Immediate endovascular repair for acute traumatic injuries of the thoracic aorta: A multicenter analysis of 28 cases

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Objective: Endovascular repair of injured thoracic aorta offers a new minimal invasive therapeutic option that could be beneficial in the urgent management of polytrauma patients. The aim of this study was to assess our multicenter experience of immediate endovascular repair for acute traumatic injuries of the thoracic aorta.
Methods: Between April 2002 and October 2007, all patients treated for an acute traumatic injury of the thoracic aorta, in a less than 12-hour delay, by endovascular repair, were reviewed retrospectively in three Parisian trauma centers. Collected data included age, sex, associated comorbidities, and traumatic lesions to determine the Traumatic Injury Severity Score (TRISS), the type of aortic lesion assessed by computed tomography (CT)-scan and transesophageal ultrasonography, technical aspects of endovascular repair, length of hospital stay, and postoperative mortality. Patients were regularly followed by clinical examination, chest radiographs, and thoracic CT-scan.
Results: Twenty-eight patients (20 males, mean age 45 ± 18.8 years) were treated in a median delay of 5 hours (range 2 to 10 hours) after initial trauma. They all experienced severe traumatic injuries with a mean predictive mortality of 55.6% ± 33.1% according to TRISS. Aortic lesions were associated with aortic parietal hematoma (71%), hemomediastinum (86%), and hemothorax (68%). All endovascular procedures were technically successful through femoral (n = 24) or iliac access (n = 4), in a mean operating time of 94 ± 35.8 minutes. Proximal sealing of the endografts required the coverage of the origin of the left subclavian artery in 13 cases and of the left common carotid in one case. The median of hospital stay was 27 days (range 9 to 127 days), with an overall hospital mortality of 17.9% (n = 5). All deaths were unrelated to the aortic rupture or the stent placement, and no intervention-related morbidity or mortality was recorded during a median follow-up of 24 months (range 5 to 73 months).
Conclusion: Endovascular stent grafting allows an immediate efficient repair for acute traumatic injuries of the thoracic aorta. This early management is, however, associated with a high in-hospital mortality, related to the severe concomitant injuries of such unselected multitrauma patients. (J Vasc Surg 2008;48:1369-74.)

Traumatic injury of the thoracic aorta (TITA) is potentially life-threatening, occurring in patients who sustain violent deceleration in road accidents or fall from great heights[1-3] and is often fatal within the first hours.[4,5] Surviving patients frequently present concomitant injuries of various other organs, complicating the conventional surgical management.[6,7] Since Volodos et al described the first thoracic endovascular stent grafting in 1991,[8] the mini-

mally invasive character of this approach makes this technique especially suitable in high risk patients with severe comorbidities and for multitrauma patients. Several series have demonstrated endovascular repair to be an efficient therapeutic option of TITAs with promising results,[9-16] but controversy persists regarding the timing of intervention.[17-20] The purpose of this multicenter study was to assess the feasibility and the outcomes of immediate endovascular management for acute TITA in the emergency setting.

METHODS

We retrospectively reviewed all patients with an acute TITA treated with an endovascular graft between April 2002 and October 2007 in three University trauma centers of the Parisian Public Hospitals (Assistance Publique – Hôpitaux de Paris: APHP). All included patients sustained a violent traumatic injury, with sudden deceleration (road accident or fall from a great height) and were treated with a less than a 12-hour delay after the initial trauma. Chronic aortic injuries, postponed repairs, and patients treated for a penetrating or iatrogenic trauma were excluded.

Initial evaluation of trauma and first-line emergency treatment were performed according to the Advanced Trauma Life Support guidelines.[21] Plain chest, pelvic, and

cervical spine radiographs were systematically completed by a contrast enhanced body scan to establish the diagnosis of aortic rupture and associated injuries. The severity of trauma was defined by an anatomic scoring system, the injury severity score (ISS, from 0 to 75),[22] and a clinical scoring system, the revised trauma score (RTS, from 0 to 7.841).[23] Both scores allow to calculate a predictive mortality rate with the traumatic injury severity score (TRISS, from 0% to 100%) formula.[24]

The type of aortic lesion was assessed on computed tomography (CT)-scan, and in selective cases, on transesophageal echocardiography, and was recorded as: intimal flap, false aneurysm, or circumferential rupture. The periaortic extension of bleeding on CT-scan was recorded as: aortic parietal hematoma, hemomediastinum, hemopericardium, and hemothorax. The aortic diameter between the left common carotid artery (LCCA) and the left subclavian artery (LSA), and the distance between the aortic tear and the origin of the LSA, were measured on CT reconstructions.

