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Early Experiences with the Endovascular Repair of Ruptured Descending Thoracic Aortic Aneurysm

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Background: The aim of this study was to report our early experiences with the endovascular repair of ruptured descending thoracic aortic aneurysms (rDTAAs), which are a rare and life-threatening condition. ***Methods:*** Among 42 patients who underwent thoracic endovascular aortic repair (TEVAR) between October 2010 and September 2015, five patients (11.9%) suffered an rDTAA. ***Results:*** The mean age was 72.4±5.1 years, and all patients were male. Hemoptysis and hemothorax were present in three (60%) and two (40%) patients, respectively. Hypovolemic shock was noted in three patients who underwent emergency operations. A hybrid operation was performed in three patients. The mean operative time was 269.8±72.3 minutes. The mean total length of aortic coverage was 186.0±49.2 mm. No 30-day mortality occurred. Stroke, delirium, and atrial fibrillation were observed in one patient each. Paraplegia did not occur. Endoleak was found in two patients (40%), one of whom underwent an early and successful reintervention. During the mean follow-up period of 16.8±14.8 months, two patients died; one cause of death was a persistent type 1 endoleak and the other cause was unknown. ***Conclusion:*** TEVAR for rDTAA was associated with favorable early mortality and morbidity outcomes. However, early reintervention should be considered if persistent endoleak occurs.

Key words: 1. Aneurysm
2. Aorta
3. Rupture
4. Stents

INTRODUCTION

Ruptured thoracic aortic aneurysms rarely occur, but once they develop, the overall mortality is so high that the number of deaths caused by these ruptures is not trivial. The incidence of this condition has been estimated as only five per 100,000 [1], but it has been reported to cause 179 per 100,000 deaths [2]. Approximately 30% of thoracic aortic ruptures have been reported to be localized in the descending aorta [1]. Thoracic endovascular aortic repair (TEVAR) with or without a hybrid procedure is a particularly attractive therapeutic option for ruptured descending thoracic aortic aneurysm (rDTAA). Favorable results have been reported in many cases of the total or hybrid endovascular management of intact DTAA over the more than 20 years that have passed since the first report of a successful early outcome of

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TEVAR for DTAA [3]. Moreover, the current literature has shown that the early morbidity and mortality associated with this condition can be improved with endovascular repair rather than traditional open repair [4-6]. However, the currently available data are limited to a small series of cases involving TEVAR performed to treat rDTAA, so the outcomes cannot be considered conclusive. In the present study, we evaluated the early clinical results of patients with rDTAA managed with TEVAR performed at a single center, with the expectation that our results will contribute to the further elucidation of the outcomes of endovascular repair as a treatment for this rare but life-threatening condition.

METHODS

The study protocol was reviewed by the institutional review board of SMG-SNU Boramae Medical Center in Korea (IRB approval number: 26-2015-135) and was approved as a minimal-risk retrospective study that did not require informed patient consent.

1) Patients

From October 2010 to September 2015, 42 patients underwent TEVAR with or without a hybrid procedure for various aortic pathologies at our institution. Among them, seven patients suffered a thoracic aortic rupture. The most frequent cause of the rupture was DTAA, which developed in the five patients who were the subjects of this study. The other two patients, who experienced a blunt traumatic aortic injury and a pseudoaneurysm that developed at the proximal anastomosis site of a previously performed thoracoabdominal aortic repair, respectively, were excluded. Since TEVAR was first introduced for the management of rDTAA at our institution in May 2012, the procedure has been a first-line treatment modality for rDTAA. Rupture was defined as the presence of extravasation around the aorta that manifested as hemoptysis, hemothorax, and/or mediastinal hematoma on computed tomography (CT) imaging. The presence of only a contained mediastinal hematoma was defined as a contained rupture.

