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Postoperative Outcomes of Complex Aortic Aneurysm Repair Using Hybrid Open-Endovascular Techniques

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Abstract

Aortic disease becomes more prevalent with age and can result in acute aortic conditions including aneurysm, dissection, intramural hematoma and penetrating ulcers. Repair techniques for these conditions remain controversial due to the varying outcomes of studies. This retrospective study collected and analyzed data from twenty-three (23) patients with complex aortic aneurysms repaired using hybrid open-endovascular techniques.

A high percentage of patients (82.6%) suffered from multiple comorbidities, including hypertension, hyperlipidemia, renal disease, coronary artery disease, congestive heart failure and prior aortic procedures. All patients presented with ASA scores 3 or 4. Eleven patients (47.8%) presented with aneurysms of the ascending, transverse and descending arch, and seven patients (30.4%) with thoracoabdominal aneurysm. 78.3% of patients underwent thoracic vessel debranching, while the remainder underwent visceral vessel debranching (13.0%) or thoracic and visceral debranching (8.7%).

No patients suffered visceral ischemia, spinal cord injury, extremity amputation or reoperation for bleeding post-operatively. Two patients suffered minor stroke (8.7%) and one patient (4.3%) had major stroke. Three patients (13.0%) suffered temporary kidney injury and one patient (4.3%) developed renal failure requiring dialysis. Four patients (17.4%) developed Type II stent graft endoleaks. All patients had patent grafts. Reintervention occurred in two patients (8.7%). Thirty-day mortality occurred in three patients (13.0%). These results are within the range reported in other studies involving hybrid repair of aortic conditions, and show that hybrid open-endovascular repair is a feasible alternative in high-risk patients.

Keywords: Aortic aneurysm; Abdominal aortic aneurysm; Thoracic aortic aneurysm; Vascular surgical procedures

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Introduction

The prevalence of aortic disease increases with age due to many factors, including higher oxidative stress, endothelial dysfunction and arterial wall changes [1]. The most emergent and acute forms of the diseases include aneurysm, aortic dissection, aortic intramural hematoma and aortic penetrating ulcers. These aortic conditions often require intervention. However, debate continues as to the optimal techniques to repair these disorders.

Open repair of aortic aneurysm has historically high rates of morbidity and mortality [2], necessitating the development of alternative practices, especially in complex aneurysms. Hybrid repair has been increasingly used as an alternative to open repair techniques since the procedure was first described in 1999 [3-5]. Hybrid repair involves debranching of the aortic arch and/or of the visceral or renal vessels, followed by supra aortic and visceral revascularization, then relining of the diseased aortic region with stent grafts [6]. The appeal of the hybrid approach (depending on aneurysm location) includes avoidance of pleural or double cavity invasion, hypothermic cardiac arrest and prolonged aortic cross-clamping [7,8].

However, hybrid techniques have shown variable success when

compared with open repair. Some studies have shown similar postoperative mortality and survival in patients undergoing hybrid repair of aortic aneurysm [9-11] and others have concluded that given the morbidity and mortality data, hybrid repair should be chosen on a case-by-case basis rather than applied broadly to a higher-risk patient population [8,12]. Other analysis of hybrid repair has determined that outcomes are acceptable but not negligible [7]. Several studies show that patients selected for Hybrid Open-endovascular Repair (HOER) have increased comorbidities and tend to be older [7,13,14].

In this study, patient outcomes after hybrid open-endovascular aortic aneurysm repair at our institution are reported and analyzed.

Methods

Twenty-four (24) patients with complex aortic aneurysms underwent hybrid open-endovascular repair procedures at Mayo Clinic Florida between June 2013 and October 2016. One patient was excluded due to device malfunction that required conversion to open thoraco abdominal repair and was followed by massive myocardial infarction and patient death. After Institutional Review Board (IRB) approval, demographics, comorbidities, disease presentation, intraoperative characteristics and post-operative outcomes were collected from patients' (n=23) medical records and analyzed.

Data was assessed for normal or skewed distribution using StatCrunch™; normally distributed data was reported with mean and standard deviation, and skewed data was reported with median and interquartile range.