After initial assessment and stabilization, patients were transferred to the operating room where injuries were treated in order of threat to life. Acute life threatening injuries such as intra-cranial or intra-abdominal hemorrhage were treated first, followed by the endovascular procedure as soon as possible. Endovascular repair was performed in the operating room by vascular surgeons, using four different self-expanding commercially available stent grafts: Talent LPS and Valiant (Medtronic AVE, Santa Rosa, Calif), Zenith TX2 (Cook Medical, Bloomington, Ind), or TAG (W. L. Gore and Associates; Flagstaff, Ariz). Sizing of the graft was based on CT measurements.

Patients were treated under general anesthesia via the common femoral artery, surgically exposed at the groin; or via the common iliac artery through a retroperitoneal access, if the small caliber of the femoral and external iliac vessels could not accommodate the stent graft delivery system. The stent graft was delivered over an extra-stiff Lunderquist guidewire (Cook Medical, Bloomington, Ind), and positioned under fluoroscopic guidance within the descending aorta for deployment. All operating rooms were equipped with portable C-arm (either General Electric OEC 9000, Fairfield, Conn, or Philips BV Pulsera, Eindhoven, The Netherlands) and a contrast injector (MedRad Mark V ProVis, Pittsburg, Pa). An intraoperative arteriography was performed, using a pigtail catheter in the ascending aorta, to evaluate the aortic lesion and to verify the position of the stent graft before deployment. After deployment, complete exclusion of the aortic injury without evidence of endoleak was confirmed by a completion angiography. Further expansion of the stent graft was performed by ballooning at the proximal and distal anchoring zones as needed. Systemic heparin was contraindicated in case of accompanying hemorrhagic lesions. In other cases, a single dose of 50 UI/kg of heparin was routinely injected prior to device insertion and fully antagonized after removal of endovascular equipment. In all cases, local heparin flush

Table I. Concomitant injuries

Concomitant injury	n	%
Head injuries		
Cerebral hemorrhage	13	46.4
Facial fracture	8	28.6
Cardiopulmonary		
Pulmonary contusion	20	71.4
Myocardial contusion	7	25.0
Abdominal		
Spleen	6	21.4
Liver	8	28.6
Renal	6	21.4
Mesenterial hematoma	2	7.1
Fractures		
Rib	22	78.6
Upper extremity	12	42.9
Lower extremity	11	39.3
Vertebral	12	42.9
Pelvic	9	32.1

was used within the sheaths. No further anticoagulation was administrated.

Follow-up collected data consisted of a clinical examination, plain chest radiographs, and a thoracic CT-scan. The data are presented as mean and standard deviation, or median and range.

RESULTS

Twenty-eight patients (20 male, mean age 45 ± 18.8 years) were treated by endovascular repair for an acute TITA, with a less than 12-hour delay following their admission in three AP-HP trauma centers: Henri-Mondor Hospital (13 patients); Georges Pompidou European Hospital (nine patients); and Bichat Hospital (six patients). The cause of aortic injuries included 17 road accidents (60.7%) and 11 falls from great height. Concomitant injuries were documented in all patients and are listed in Table I. Patients experienced severe traumatic injuries, with a mean ISS at 49.3 ± 13.2, a mean RTS at 5.9 ± 1.6, and a mean predictive mortality rate calculated at 55.6% ± 33.1% according to TRISS. Two patients presented an initial paraplegia, due to a T11 vertebral fracture with spinal cord injury in one case, and to an associated dissection of the descending thoracic aorta in the other. In three patients, an emergency procedure was performed before endovascular repair: 2 laparotomies for hemostasis (1 liver packing, 1 splenectomy) and 1 sternotomy for suture of a myocardial rupture.

Aortic lesions were diagnosed on CT-scan as an intimal flap (n = 6) or a false aneurysm (n = 17). These diagnoses were confirmed by an endoesophageal echocardiography in 11 cases (39.3%). Each lesion was associated with periaortic blood effusion identified as an aortic parietal hematoma in 20 cases (71%), a hemomediastinum in 24 cases (86%), a hemopericardium in three cases (11%), and a hemothorax in 19 cases (68%). The mean aortic diameter measured between the LCCA and LCA was 24.6 ± 4.4 mm. The mean distance between the aortic tear and the origin of the LSA was 22.4 ± 10.0 mm.

