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Review

Endovascular versus open repair for descending thoracic aortic rupture: institutional experience and meta-analysis

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Summary

Rupture of thoracic aneurysm, acute type B dissection, blunt thoracic trauma, and penetrating aortic ulcer can present with a similar clinical profile of thoracic aortic rupture. We report a meta-analysis of comparative studies evaluating endoluminal graft versus open repair of these lesions as well as the early experience from our institution. We searched the following databases for reports of endovascular versus open repair of acute descending thoracic aortic rupture: Medline/PubMed, OVID, EMBASE, CINAHL, ClinicalTrials.gov, the Cochrane central register of controlled trials and the Cochrane database of systematic reviews. We used the random-effects model to calculate the odds ratio (OR) and 95% confidence intervals (CI) for mortality, paraplegia/paraparesis and stroke rates. Also, the medical records of the patients treated in our institution with this technique from 2000 to 2008 were reviewed. Demographics, comorbidities and operative procedure information were retrieved. Outcomes examined were mortality, paraplegia and stroke. Meta-analysis indicates that endoluminal graft repair is accompanied by lower procedure related mortality (OR 0.46, 95% CI 0.26—0.78, $p = 0.005$) and paraplegia rates (OR 0.23, 95% CI 0.08—0.65, $p = 0.005$), as compared to open repair. There was no difference in stroke rate between the two methods (OR 0.86, 95% CI 0.26—2.8, $p = 0.8$). We have treated 13 patients with endoluminal stent-grafts. No conversion to open repair was necessary. Stroke rate was15%, no patient died as a result of the stent-graft placement, one patient died as a result of massive head injury (overall 30-day mortality: 7.5%). There were no spinal cord ischemic complications. Our experience and meta-analysis indicate that thoracic endograft repair has low mortality and spinal cord complication rates for treatment of acute thoracic aortic rupture. If this method proves to be durable, it could replace open repair as the treatment of choice for these critically ill patients.

Keywords: Thoracic aortic rupture; Endoluminal repair

1. Introduction

Thoracic aortic rupture encompasses a heterogeneous group of patients with a similar clinical profile including free or contained rupture of thoracic aneurysm, complicated acute type B dissection, injury following blunt thoracic accidents, and penetrating aortic ulcer [1]. Emergency conventional surgical repair of the descending thoracic aorta remains a therapeutic challenge and is associated with significant risk of mortality, ranging from 24% to 42% [2]. The traditional treatment for most patients with diseases of the descending aorta is surgical intervention with graft interposition [3]. The morbidity and mortality of this operation, however, have spurred interest in less invasive, less traumatic methods of repair. Since Parodi and Palmaz [4] first reported the use of an endoluminal stent-graft repair for abdominal aortic aneurysms, use of the endoluminal stent-graft procedure has expanded rapidly. We reviewed our experience using endografts for acute rupture of the descending thoracic aorta and performed a meta-analysis of comparative studies evaluating endovascular versus open repair.

2. Materials and methods

2.1. Meta-analysis

A systematic search of published studies reporting treatment of acute descending thoracic aortic rupture was performed. The following databases were searched: Medline/PubMed, OVID, EMBASE, CINAHL, ClinicalTrials.gov, the Cochrane central register of controlled trials and the Cochrane database of systematic reviews. Search terms included *thoracic aortic rupture, acute aortic dissection,*

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traumatic aortic rupture, stent-graft repair, endovascular repair. We considered reports in all languages form 1966 to 2007. The 'related articles' function was used to broaden the search. All article titles, abstracts, and subject headings were screened by one reviewer for potential relevance. Abstracts of articles selected by title were read online to reduce the number of articles for full-text examination. Finally, additional titles were sought in the bibliographies of the retrieved article. Outcomes examined were mortality related to aortic graft placement (procedure related mortality), paraplegia/paraparesis and stroke rate after intervention. The articles included satisfied the following requirements: (1) studies comparing outcomes of endoluminal treatment of acute thoracic aortic rupture versus open repair and (2) report on at least one outcome of interest. Articles were excluded for one of the following reasons: (1) no open surgical repair cohort comparison or (2) repeat inclusion of patients or duplicate publications. A standard form was used to extract the data from the articles, including characteristics of study design, study population, demographics, other injuries/comorbidities, intervention type, interval to repair, procedure related mortality, paraplegia/paraparesis and stroke rate. Data extraction was done from life tables, text, or graphs. Statistical analysis was performed using the commercially available software CMA Version 2 (Biostat Inc., Englewood NJ). Publication bias was investigated using funnel plots. Q tests were performed to determine homogeneity of the samples; statistical heterogeneity was considered present if $p < 0.05$. Meta-analysis was performed by calculating the pooled odds ratios and 95% confidence intervals for the study outcomes. The random-effects model was used. The odds ratio represents the odds of an adverse event occurring in the thoracic endoluminal graft (TELG) group divided by the odds in the open repair group. An odds ratio of less than one favors the TELG group, and the point estimate of the odds ratio is considered statistically significant at the $p < 0.05$ level if the 95% confidence interval does not include the value 1.0. Studies with no occurrence of an outcome in either the endoluminal or the open repair group were excluded from the statistical calculations for that outcome. The two-tailed t-test was used for comparisons between the two group characteristics, $p < 0.05$ was considered significant. The meta-analysis was carried out in line with Cochrane Collaboration recommendations and quality of reporting of meta-analyses guidelines [19,20].

