemic complications. However, this topic is very controversial in the available literature. The optimization of the care system with the assistance of experienced anesthesiologists, vascular surgeons and interventional radiologists improves overall care for these complicated patients. Standardized care leads to improved diagnosis and time periods leading to life-saving procedures. At present, we prefer percutaneous femoral techniques with minimal complications in our Trauma Centre. In our group of patients, we had a 100% technical success rate of implantation and the necessary coverage of subclavian artery on the left did not result in upper limb ischemia. An analysis of the mortality of polytraumatized patients with TAT based on our data and experience shows that systemic complications and complications resulting from damage to the brain, abdominal cavity and cardiorespiratory system, are the dominant cause of death after timely adequate endovascular treatment of the thoracic aorta. Our group of patients shows that the ISS score does not affect the technical success rate of thoracic stentgraft implantation. The results show that patients with a higher ISS score have higher mortality. The advantage of stentgraft implantation without the need for heparin is a lower risk of further bleeding. At the same time, in these mostly young patients, a post-implantation check-up of stentgrafts is necessary due to the possibility of further re-interventions, which are likely due to the expected length of time of artificial material in the thoracic aorta. This potential need for re-interventions after the endovascular treatment of TAT is a certain disadvantage.

Conclusion

Endovascular treatment of TAT, as a minimally invasive and effective procedure with rapid bleeding control, may increase survival chances for severely compromised polytraumatized patients in the context of multiple-organ damage and the need for a major cardio-vascular surgery. An important role in improving survival results for these patients has the need for patient centralization in large centres that have experience with this specific issue and a clearly established algorithm for timely and targeted care for these patients. The algorithm mainly includes a clearly defined targeted aortic examination and early transport, and thoracic stentgraft implantation to control bleeding.

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