Table II. Hospital mortality

Patient no.	Age	ISS	TRISS %	Cause of death	Time after intervention
1	22	75	99	MOF after hemorrhagic shock with severe hepatic trauma	12 h
2	90	50	50.7	Coagulopathy after hemorrhagic shock	2 d
3	86	57	91.9	Renal failure with severe myocardial contusion	3 d
4	40	57	88.5	Severe intracranial hypertension after cerebral hemorrhage	10 d
5	58	56	98.1	Severe epileptic attack with cerebral injury and hemorrhagic shock	13 d

ISS, Injury severity score; *TRISS,* traumatic injury severity score; *MOF,* multiple organ failure.

Endovascular repair was performed within a median of 5 hours (range 2 to 10 hours) from initial trauma and was technically successful in all cases. Delivery of the stent graft was possible through a femoral access in 24 cases (86%) and required an iliac access for the four other cases. Twenty-nine stent grafts were deployed: 16 Valiant and 2 Talent LPS (Medtronic AVE, Santa Rosa, Calif), 7 Zenith TX2 (Cook Medical, Bloomington, Ind), and 4 TAG (W. L. Gore and Associates, Inc, Flagstaff, Ariz). One patient presented an isthmus rupture complicated with a dissection of the descending thoracic aorta and required the deployment of two stent grafts to allow complete exclusion of the aortic tear and correct distal perfusion. The mean length of implanted covered stent grafts was 135.2 ± 32.1 mm. Their mean proximal diameter was 28.4 ± 4.1 mm, with a mean calculated oversizing rate of 19% ± 5.0%. Proximal sealing of the stent grafts required the coverage of the origin of the LSA in 13 cases (46.4%) and of the LCCA in one case. This last patient required intraoperative revascularization of the LCCA from the ascending aorta via sternotomy. In these patients, the distance between the aortic tear and the origin of the LSA was <20 mm. None of them experienced vertebrobasilar or left arm ischemia in the immediate postoperative period. All aortic lesion were correctly excluded with no type I endoleak on completion arteriographies. The mean operating time was 94 ± 35.8 minutes. The mean intraoperative use of contrast media was 156 ± 74.1 mL, with a mean time of fluoroscopy of 18.3 ± 12.6 minutes. No thrombotic complication occurred during the procedures.

The overall hospital mortality was 17.9% (n = 5), and all deaths were unrelated to the aortic rupture or the stent graft placement (Table II). The mean ISS and TRISS were significantly higher in the deceased population than in the survivors (respectively: ISS = 59.0 ± 9.4 vs 47.2 ± 13.1: *P* = .03; and TRISS = 85.6 ± 20 vs 49.0 ± 32: *P* = .01). The median of stay in intensive care unit was 21 days (range 5 to 120 days), and the median hospital stay was 27 days (range 9 to 127 days). No patient developed any neurological complication due to the endovascular procedure.

The median follow-up for survivors was 24 months (range 3 to 73 months), with two patients lost to follow-up after 3 months. One patient developed left arm claudication 2 months after discharge, which required LSA revascularization via a left carotid subclavian transposition. There were no other late endovascular procedure related complications, such as endoleaks or graft migration.

DISCUSSION

This observational retrospective study presents the largest series, to our knowledge, of multitrauma patients treated by immediate endovascular stent grafting for acute TITA. It confirms the feasibility and the midterm efficiency of emergent endovascular repair of such life-threatening lesions, with a still high in-hospital mortality related to concomitant injuries.

Operative requirements of conventional open repair complicate the management of such polytrauma patients in urgent situation and result in high postoperative mortality rates ranging from 15% to 30% in recent published series.[25,26] The lateral positioning in patients with multiple extremity fractures, vertebral or spinal cord injuries (82% in our series, with two preoperative paraplegia) increases the risk of morbidity. Left thoracotomy and single lung ventilation in the presence of lung contusions results in prolonged respiratory insufficiency and infectious complications (range 24% to 65% in the literature and 36% in our series).[2,25,26] With aortic cross-clamping remains the risk of paraplegia due to spinal cord ischemia (range 2.3% to 25.5%),[27,28] despite the use of circulatory assistance.[25,29] The need of systemic heparinization also increases the hemorrhagic morbidity in patients with multiple injuries.