2) Endovascular techniques

We routinely performed CT angiography to assess the anatomical suitability of TEVAR. All endovascular repairs were performed under general anesthesia and guided by a vascular C-arm in the operating room. Although we usually considered spinal drainage before TEVAR when it was necessary for the coverage length of the aorta to exceed 200 mm, allowing the distal end of the endograft to reach the celiac axis, no patients in this study underwent preemptive spinal drainage. For access, an inguinal oblique incision was made, and purse string sutures were placed at the common femoral artery to control bleeding at the puncture site. We used a single stent graft brand, SEAL Thoracic Stent Graft (S&G Biotech Inc., Seongnam, Korea), which was made of nitinol wire and polyester fabric. The diameter of the stent graft was 20% larger than the proximal and distal landing zones of the native aorta. If the diameter difference between the proximal and distal landing zones was relatively large, we chose a tapered stent graft. The length of the landing zone had to be at least 15 mm to avoid endoleak and graft migration. When it was necessary to expand the landing zone, we performed a preemptive right common carotid artery (RCCA) to left common carotid artery (LCCA) bypass and/or a LCCA to left subclavian artery (LSA) bypass. During emergency operations, we usually first covered the LSA ostium to obtain a more proximal landing zone and then evaluated the necessity of LSA revascularization. Accurate deployment and endoleaks were assessed by completion angiography, and we defined the absence of type I or III endoleak as procedural success. All patients were admitted to the intensive care unit (ICU) following TEVAR for postoperative care. CT angiography was routinely performed in all patients before discharge.

3) Follow-up and statistics

We reviewed patients' electronic medical records and, if necessary, interviewed patients or their families by phone. No patient was lost to follow-up. Routine follow-up CT angiography was conducted six months after discharge and then annually. However, in patients who exhibited untreated endoleak, CT angiography was conducted monthly. We investigated late mortality and aortic events, such as aortic reintervention, re-rupture, newly appeared endoleak, and retrograde aortic dissection. Since our study included only five participants, the clinical data are shown as either frequencies

Table 1. Preoperative baseline characteristics and clinical presentation (N=5)

Characteristic	Value
Age (yr)	72.4±5.1
Male	5
Comorbidities	
Hypertension	4
Hyperlipidemia	1
Diabetes mellitus	0
Smoking	2
Chronic obstructive pulmonary disease	1
Coronary artery disease	1
Cerebrovascular accident	1
Chronic kidney disease (>2)	3
Stage 2	1
Stage 3	1
Stage 4	0
Stage 5	1
Prior cardiac surgery	0
Prior aortic intervention	1
Presentation	
Hoarseness	3
Hemoptysis	3
Hemomediastinum	0
Hemothorax	2
Associated dissection	0
Hypovolemic shock	3
Aneurysm diameter (mm)	62.7±18.4
Saccular aneurysm	1

Values are presented as mean±standard deviation or number.

or mean±standard deviation.

RESULTS

1) Characteristics of patients and operations

During the study period, five patients underwent endovascular repair with TEVAR for rDTAA. The characteristics of the patients are summarized in Table 1. The mean age was 72.4±5.1 years, and all the patients were male. Most patients had hypertension (n=4) and at least stage 2 chronic kidney disease (n=3). None of the patients were diabetic. The mean diameter of the DTAA was 62.7±18.4 mm. Hemoptysis and hemothorax were present in three (60%) and two (40%) patients, respectively. The maximum diameter of the aortic aneurysm was 62.7±18.4 mm. Hypovolemic shock was observed in three patients who underwent emergency surgery. Hybrid TEVAR was performed in three patients: an emergency RCCA to LCCA bypass with double ligation of the proximal LCCA followed by zone 1 deployment of the stent graft (Fig. 1); a double transposition procedure (transposition of the LCCA onto the innominate artery, along with transposition of the LSA onto the transposed LCCA) under hemisternotomy followed by zone 1 deployment of the stent graft; and a left carotid to LSA bypass with an 8-mm Dacron graft followed by zone 2 deployment of a stent graft. The other two rDTAA patients were treated by isolated TEVAR. One of them suffered retroesophageal hematoma caused by a delayed type III endoleak that developed two years after combined TEVAR and endovascular abdominal aortic aneurysm repair (EVAR). The other patient suffered a distal DTAA.

