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Traumatic Aortic Injury: Single-center Comparison of Open versus Endovascular Repair

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Background: Conventional open repair is a suboptimal therapy for blunt traumatic aortic injury (BTAI) due to the high postoperative mortality and morbidity rates. Recent advances in the thoracic endovascular repair technique may improve outcomes so that it becomes an attractive therapeutic option. ***Materials and Methods:*** From August 2003 to March 2012, 21 patients (mean age, 45.81 years) with BTAI were admitted to our institution. Of these, 18 cases (open repair in 11 patients and endovascular repair in 7 patients) were retrospectively reviewed and the early perioperative results of the two groups were compared. ***Results:*** Although not statistically significant, there was a trend toward the reduction of mortality in the endovascular repair group (18.2% vs. 0%). There were no cases of paraplegia or endoleak. Statistically significant reductions in heparin dosage, blood loss, and transfusion amounts during the operations and in procedure duration were observed. ***Conclusion:*** Compared with open repair, endovascular repair can be performed with favorable mortality and morbidity rates. However, relatively younger patients who have acute aortic arch angulation and a small aortic diameter may be a therapeutic challenge. Improvements in graft design, delivery sheaths, and graft durability are the cornerstone of successful endovascular repair.

Key words: 1. Endovascular stent
2. Trauma
3. Aorta

INTRODUCTION

Blunt traumatic aortic injury (BTAI) is highly lethal. About 80% of patients with BTAI die at the scene of the injury [1], and the mortality rate during hospitalization without any treatment is about 81% [2]. In most of these patients, a sudden decelerating force acts on the isthmic portion that connects the fixed aortic arch and the relatively mobile descending thoracic aorta. The tear is transverse in 80% to 90% of the patients. BTAI was traditionally treated with an open surgical approach. It consisted of clamp-and-sew and distal aortic perfusion with cardiopulmonary bypass or left heart bypass. The improvement of perioperative care and maintenance of distal aortic perfusion during aortic cross-clamp has reduced terrible complications such as spinal cord ischemia. Nevertheless, the reported mortality and paraplegia incidence of a group undergoing open surgery were 20.2% and 5.7%, respectively [3]; this is mostly because many of the patients had severe associated injuries, and such injuries serve as an independent mortality factor. Indeed, a trauma severity score such as the injury severity score (ISS) has a very close correlation with the mortality rate of BTAI patients [4]. Moreover, systemic heparinization, one-lung ventilation, and aortic cross-clamping can cause further multi-organ dysfunction. To overcome these

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Table 1. Patients' characteristics

	Open repair group	Endovascular repair group	p-value
Age (yr)	43.18	40	0.710
Male:female	6:5	6:1	0.316
Mean ISS	26.27	31.14	0.231
Time to intervention (hr on hr)	95.09	32.57	0.425

ISS, injury severity score.

limitations, an endovascular approach was introduced in the late 1990s, and good results with endovascular repair have been reported [5]. In this study, we retrospectively reviewed our cases of endovascular repair and compared it with open repair in order to analyze the impact of endovascular repair on perioperative results.

MATERIALS AND METHODS

From August 2003 to March 2012, 21 patients were diagnosed with BTAI at Catholic University of Daegu School of Medicine. Of these, 18 patients (mean age, 41.94 years; female:male=6:12) who had an injury at the isthmic portion were evaluated; the excluded cases were ascending aorta injury in 2 cases and a combined distal arch aneurysm requiring hybrid thoracic endovascular aortic repair in 1 case. During the study period, 11 patients underwent open repair and 7 patients underwent endovascular repair. In all 18 cases, preoperative diagnosis was achieved using a contrast enhanced computed tomography (CT) scan. In the early phase of treatment, hemodynamic stabilization and strict blood pressure control were performed expeditiously. As a general rule, we performed open or endovascular repair as soon as possible. Delayed treatment (treatment beyond 24 hours of admission) was considered only for patients with severe non-aortic injuries. In Catholic University of Daegu School of Medicine, endovascular repair was used as a first treatment strategy beginning in August 2008. The patients' characteristics and perioperative results were retrospectively reviewed using the hospital records and radiologic findings. The clinical characteristics of the patients are summarized in Table 1.