Results

Demographics and comorbidities

At the time of surgery, median age was 72 years, mean BMI 27 ± 4.8, and males represented 52.2% of the patient sample **(Table 1)**. All patients were diagnosed with ASA scores 3 or 4. Eight patients (34.8%) were current smokers or had smoked in the past 10 years. Patients suffered from a variety of comorbidities, notably hypertension (78.3%), hyperlipidemia (60.9%), COPD (13.0%) and renal disease (34.8%). Other comorbidities included coronary artery disease (26.1%), congestive heart failure (17.4%), diabetes mellitus (8.7%), prior aortic procedures (13.0%), stroke history (4.3%) and connective tissue disease (4.3%). Nineteen patients (82.6%) suffered from two or more of the specified comorbidities.

Disease presentation and operative characteristics

Patients presented with a variety of aortic disease conditions **(Table 2)**. Five patients (21.7%) presented with aortic dissection **(Table 3)**. Median aortic aneurysm diameter was 5.4 cm. Of the seven patients with thoracoabdominal aneurysm, four patients presented with Type I, two with Type II and one patient with Type V aneurysm. Only one patient required emergent surgery, and six

Table 1 Aortic repair patient demographics and comorbidities*.

Variable	Total, n=23	Variable	Total, n=23
Age, years	-	COPD**	3 (13.0%)
Median, IQR	72 (66-77)	Hypertension	18 (78.3%)
Range	(35-81)	Hyperlipidemia	14 (60.9%)
White race	19 (78.3%)	Renal disease	8 (34.8%)
Male gender	12 (52.2%)	Coronary artery disease	6 (26.1%)
BMI	27±4.8	Congestive heart failure	4 (17.4%)
ASA score		Diabetes mellitus (Type II)	2 (8.7%)
• ASA 3	8 (34.8%)	Prior aortic procedure	3 (13.0%)
• ASA 4	15(65.2%)	Stroke history	1 (4.3%)
Smoking status		Connective tissue disease (Marfan)	1 (4.3%)
• Current	4 (17.4%)	Multiple specified comorbidities	19 (82.6%)
• Past 10 years	4 (17.4%)		
• None/none in 10 years	15(65.2%)		

*Continuous variables with normally distributed data reported as mean ± standard deviation, variables with skewed data reported as median with Interquartile Range (IQR)
**COPD: Chronic obstructive pulmonary disorder

Table 2 Aortic disease diagnoses in hybrid repair patients.

Description	Total, *n*=23
Ascending ± arch ± descending aneurysm	11 (47.8%)
Thoracoabdominal aneurysm	7 (30.4%)
Large innominate artery aneurysm	1 (4.3%)
Left aberrant subclavian artery with Kommerell aneurysm and right aortic arch, thoracic aneurysm	1 (4.3%)
Chronic contained rupture of the aortic arch with a 14 cm arch aneurysm and 7.4 cm juxtarenal AAA	1 (4.3%)
Thoracic aortic aneurysm with Kommerell diverticulum	1 (4.3%)
Juxtarenal AAA	1 (4.3%)

Table 3 Disease presentation and operative characteristics*.

Variable	Total, *n*=23	Variable	Total, *n*=23
Dissection	5 (21.7%)	Spinal drain	13 (56.5%)
Crawford classification		Deep hypothermic circulatory arrest	3 (13.0%)
• Type I	4 (17.4%)	Intravascular ultrasound	4 (17.4%)
• Type II	2 (8.7%)	Operative time, min.	
• Type III	0 (0%)	*Median, IQR*	527 (420-652)
• Type IV	0 (0%)	*Range*	(342-1665)
• Type V	1 (4.3%)	Surgery on CPB**	17 (73.9%)
Aneurysm diameter, cm		CPB time, min	
Median, IQR	5.4 (5.1-5.9)	*Mean ± SD*	181 ± 45
Range	(4-14)	*Range*	(90-244)
Emergent surgery	1 (4.3%)	Aortic clamping time, min.	
Staged surgery	6 (26.1%)	*Median, IQR*	114 (65-136)
Days between surgery stages		*Range*	(21-163)
Median, IQR	251 (6-608)	Fluoroscopy time, min.	
Range	(3-815)	*Median, IQR*	18 (14.5-45.5)
Debranching regions		*Range*	(8-125)
• Thoracic	18 (78.3%)	Contrast volume, mL	
• Visceral	3 (13.0%)	*Median, IQR*	110 (60-170)
• Thoracic and visceral	2 (8.7%)	*Range*	(45-675)
Intraoperative complications	2 (8.7%)	Estimated blood loss, L	
Ascending aorta replacement (*n*=22)	16 (72.7%)	*Median, IQR*	2.2 (1.4-4.5)
Subclavian revascularization (*n*=20)	18 (90.0%)	*Range*	(.06-6.1)