Because of the invasive character of open surgery, aortic repair is often deliberately postponed to decrease the procedure related mortality.[1,30,31] But even under intensive surveillance, the risk of secondary aortic rupture remains around 5%, mostly within the first week after the trauma.[1,32] Furthermore, most of the patients present an initial hemodynamic instability with peri-aortic blood effusion (78% in our series), prompting immediate aortic repair.

Endovascular stent grafting is a less invasive technique that invalidates the reasons for postponing aortic repair. Additional injuries do not represent an obstacle to immediate stent grafting, because it can be performed with no mobilization of the patient, no heparinization and no aortic cross-clamping. In our early experience, stent grafting was only considered for TITA associated with significant concomitant injuries. In that time-period, open surgery was performed in six additional cases. Impressed by the safety and simplicity of the endovascular approach, we decided to extend the indication to all anatomically suitable cases and to perform endovascular repair as soon as possible. As in other recent published series,[20,33] we believe that this technique should be performed without delay, or immedi-

Table III. Recent largest case series of endovascular repair for acute TITA

Study	Number of patients (Delay of repair)	Stent graft-related mortality (%)	Comorbid mortality (%)	Injury severity score
Melnitchouk et al[35]	15 (<14 d)	0	2 (13.4%)	ND
Amabile et al[36]	9 (<14 d) 7 (<24 h)	0	0	ND
Dunham et al[37]	16 (<14 d) 9 (<24 h)	0	1 (6.3%)	36.9 ± 12.0
Lachat et al[15]	10 (<14 d) 9 (<24 h)	1 (10%)	0	ND
Bent et al[33]	13 (<14 d) 8 (<24 h)	0	0	ND
Buz et al[39]	34 (<7 d) 29 (<48 h)	1 (2.9%)	2 (5.9%)	41 (range 13-66)
Marcheix et al[19]	12 (<14 d) 4 (<24 h)	0	0	40.2 ± 10.7
Hoornweg et al[20]	28 (<14 d) 21 (<24 h)	0	4 (14.3%)	37.1 ± 7.8
Canaud et al[38]	27 (<14 d) 21 (<5 d)	0	(3.7%)	ND
This series	28 (<12 h)	0	5 (17.9%)	49.3 ± 13.2

ND, Not defined.

ately after the treatment of acute life-threatening injuries (intracranial or intra-abdominal hemorrhage). This early management limits the risk of total rupture, without worsening the global mortality of such severe traumatized patients.[15,34] All patients presented in this series were treated before a delay of 12 hours after initial trauma. During the observed time period, two other cases were postponed for endovascular repair and, therefore, excluded from the study: one patient initially managed in an other trauma center, presented after 4 days with a sudden hemodynamic degradation that led to the diagnosis of aortic rupture; another patient had to sustain 9 days of intensive care for a fat embolism before being considered for aortic repair. These events led us to favor early repair with less selection of patients and may explain the higher mean ISS and comorbid mortality rate of our series compared with other recently published studies (Table III).

Vessel access for the device remains a significant issue of endovascular repair. Most of our procedures could be performed through a femoral access by a cutdown at the groin. In four cases though (14.3%), the diameter of the external iliac artery was considered too small by the operator, and the endograft was introduced through the common iliac artery, exposed by retroperitoneal access. We have chosen iliac access more frequently than other authors,[19,20,33] in order to prevent external iliac avulsion, which may have major consequences.[15] This approach could be explained by the fact that all our patients were treated at the operating room by a surgical team. No complications of surgical access were seen in this series.

Another issue particular to endovascular repair is to assure an efficient proximal sealing of the stent graft to avoid proximal type I endoleak. Considering 20 mm as a minimum length of proximal landing zone, endovascular exclusion of the traumatic lesions remained durable, without any endoleak recorded in the follow-up. This approach

may have led to the high coverage rate of the LSA ostium (46.4%) compared with the range of 23% to 32% described in the literature.[19,20,33,39] In all these cases, the landing zone between the LSA and the aortic tear was <20 mm and considered insufficient to assure proximal sealing.