The mean operation time was 269.8±72.3 minutes. One patient who was treated with emergency isolated TEVAR to address a distal DTAA rupture experienced an access problem. His bilateral common iliac arteries were so narrowed that the stent graft device could not be advanced through them. However, there was not enough time for surgical exposure of the iliac artery and anastomosis for the access conduit; therefore, we dilated the right iliac artery with a 7-mm balloon catheter to successfully deliver the stent graft. The total length of aortic coverage was 186.0±49.2 mm. Revascularization of the LSA was performed in 66.7% of the patients who underwent LSA coverage (Table 2).

2) Early outcomes

Table 3 shows the postoperative morbidity and early mortality outcomes in this study. Stroke, delirium, and atrial fibrillation were each diagnosed in one patient. Paraplegia did not occur. Acute respiratory distress syndrome (ARDS) developed in one patient who presented with a tension hemothorax preoperatively. Technical success was achieved in four patients (80%). A single case of type I endoleak was found on completion angiography, but the endoleak was so faint that we decided to wait and observe subsequent developments without any further adjunctive procedures, with the expectation that the endoleak would disappear. However, postoperative CT angiography revealed a persistent endoleak, and it was addressed by a successful reintervention before

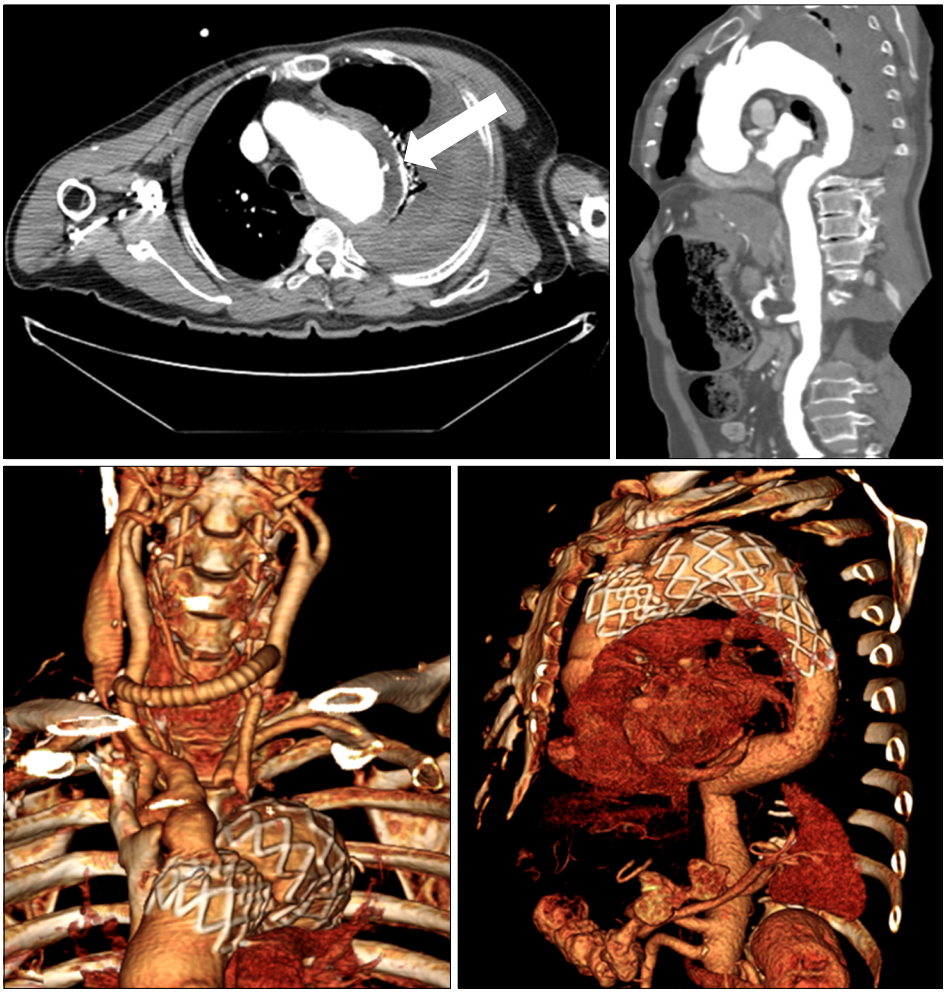

Fig. 1. (A, B) Preoperative CT angiography shows a ruptured (white arrow) descending thoracic aortic aneurysm with mediastinal shift due to a large hemothorax. (C, D) Six-month follow-up CT angiography shows the carotid to carotid artery bypass with ligation of the left common carotid artery followed by zone 1 deployment of the stent graft. CT, computed tomography.

Table 2. Characteristics of the operations (N=5)

Characteristics of the operations	Value
Operation time (min)	269.8±72.3
Access problem	1
Graft brand	
S&G	5
Maximum graft diameter (mm)	42.0±6.1
Total graft length (mm)	186.0±49.2
Hybrid procedure	3
Coverage of the left subclavian artery	3
With revascularization	2
Coverage of the common carotid artery	2

Values are presented as mean±standard deviation or number.

discharge. Another endoleak was thought to be type III. In fact, this endoleak was not observed on completion angiography but was instead identified on CT angiography performed at a later point. This endoleak was considered recurrent because the rupture was associated with a delayed type III endoleak, which developed two years after a combined TEVAR and EVAR procedure. No 30-day mortality was observed. The average length of the ICU stay was 2.7±1.2 days, while the mean hospital stay was 11.8±11.1 days.

3) Late outcomes

During the mean follow-up period of 16.8±14.8 months, none of the patients developed a new endoleak, but two patients (40%) died, including the patient who had suffered the recurrent endoleak. When he visited our outpatient department after discharge, reintervention was strongly recommended, but was rejected by the patient. Approximately 3.5 months following discharge, he presented to the emergency department in cardiac arrest. We assumed that the cause of the cardiac