2.2. Institutional experience

A retrospective review of the patients who underwent endograft placement for acute pathology of the thoracic descending aorta from 2000 to 2008 was performed. The medical records and radiological examinations of these patients were retrieved and the following data were extracted: demographic information, mechanism of injury, location, comorbidities including injury severity score (ISS) and Glasgow coma scale, type of device used, coverage of left subclavian, postoperative mortality/morbidity (stroke, paraplegia), interval to repair, and need for secondary interventions for endoleak/device collapse or migration.

3. Results

3.1. Meta-analysis

Twenty-three retrospective cohort studies from 2003 to2007 were retrieved [5–17], [18–25]. One study reported duplicate data and was excluded [26]. Twenty-two were included in this analysis. Twenty-one studies are published and one is un-published (Chung et al., data presented at the Society of Interventional Radiology 32nd Annual Meeting, Seattle, WA 2007). All were non-randomized; no prospective randomized trials were found. These studies reported on 859 patients. Five hundred and one patients were treated with open repair and they were compared with 358 patients who were treated with thoracic endograft aortic repair. Blunt thoracic aortic trauma was the underlying pathology in 68% of the subjects. The two groups were similar in terms of gender and age distribution, injury severity score (for patients with traumatic thoracic aortic rupture) and interval time to repair as shown in Table 1.

Procedure related mortality was significantly lower with TEVAR, odds ratio 0.34 (95% confidence interval 0.18–0.66, $p = 0.001$), $p = 0.98$ for heterogeneity (Fig. 1). Paraplegia/paraparesis was also lower after TEVAR as compared to open repair, odds ratio 0.27(95% confidence interval 0.11–0.63, $p = 0.003$), $p = 0.96$ for heterogeneity (Fig. 2). There was no significant difference in stroke rate between the open or endoluminal repair, odds ratio 0.86 (95% confidence interval 0.26–2.8, $p = 0.8$), $p = 0.6$ for heterogeneity (Fig. 3). Studies that do not appear in the forest plots had zero outcomes for both the endoluminal and the open repair groups. Publication bias was limited.

Also, sensitivity analysis was performed by removing each of the studies one at a time and evaluating the effect on the results; this did not demonstrate any single study to over influence the results.

3.2. Institutional experience

Thirteen patients underwent placement of endografts in the descending thoracic aorta between 2000 and 2008. Eleven patients had suffered blunt traumatic injury, one presented with rupture of an acute type B dissection and one with rupture of a chronic pseudoaneurysm of the descending thoracic aorta. All the traumatic lesions were located in the aortic isthmus. Table 2 summarizes the characteristics of these patients. Eight patients underwent placement of Gore Excluder® cuffs and five patients Gore TAG® endoprostheses. No conversions to open repair was necessary. Femoral access was used in all cases. The subclavian artery was covered in five patients to achieve an adequate proximal seal zone. One

Table 1
Demographics, ISS and interval to repair from included studies; data are presented as mean ± standard deviation.

	TELG	Open repair	p value
Gender (%males)	73 ± 0.11	72 ± .012	0.89
Age (years)	45.8 ± 14	44.7 ± 14	0.83
ISS	42 ± 5	38 ± 5	0.12
Interval to repair (h)	79 ± 30	28 ± 20	0.22