Most authors agree that LSA should not be systematically revascularized, except in cases of an ipsilateral large dominating vertebral artery or of coronary bypass from the left internal mammary artery. One case of fatal vertebral embolic complication has been described by Buz et al,[39] with a mobile thrombus on a partially occluded LSA. In our series, only one case out of 13 covered LSA (7.7%), presented a delayed ischemic arm claudication 2 months after the procedure, which led to a carotid-subclavian transposition without complication. Various rates of indication for LSA revascularization are published ranging from 0% to 25%,[39,40] after coverage of the LSA ostium by an endograft. LSA revascularization appears also mandatory in cases of extensive stent grafting of the descending aorta, in order to favor spinal cord's collateral vascularization.[39,41] However, endovascular repair of TITAs usually requires only a short length of aortic stent grafting, resulting in a very low risk of spinal cord ischemia and paraplegia.

In spite of many benefits on the short- and midterm outcomes, the long-term results of endovascular repair remain a major issue in relatively young patients. The fabric of the stent graft is exposed to pulsatile shear stress forces and consequences of placement in the curvature of the distal arch which might impair these promising results. Therefore, the development of an ideal stent graft is important: it should be adapted to the anatomic tight curvature of the distal arch of young patients, correctly oversized of 15% to 20%, short enough to avoid excessive coverage of intercostal arteries, precisely deployable with a stable and flexible delivery system, and durably anchored to prevent late migration.

Actual commercially available devices try to reach this ideal profile, and each of them presents some pros and cons. The curvature of the aortic arch in young patients represents a challenge for manufacturers in terms of stent graft delivery and proximal apposition. The proximal end of the delivery sheaths are often not flexible enough to turn softly into the ascending aorta. In such cases, we recommend placing the proximal "nose" of the delivery sheath into the brachio-encephalic arterial trunk to allow a stable deployment of the stent graft.

Proximal apposition is also an important issue for long-term stability, since individual case reports of stent graft collapse resulting in major morbidity and mortality and the need for reintervention have been reported with several different devices.[42,43] In our experience, a proximal bare stent seems to insure a better apposition of the proximal seal zone to the inner curvature of a tight aortic arch. This should also help avoid problems such as "bird-beaking", a phenomenon that occurs when aortic blood compresses the endograft at the proximal seal zone. On the other hand, the radial force of such stents may create later lesions in the aortic wall that could have dramatic effects on supra-aortic trunks.

Another issue is the need for smaller diameter devices in these younger patients whose aortas have not begun to dilate. We often struggle with the size miss match between the small aortic diameter and the smallest stent graft diameter. In our series, the most oversized stent graft was a Talent of 26 mm of diameter for an aorta of 20 mm and was performed in the early period of our experience. This resulted in an oversizing of 30%, with no late complication during a follow-up of 66 months. The range of stent graft diameters available in the three trauma centers was 24 to 40 mm during the observed time period. Main thoracic stent graft manufacturers actually provide commercially available devices with a smallest diameter of 22 mm.

However, of all the important qualities, the appropriate device should be available "on the shelf" to allow immediate repair. Trauma centers who manage such traumatic lesions should therefore be equipped of short stent grafts (<150 mm) with small diameters (20 to 30 mm).

CONCLUSION

This study, despite the limits related to its retrospective character, demonstrates that the minimally invasive character of endovascular stent grafting allows early repair of acute TITA in safely and with good short- and midterm results. Immediate repair for this life-threatening lesion should insure a more comfortable reanimation of such severe multitrauma patients. This approach is, however, still associated with a high in-hospital mortality related to their severe concomitant injuries.

AUTHOR CONTRIBUTIONS

Conception and design: JMA, PD, GL
Analysis and interpretation: JMA, PD, BB
Data collection: JMA, BB
Writing the article: JMA

Critical revision of the article: JMA, PD, GL, JNF, JPB
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REFERENCES