Table 3. Early outcomes of the endovascular repair of ruptured descending thoracic aortic aneurysms

Outcomes	Value
Deployment success	4
Stroke	1
Delirium	1
Paraplegia	0
Cardiac complications	1
Pulmonary complications	1
Acute kidney injury	0
Reoperation for bleeding	0
Endoleak	2
Aortic dissection	0
Reintervention	1
30-Day mortality	0
Intensive care unit stay (day)	2.7±1.2
Hospital stay (day)	11.8±11.1

Values are presented as mean±standard deviation or number.

arrest was a rerupture associated with the persistent endoleak. The other patient died seven months after discharge and had undergone successful endovascular repair without postoperative complications except for transient atrial fibrillation. He rejected a six-month follow-up via CT angiography. The cause of his late death was not able to be determined in a phone interview.

DISCUSSION

We described and evaluated the outcomes of five cases of the endovascular repair of rDTAA, which is a quite rare and life-threatening condition. All patients who underwent TEVAR survived and were discharged, but two patients died within a year thereafter. In one case, persistent type III endoleak resulted in early rerupture of the DTAA.

Few data are available regarding the overall prognosis of rDTAA. Johansson et al. [1] reported that 54% of patients with ruptured thoracic aortic aneurysm died within six hours after the onset of their symptoms, and only 41% of patients were alive upon arrival to the hospital arrival. The overall mortality rate was more than 95%, and in their series, 30% of patients had an rDTAA.

The conventional open repair of rDTAA has been associated with high mortality rates, ranging from 22% to 45% [7-11]. According to a recently published United States population-based analysis [11], TEVAR rates for rDTAA increased steeply from 0.1 per million in 2005 to 0.7 per million in 2008, while open repair rates were stagnant during the same period. The operative mortality rate was more than 50% in 1998 but significantly decreased to 23.4% in 2008 due to the introduction of endovascular repair (odds ratio, 0.41; p=0.001). TEVAR with or without a hybrid debranching procedure can offer prompt sealing of the rupture site to prevent hypovolemic shock and avoid aortic cross-clamping and thoracotomy. These advantages over open repair may play an important role in the recently published improved results. Jonker et al. [4] identified 224 patients with rDTAA through a systemic review of all studies and databases published since 1995 and found that TEVAR was associated with a significantly lower 30-day mortality rate in comparison with open repair (19% versus 33%; odds ratio, 2.15). This result agreed with the outcomes of a multicenter study that included 87 patients from seven referral centers. Hypovolemic shock was present in 21.8% of the patients, and the 30-day mortality rate was 18.4%. In a small but recent series that included 23 patients, 21.7% were in shock before surgery, and the 30-day mortality rate was greatly reduced to 4.3%; however, the in-hospital mortality rate was 21.7% [6].