Procedure related mortality

Study name	Odds ratio	Lower limit	Upper limit	P-Value
Amabile 2004	0.368	0.013	10.178	0.555
Andrassy 2006	0.435	0.037	5.161	0.509
Broux 2006	0.407	0.015	10.832	0.592
Buz 2007	0.577	0.091	3.669	0.560
Chung 2007	0.145	0.008	2.801	0.201
Doss 2005	0.148	0.016	1.358	0.091
Kasirajan 2003	0.091	0.004	2.073	0.133
Kuhne 2005	0.427	0.021	8.709	0.580
Lebl 2006	0.667	0.048	9.189	0.762
McPhee 2007	0.176	0.006	5.280	0.317
Morishita 2004	2.000	0.181	22.056	0.571
Ott 2004	0.323	0.013	7.847	0.488
Pacini 2005	0.447	0.022	9.140	0.601
Reed 2006	0.833	0.046	15.086	0.902
Rieseman 2007	0.112	0.006	2.035	0.139
Rousseau 2005	0.077	0.004	1.428	0.085
Stone 2006	0.376	0.046	3.080	0.362
	0.346	0.180	0.662	0.001

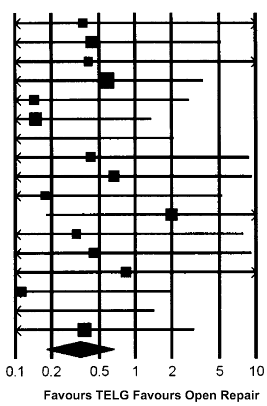

Fig. 1. Forest plot for procedure-related mortality in TELG versus open repair of acute descending aortic rupture.

patient underwent axillo-axillary bypass prior to the endograft placement to maintain perfusion of an internal mammary artery coronary bypass graft. None of the other four patients experienced arm ischemia requiring intervention. Stent-graft collapse was noted in two patients, one during the procedure and one on postoperative day 14. These were treated with deployment of an additional stent-graft in the first patient with coverage of the left subclavian artery, and with deployment of a Palmaz® 3110 stent in the second patient. No patient died as a result of the endograft placement, one patient died because of massive head injuries (overall 30-day mortality 8%). We did not observe ischemic spinal cord complication in our cohort. Incidence of perioperative stroke was 15%. One stroke had pontine and one stroke had cerebellar distribution, both appeared to be embolic in nature on imaging studies of the brain. The left subclavian had been covered in the patient that suffered a cerebellar stroke. Six patients had follow-up computed

Paraplegia/Paraparesis

Study name	Odds ratio	Lower limit	Upper limit	P-Value
Stone 2006	0.305	0.017	5.542	0.422
Rousseau 2005	0.157	0.008	3.176	0.228
Pacini 2005	0.341	0.017	6.687	0.478
Ott 2004	0.323	0.013	7.847	0.488
Morishita 2004	0.189	0.007	5.073	0.321
Kokotsakis 2007	0.141	0.005	3.775	0.243
Glade 2004	0.378	0.013	10.744	0.569
Doss 2005	0.871	0.052	14.604	0.923
Cook 2006	0.385	0.015	9.995	0.565
Chung 2007	0.069	0.004	1.243	0.070
Broux 2006	0.407	0.015	10.832	0.592
Brandt 2004	0.458	0.036	5.789	0.547
Andrassy 2006	0.167	0.008	3.687	0.257
	0.274	0.118	0.638	0.003

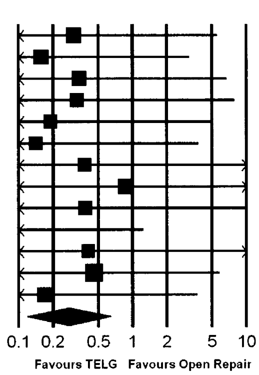

Fig. 2. Forest plot for paraplegia/paraparesis in TELG versus open repair of acute descending aortic rupture.

Stroke

Study name	Odds ratio	Lower limit	Upper limit	p-Value
Brandt 2004	1.000	0.056	17.903	1.000
Broux 2006	0.230	0.010	5.215	0.356
Buz 2007	2.766	0.109	70.135	0.537
Doss 2005	2.714	0.106	69.338	0.546
Glade 2004	0.200	0.008	4.909	0.324
McPhee	0.176	0.006	5.280	0.317
Riesenman 2007	3.615	0.211	61.821	0.375
	0.863	0.266	2.800	0.806

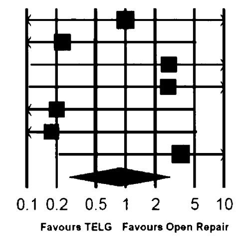

Fig. 3. Forest plot stroke in TELG versus open repair of acute descending aortic rupture.

Table 2
Characteristics of patients treated at our institution, median (range) is shown.

Gender	8 male, 5 female
Glasgow coma scale	7 (3—15)
Age	60 (17—72) years
Injury severity score	49 (36—66)
Interval to repair	8.5 h (3 h to 4 days)
Mean hospital stay length	15 days (1—60)
Coverage of left subclavian	5/11
Endoleak	0/11
Stent collapse	2/11
Paraplegia	None
Conversion	None
Death related to TELG	None

tomography (follow-up range one to ten months, average 3.4 months); no device migration or endoleak was identified.