1. Pierangeli A, Turinetto B, Galli R, Caldarera L, Fattori R, Gavelli G. Delayed treatment of isthmus aortic rupture. Cardiovasc Surg 2000;8:280-3.
2. Gammie JS, Shah AS, Hattler BG, Kormos RL, Peitzman AB, Griffith BP, et al. Traumatic aortic rupture: diagnosis and management. Ann Thorac Surg 1998;66:1295-300.
3. Galli R, Pacini D, Di Bartolomeo R, Fattori R, Turinetto B, Grillone G, et al. Surgical indications and timing of repair of traumatic ruptures of the thoracic aorta. Ann Thorac Surg 1998;65:461-4.
4. Parmley LF, Mattingly TW, Manion WC, Jahnke EJ Jr. Nonpenetrating traumatic injury of the aorta. Circulation 1958;17:1086-101.
5. Ferrari E, Tozzi P, von Segesser L. Thoracic aorta emergencies: is the endovascular treatment the new gold standard? Interact Cardiovasc Thorac Surg 2006;5:730-4.
6. Fabian TC, Richardson JD, Croce MA, Smith JS, Rodman G, Kearney PA, et al. Prospective study of blunt aortic injury: multicenter trial of the American Association for the Surgery of Trauma. J Trauma 1997;42:374-83.
7. Crowley RA, Turney SZ, Hankins JR, Rodriguez A, Attar S, Shanskar BS. Rupture of the thoracic aorta caused by blunt trauma. J Thorac Cardiovasc Surg 1990;100:652-61.
8. Volodos NL, Karpovich IP, Troyan VI, Kalashnikova YuV, Shekhanin VE, Ternyuk NE, et al. Clinical experience of the use of self-fixing synthetic prostheses for remote endoprosthetics of the thoracic and the abdominal aorta and iliac arteries through the femoral artery and as intraoperative endoprosthesis for aorta reconstruction. Vasa Suppl 1991;33:93-5.
9. Amabile P, Collart F, Gariboldi V, Rollet G, Bartoli JM, Piquet P. Surgical versus endovascular treatment of traumatic thoracic aortic rupture. J Vasc Surg 2004;40:873-9.
10. Czermak BV, Waldenberger P, Perkmann R, Rieger M, Steingruber IE, Mallouhi A, et al. Placement of endovascular stent grafts for emergency treatment of acute disease of the descending thoracic aorta. AJR Am J Roentgenol 2002;179:337-45.
11. Daenen G, Maleux G, Daenens K, Fourneau I, Nevelsteen A. Thoracic aorta endoprosthesis: the final countdown for open surgery after traumatic aortic rupture? Ann Vasc Surg 2003;17:185-91.
12. Dunham MB, Zygun D, Petrasek P, Kortbeek JB, Karmy-Jones R, Moore RD. Endovascular stent grafts for acute blunt aortic injury. J Trauma 2004;56:1173-8.
13. Karmy-Jones R, Hoffer E, Meissner MH, Nicholls S, Mattos M. Endovascular stent grafts and aortic rupture: a case series. J Trauma 2003;55:805-10.
14. Kato N, Dake MD, Miller DC, Semba CP, Mitchell RS, Razavi MK, et al. Traumatic thoracic aortic aneurysm: treatment with endovascular stent grafts. Radiology 1997;205:657-62.
15. Lachat M, Pfammatter T, Witzke H, Bernard E, Wolfensberger U, Künzli A, et al. Acute traumatic aortic rupture: early stent graft repair. Eur J Cardiothorac Surg 2002;21:959-63.
16. Marty-Ané CH, Berthet JP, Branchereau P, Mary H, Alric P. Endovascular repair for acute traumatic rupture of the thoracic aorta. Ann Thorac Surg 2003;75:1803-7.
17. Creasy JD, Chiles C, Routh WD, Dyer RB. Overview of traumatic injury of the thoracic aorta. Radiographics 1997;17:27-45.
18. Lebl DR, Dicker RA, Spain DA, Brundage SI. Dramatic shift in the primary management of traumatic thoracic aortic rupture. Arch Surg 2006;141:177-80.
19. Marcheix B, Dambrin C, Bolduc JP, Arnaud C, Hollington L, Cron C, et al. Endovascular repair of traumatic rupture of the aortic isthmus: midterm results. J Thorac Cardiovasc Surg 2006;132:1037-41.
20. Hoornweg LL, Dinkelman MK, Goslings JC, Reekers JA, Verhagen HJ, Verhoeven EL, et al. Endovascular management of traumatic

ruptures of the thoracic aorta: a retrospective multicenter analysis of 28 cases in The Netherlands. J Vasc Surg 2006;43:1096-102; discussion 1102.

21. American College of Surgeons. Advanced trauma life support course for physicians. 7th ed. Chicago: Committee on Trauma, American College of Surgeons; 2004.

22. Baker SP, O'Neill B, Haddon W Jr, Long WB. The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma 1974;14:187-96.

23. Champion HR, Sacco WJ, Copes WS, Gann DS, Gennarelli TA, Flanagan ME. A revision of the trauma score. J Trauma 1989;29:623-9.