1) Open repair techniques

All operations were performed under general anesthesia with a double lumen endotracheal tube. No patients underwent cerebrospinal fluid drainage. The patients were placed in the right lateral decubitus position with the left pelvis rotated posteriorly to access the left femoral vessels. After left femoral artery and vein isolation, left posterolateral thoracotomy in the fourth intercostal space was performed. Meticulous dissection was performed around the left side aortic arch vessels and distal descending thoracic aorta for proximal and distal clamping. After systemic heparinization and femoral cannulation, cardiopulmonary bypass was carried out, along with mild systemic hypothermia (32^{o}C to 34^{o}C) for spinal cord protection. Aortic clamping was applied proximally between the left common carotid and left subclavian arteries, and distally at the distal descending thoracic aorta beyond the site of injury. During the aortic cross-clamping, cardiopulmonary bypass flow was adjusted to 60% to 70% of the maximum flow rate in order to maintain the femoral blood pressure at 70 to 80 mmHg. After the aorta was opened longitudinally, the injured aortic edges were carefully debrided and any of the bleeding intercostal arteries were controlled. The injured aorta was repaired with graft interposition using 4-0 Prolene continuous sutures (Ethicon, Somerville, NJ, USA). After protamine reversal, the wound was closed in layers. If necessary, combined operations were performed immediately after aortic repair.

2) Endovascular repair techniques

All operations were performed under general anesthesia in the operating room. A portable C-arm fluoroscopic device was used in all of the cases. After induction, all of the patients underwent cerebrospinal fluid drainage through the third lumbar space, and cerebrospinal fluid pressure was kept below 10 mmHg during the operation. The femoral artery was exposed through a small longitudinal incision and cannulated with a sheath. Percutaneous access of the contralateral femoral artery was performed, and a sheath was introduced. Under fluoroscopic guidance, the marked pigtail catheter for measuring treatment lengths and landing zones was introduced into the contralateral femoral artery. A soft guidewire was advanced through the sheath into the femoral artery until it reached the ascending aorta. A Bern catheter was used to exchange the soft wire for a stiff one. An endovascular stent-graft (S&G Biotech, Seoul, Korea) was then introduced until it lay within the distal aortic arch. Fluoroscopy with contrast was performed in order to position the stent-graft for deployment. During deployment, the systolic blood pressure was lowered below 100 mmHg. The proximal and distal landing zones of at least 2 cm were confirmed, and the device was deployed; the completion angiogram was then obtained. After deployment of the stent-graft, the mean blood pressure was kept above 90 mmHg. All wires and sheaths were removed.

3) Statistical analysis

For normally distributed continuous data, the Student's t-test, non-normally distributed data, and Mann-Whitney U-test were used. The chi-squared test was used for categorical data. Statistical analysis was performed with SPSS ver. 12.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

1) Open repair group

All cases were treated with graft interposition; in 3 cases treatment was delayed due to large liver contusion and cerebral hemorrhage. After aortic repair, a combined operation was performed in 5 cases. One patient required deep hypothermic circulatory arrest because of a preoperative rupture and severe hemodynamic instability. Overall, the mortality rate was 18.2% (2/11). One patient died of acute renal failure requiring peritoneal dialysis, and another patient died of intractable bleeding due to underlying severe coagulopathy. Postoperatively, there was no paraplegia. Mean cardiopulmonary bypass time and mean aorta cross-clamping time were 103.90 minutes (range, 50 to 305) and 57.27 minutes (range, 28 to 83), respectively.