4. Discussion

Elective surgical procedures performed by experienced cardiothoracic and vascular surgeons in good surgical candidates result in a relatively low ($\leq$15%) surgical mortality rate for thoracic aortic aneurysm repair [27]. However, the operative mortality rate is nearly 50% in patients requiring emergency treatment [28,29]. The decision for surgical repair becomes increasingly complicated if patients have serious coexisting illnesses such as chronic obstructive pulmonary disease, coronary ischemia, renal failure, or multiorgan trauma [30].

The current status of traumatic aortic disruption and traditional repair is not ideal. Approximately 80—90% of patients die in the field [31—33]. Traumatic rupture of the thoracic aorta is often immediately fatal, and patients who survive frequently have multiple system injuries, including pulmonary contusions, cranial injuries, multiple fractures, and solid organ injuries. Operative repair of a thoracic aortic injury in the setting of these other injuries is associated with significant morbidity and mortality, and studies [34,35] have reported mortality rates approaching 18—28% and paraplegia rates of 2.3—14% among survivors. Because of the high risk of immediate surgery, some have advocated delaying intervention with antihypertensive therapy until the patient is more stable [36,37]. Although this has enabled surgery after recovery from the acute trauma, complications remain high and delayed open surgery may lead to in-hospital death in 2–5% of patients [38]. Patients treated for non-traumatic rupture have an even more unfavorable prognosis. Rupture generally occurs in elderly patients with multiple medical risk factors and extensive aortic lesions, which account for the poor outcomes observed after surgical treatment. Thoracic aortic emergencies, such as contained or free rupture of thoracic aortic aneurysm, acute type B dissection, and traumatic rupture of the aorta, have always been considered a surgical challenge. The association of acute aortic syndrome with older age and comorbidities has shown a high mortality rate [39,40]. Meta-analyses of thoracic aortic repair studies reported a 10–22% incidence of paraplegia following emergent open repair of thoracic aortic aneurysm.

Following the initial reports of stent-graft repair of abdominal and thoracic aneurysm disease, surgeons have considered this minimally invasive approach for treatment of thoracic aortic disruptions [41]. Retrospective series have shown successful emergency repair of acute thoracic aortic disease by endovascular stent-grafting [42–46]. Its use eliminates the need for extensive surgery with the attendant risks of anticoagulation, single-lung ventilation, aortic cross-clamping, and thoracotomy.

The results of our meta-analysis indicate that TELG is associated with lower procedure related mortality and paraplegia rates as compared to open repair. Stroke rates were not different. Our population included patients with thoracic aortic pathology of varying etiology; traumatic (68% of the patients) and non-traumatic lesions were included. This does not appear to alter the validity of our results since demographic characteristics and associated injuries or comorbidities had similar distribution between the comparison groups and p values for heterogeneity were not significant, additionally omitting each study and repeating the analyses did not alter the findings. A limitation of our study is related to the fact that all reports were retrospective cohort studies without randomization, however due to the relatively small number of patients with these lesions as well as ethical issues it is unlikely that there will be comparison of TELG and open repair in a prospective randomized trial. Our experience supports the findings of our meta-analysis. We had no procedure related mortality and no paraplegia/paraparesis. The relatively significant incidence of stroke in our patients can be attributed to manipulation of wires and catheters in the aortic arch leading to athero-embolism. Coverage of the left subclavian was well tolerated. Stent-graft collapse is a significant problem with TEVAR. This is caused by the relatively acute angle of the aortic arch in younger patients leading to poor apposition of the endograft to the inferior aspect of the arch. Coverage of the left subclavian with an additional stent-graft or deployment of a Palmaz® stent may be necessary to address this problem. Also, the small size of the thoracic aorta frequently necessitates the use of abdominal aortic cuffs since the smallest Gore TAG® device available in the USA is 26 mm in diameter.

To conclude, endovascular repair appears to have lower mortality and spinal cord ischemic complications, even for high-risk patients. Although short-term data are encouraging, concerns have been raised regarding stent-graft failure, collapse due to the acute angle of the aortic arch in young patients, stent-graft migration and need for repeat intervention. Obviously, the issue of durability of endovascular repair is highly relevant in younger patients and patients with an endovascular graft for aortic rupture will have to be closely monitored for a long period of time. Nevertheless many centers have reported a shift in the way thoracic aortic rupture is managed, using the endoluminal approach as the procedure of choice. Since it is unlikely that randomized trials will be performed, prospective population based studies including all patients with thoracic aortic rupture will provide the best attainable level of evidence on this issue.

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