24. Boyd CR, Tolson MA, Copes WS. Evaluating trauma care: the TRISS method. Trauma Score and the Injury Severity Score. J Trauma 1987;27:370-8.

25. Jahromi AS, Kazemi K, Safar HA, Doobay B, Cina CS. Traumatic rupture of the thoracic aorta: cohort study and systematic review. J Vasc Surg 2001;34:1029-34.

26. Razzouk AJ, Gundry SR, Wang N, del Rio MJ, Varnell D, Bailey LL. Repair of traumatic aortic rupture: a 25-year experience. Arch Surg 2000;135:913-8.

27. Attar S, Cardarelli MG, Downing SW, Rodriguez A, Wallace DC, West RS, et al. Traumatic aortic rupture: recent outcome with regard to neurologic deficit. Ann Thorac Surg 1999;67:959-64.

28. von Oppell UO, Dunne TT, De Groot MK, Zilla P. Traumatic aortic rupture: twenty-year meta-analysis of mortality and risk of paraplegia. Ann Thorac Surg 1994;58:585-93.

29. Zeiger MA, Clark DE, Morton JR. Reappraisal of surgical treatment of traumatic transection of the thoracic aorta. J Cardiovasc Surg (Torino) 1990;31:607-10.

30. Kipfer B, Leupi F, Schuepbach P, Friedli D, Althaus U. Acute traumatic rupture of the thoracic aorta: immediate or delayed surgical repair? Eur J Cardiothorac Surg 1994;8:30-3.

31. Symbas PN, Sherman AJ, Silver JM, Symbas JD, Lackey JJ. Traumatic rupture of the aorta: immediate or delayed repair? Ann Surg 2002;235:796-802.

32. Hemmila MR, Arbabi S, Rowe SA, Brandt MM, Wang SC, Taheri PA, et al. Delayed repair for blunt thoracic aortic injury: is it really equivalent to early repair? J Trauma 2004;56:13-23.

33. Bent CL, Matson MB, Sobeh M, Renfrew I, Uppal R, Walsh M, et al. Endovascular management of acute blunt traumatic thoracic aortic injury: a single center experience. J Vasc Surg 2007;46:920-7.

34. Ahn SH, Cutry A, Murphy TP, Slaiby JM. Traumatic thoracic aortic rupture: treatment with endovascular graft in the acute setting. J Trauma 2001;50:949-51.

35. Melnitchouk S, Pfammatter T, Kadner A, Dave H, Witzke H, Trentz O, et al. Emergency stent graft placement for hemorrhage control in acute thoracic aortic rupture. Eur J Cardiothorac Surg 2004;25:1032-8.

36. Amabile P, Rollet G, Vidal V, Collart F, Bartoli JM, Piquet P. Emergency treatment of acute rupture of the descending thoracic aorta using endovascular stent grafts. AnnVasc Surg 2006;20:723-30.

37. Dunham MB, Zygun D, Petrasek P, Kortbeek JB, Karmy-Jones R, Moore RD. Endovascular stent grafts for acute blunt aortic injury. J Trauma 2004;56:1173-8.

38. Canaud L, Alric P, Branchereau P, Marty-Ané C, Berthet JP. Lessons learned from midterm follow-up of endovascular repair for traumatic rupture of the aortic isthmus. J Vasc Surg 2008;47:733-8.

39. Buz S, Zipfel B, Mulahasanovic S, Pasic M, Weng Y, Hetzer R. Conventional surgical repair and endovascular treatment of acute traumatic aortic rupture. Eur J Cardiothorac Surg 2008;33:143-9.

40. Pamler RS, Kotsis T, Görich J, Kapfer X, Orend KH, Sunder-Plassmann L. Complications after endovascular repair of type B aortic dissection. J Endovasc Ther 2002;9:822-8.

41. Dake MD. Endovascular stent-graft management of thoracic aortic diseases. Eur J Radiol 2001;39:42-9.

42. Muhs BE, Balm R, White GH, Verhagen HJ. Anatomic factors associated with acute endograft collapse after Gore TAG treatment of thoracic aortic dissection or traumatic rupture. J Vasc Surg 2007;45:655-61.

43. Idu MM, Reekers JA, Balm R, Ponsen KJ, de Mol BA, Legemate DA. Collapse of a stent graft following treatment of a traumatic thoracic aortic rupture. J Endovasc Ther 2005;12:503-7.