2) Endovascular repair group

Technical success was achieved in all of the cases. All of the patients underwent single graft surgery. In 1 case, treatment was delayed due to cerebral hemorrhage. All patients had cerebrospinal fluid drainage. The left subclavian artery was covered in 3 patients (42.85%), but no patient suffered from upper arm ischemia or stroke. The mean stent-graft diameter and length were 26 mm (range, 24 to 36) and 115.71 mm (range, 100 to 130). The overall mortality rate was 0% (0/7), and there was no endoleak or paraplegia. Five patients underwent the procedure without systemic heparinization due to the risk of bleeding. The mean interval from diagnosis to intervention was 70.78 hours, and no patient suffered from aortic rupture during the waiting period. There were no statistically significant differences between the two groups in the mortality rate, and the duration of intensive care unit and hospital stay. However, the statistically significant differences between the two groups included heparin dosage, blood loss, and transfusion amounts during operation, as well as procedure time (Table 2).

Table 2. Comparative analyses between the repair and endovascular groups based on the postoperative results

	Open repair group	Endovascular group	p-value
No. of deaths (%)	2 (18.18)	0 (0)	0.497
Mean ICU stay time (hr)	192.0	217.71	0.774
Mean hospital stay time (day)	27	19	0.297
Mean heparin dosage (units)	22,181.81	1,857.14	0.000
Mean blood loss (mL)	2,045.45	614.29	0.006
Mean transfusion amount (units)	14	4.14	0.01
Mean procedure time (hr)	430.73	114.43	0.000

ICU, intensive care unit.

DISCUSSION

According to their natural history, most aortic ruptures will occur within 24 hours of initial presentation. Therefore, reducing aortic wall stress with anti-hypertensive medication and restrictive fluid resuscitation should be the first priority. Traditional diagnostic methods such as chest X-ray, transesophageal echocardiography, and aortography have limited sensitivity and specificity. Therefore, even if the initial chest X-ray appears normal, a CT scan should be considered for confirmation depending on the mechanism of the injury [6,7]. Information about the aortic arch vessel anatomy including both vertebral arteries, the diameter of the normal aortic segment, and the status of the iliac and femoral arteries should also be obtained. Several anatomic variants such as ductus diverticulum and aortic spindle can mimic an aortic injury [7,8]. Azizzadeh et al. [4] introduced 4 categories of aortic injury based on CT findings. They defined grade 1 as intimal tear, grade 2 as intramural hematoma, grade 3 as pseudoaneurysm, and grade 4 as free rupture; medical management was suggested for grade 1 injuries. Our patients exhibited 17 cases of grade 3 and 1 case of a grade 4 injury.

There are two major changes that occur in different periods during the treatment of BTAI. The first is the introduction of delayed repair, and the second is the application of endovascular treatment. There are still some conflicting reports about the optimal time for intervention. Pate et al. [9] reported that if hemodynamic stability was maintained during the initial 4 hours of treatment, aortic rupture rarely occurred before repair because of the reduction of aortic wall stress. Camp and Shackford [10] also reported that most causes of mortality during the early period of hospitalization were associated with combined injury rather than with aortic rupture itself. Therefore, they concluded that in high-risk patients early stabilization followed by delayed aortic repair is favorable.

On the other hand, there are some limitations of delayed repair. In the state of increased intracranial pressure, lowering the blood pressure limits brain perfusion and this can potentially cause brain injury. Progressive dilatation of pseudoaneurysms can compress the trachea and left main bronchus. Finally, despite aggressive anti-impulse therapy, there is a risk of delayed free rupture [11,12]. Early repair is advantageous for the total hospital stay period, total hospitalization cost, and the ability to perform combined aortic and non-aortic procedures at the same time [13,14]. Altogether, the trends in recently published papers are toward favoring delayed repair [2,15]. However, early repair should be considered for patients with massive hemothorax, rapid growth of a pseudoaneurysm, or active contrast leakage based on a CT scan. Starnes et al. [16] also recommend urgent repair in cases of periaortic hematoma at the aortic arch level exceeding 15 mm and when the initial systolic blood pressure is less than 90 mmHg, because these are predictors of death from BTAI.