The clinical presentation has been found to be closely related to the prognosis of the endovascular repair of rDTAA. Hypovolemic shock and hemothorax have been reported to be strong predictors of early mortality [5,6]. Hypovolemic shock at presentation indicates that excessive blood loss can result in systemic hypoperfusion with ischemic multi-organ injuries. In our study, all patients with hemothorax (n=2) were in hypovolemic shock, and one of them, who presented with tension hemothorax, suffered postoperative ARDS despite complete intrathoracic decompression via thoracic drainage. Tension hemothorax and tension hemomediastinum can cause ventilatory failure and secondary esophageal necrosis, which is thought to be caused by an acutely elevated intrathoracic or mediastinal pressure [6,12,13]. Of the three patients who presented with hemoptysis in this study, one patient suffered from postoperative delirium and transient atrial fibrillation. In addition, three patients complained of hoarseness before descending thoracic aortic rupture. We think that hoarseness

may be a risk factor for aortic rupture, though little is known about the association between hoarseness and rDTAA. No paraplegia was observed, but one stroke occurred postoperatively due to interruption of the left posterior inferior cerebellar artery (PICA). Although stroke developed in the patient who underwent covering of the LSA with a stent graft without revascularization, the association between PICA-related stroke and simple occlusion of the LSA is not clear [14]. In practice, it is not easy to routinely revascularize the LSA when emergency or urgent TEVAR is required for life-threatening rDTAA. Therefore, revascularization should be performed on an individualized basis for this subset of patients who require coverage of the LSA [15]. Based upon limited data, the incidence rates of paraplegia after the endovascular repair of rDTAA have been reported to range from 3.1% to 8.7%. The incidence rates of periprocedural stroke have been reported to range from 4.1% to 26.1% [4-6]. These results are encouraging, considering that the incidence rates of paraplegia and stroke after open repair have been reported to be as high as 12.5% and 25%, respectively [8,16].

However, the current evidence supporting the superiority of TEVAR is too limited to recommend choosing endovascular management as the first line of therapy for rDTAA, as it is based on small case series. In addition, endovascular management has inherent problems that should be addressed during follow-up, including endoleak, endograft infection with or without fistula, and retrograde aortic dissection. In this study, one case of type I endoleak, which was found during completion angiography, was addressed with early reintervention, while another case of type III endoleak, belatedly found upon CT angiography, led to a late death. In reality, urgent or emergency situations caused by rDTAA may not allow for the optimal selection of a stent-graft device because the large amount of blood loss may reduce the aortic diameter; even though the aortic sizing may be accurate, an adequately sized endograft may not be immediately available. Therefore, the rate of endograft-related complications tends to increase in patients with rDTAA. A recent meta-analysis found the rates of endoleak and endograft-related complications to be 63% and 59%, respectively. At some point during follow-up, a type I endoleak developed in 10% of patients, and 4.6% of the patients with available follow-up data died of endograft-related complications [4]. Early outcome results of a smaller series of rDTAA patients likewise showed high rates of endoleak of approximately 18% [5,6].

In conclusion, the rare cases of rDTAA that have been repaired using endovascular techniques showed favorable early mortality and morbidity outcomes. However, endograft-related complications, such as endoleaks, should be addressed in the early stage of follow-up. Although the endovascular repair of rDTAA in our study was successful, and no complications were observed, continued surveillance of these patients is imperative.

CONFLICT OF INTEREST

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

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