Currently, endovascular approaches for treating BTAI are being considered as the preferred method due to the avoidance of thoracotomy, one-lung ventilation, and aortic cross-clamping. There are numerous articles comparing endovascular repair with open repair, but because BTAI is a rare injury, the number of patients has been small in most studies. Recently, several meta-analyses of retrospective studies on BTAI were published [3,17]. Tang et al. [17] reported that in 699 patients with a similar level of ISS (meta-analysis 4), the endovascular repair technique and open repair had a mortality rate of 7.6% and 15.2%, a rate of paraplegia of 0% and 5.6%, and a rate of stroke of 0.85% and 5.3%, respectively, among which the rates were significantly lower with endovascular repair. In 2008, the American Association for the Surgery of Trauma published a multicentered prospective study of 193 patients that included endovascular repair in 125 patients compared to open repair in 68 patients [18]. The study also concluded that mortality was significantly lower in the endovascular repair group, even in the patients with major associated injuries. Based on these results, the Society for Vascular Surgery suggested that endovascular repair should be performed preferentially over open surgical repair [19].

However, there are several considerations for endovascular repair in BTAI. The first is the device-related complications, which have an incidence of about 20%. Based on this rate, Caffarelli et al. [20] reported early favorable outcomes from a deliberate nonoperative strategy. Of a total of 53 patients, 29 patients were treated with planned, nonoperative management, and the in-hospital survival rate was 93%. The most common device-related complication is endoleak. Patients with BTAI tend to be younger than patients with other degenerative aneurysmal diseases. Acute angulation of the aortic arch and the relatively small aortic diameter can cause excessive oversizing of the graft in these patients. The average diameter of the aorta proximal to the lesion is 18 to 26 mm, and oversizing can result in graft infolding or collapsing, and acute aortic occlusion [8,19]. Atkins et al. [21] suggested that conventional open repair should be considered in patients whose outer aortic wall diameter is less than 18 mm or who are under 18 years old.

The second consideration is left subclavian artery (LSA) coverage. The minimum length of the normal proximal landing zone required to perform endovascular repair without

LSA coverage is about 1.5 to 2 cm. In BTAI, the incidence of LSA coverage is 25%, and this results in a perioperative stroke rate of 1.19% and an arm ischemia rate of 4.06%, but it does not show a significant difference in mortality [22]. Of our patients, 37.5% (3/8) required coverage, and there was no neurologic deficit during the follow-up period. Cooper et al. [23] also reported that preemptive LSA revascularization had less effect on the prevention of neurologic complications. Therefore, the patency of the right subclavian artery should be evaluated via angiography during endovascular repair, and selective revascularization rather than routine revascularization should be considered in cases of an atretic or a hypoplastic right subclavian artery [19].

The third consideration is heparinization. As previously mentioned, a reason for paying attention to delayed open repair is the risk of fatal bleeding associated with systemic heparinization in patients who have cerebral or intraperitoneal hemorrhage. Unlike other diseases, endovascular repair for BTAI has a relatively short procedural time; therefore, it can be successfully performed with a low-dose of heparin. Garcia-Toca et al. [24] reported that 84% of endovascular repair patients (20/24) did not undergo heparinization, and only 1 patient developed a thrombotic complication. Thus, whether to use heparin and its optimal dosage should be based upon each patient's risk of bleeding and thromboembolism.

The fourth consideration is the cerebrospinal fluid drainage. In contrast to degenerative aneurysmal disease, BTAI requires less graft coverage length, and there is a risk of epidural hematoma in coagulopathic patients; thus, cerebrospinal fluid drainage is not routinely indicated [2,19]. However, Desai et al. [25] reported that BTAI itself can increase the risk of paraplegia regardless of the aortic coverage length. All of our patients received cerebrospinal fluid drainage, and there was no paraplegia or drainage-related complications.

The main limitation of this study was the small sample size and the use of a retrospective review of a non-randomized patient sample.

CONCLUSION

Our study did not show a statistically significant advantage of endovascular repair in terms of mortality and hospital stay. However, there was a trend toward a lower mortality rate in the endovascular repair group with a similar ISS and time to intervention. In conclusion, an endovascular approach can be performed expeditiously and even without heparinization in selected cases. The long-term durability of endovascular repair should be evaluated because there is uncertainty of the long-term aortic conformational changes in these relatively younger patients.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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