*Continuous variables with normally distributed data reported as mean ± standard deviation, variables with skewed data reported as median with Interquartile Range (IQR)
**CPB: Cardiopulmonary bypass

patients (26.1%) required staged surgeries (debranching in the first stage, followed by endovascular repair in stage two). Median time between staged surgeries was 251 days.

The majority of patients (78.3%) underwent thoracic vessel debranching, while the remainder underwent visceral vessel debranching (13.0%) or thoracic and visceral debranching (8.7%). Ascending aorta replacement was necessary in 72.7% of patients (*n*=22, one patient with prior replacement), and the left subclavian artery was covered without revascularization in 10% of patients.

During surgery, thirteen patients (56.5%) received a spinal drain and three patients were put into deep hypothermic circulatory arrest. Intravascular ultrasound was utilized for four patients (17.4%).

Seventeen patients (73.9%) required cardiopulmonary bypass during surgery, with a median bypass time of 181 minutes. Median operative time was 527 min, median aortic clamp time was 114 min, and median fluoroscopy time was 18 min. Median blood loss was 2.2 L (interquartile range 1.4-4.5 L). Two patients experienced intraoperative complications of ventricular fibrillation and splenic bleeding (requiring splenectomy).

Postoperative characteristics and outcomes

Median ICU stay was 4.0 days with a median total length of stay of 9.5 days **(Table 4)**. Eight patients (34.8%) required ventilation postoperatively for more than 24 h. No patients suffered visceral ischemia or spinal cord injury following surgery. Minor stroke occurred postoperatively in two patients and major stroke in one patient. One patient developed renal failure requiring dialysis and three patients (13.0%) suffered temporary kidney injury. Type II stent graft endoleak occurred in four patients (17.4%). All patients had patent grafts.

Reintervention was required in one patient for pseudoaneurysm, and in a second patient for dissection. No patients required extremity amputation or reoperation for bleeding. Thirty-day mortality occurred in three patients (13.0%). Patients were followed for a median 218 days, with a six-month and one-year survival was 78.9% and 75.0%, respectively.

Discussion

As found in this study, patients with aortic aneurysm are often elderly and suffer from multiple comorbidities [9,15]. The cumulative impact of these factors on patients' health status and the heightened risk of aneurysm repair often eliminates conventional open repair as an option [9,15], with hybrid repair as an appealing alternative. Evaluating the outcomes of hybrid procedure and comparing it to open repair creates a dilemma due to the inherent selection bias in most of these studies.

Patients in this study had a wide range of aortic disease **(Table 2)**, which is expected as the degenerative state of the aorta is a systemic and widespread pathology.

Four patients (17.4%) developed Type II endoleak that did not require any reintervention, which is similar with the results of other studies in the literature [16]. However, intervention was

Table 4 Post-operative characteristics and outcomes*.

Variable	Total, *n*=23	Variable	Total, *n*=23
ICU stay, days		Stent graft endoleak (Type II)	4 (17.4%)
Median	4.0 (3.5-6.5)	Stent graft patency (*n*=23)	23 (100%)
Range	(2-22)	Debranching graft patency (*n*=23)	23 (100%)
Length of stay, days		Reintervention	2 (8.7%)
Median	9.5 (8-15)	Reoperation for bleeding	0 (0%)
Range	(5-41)	Extremity amputation	0 (0%)
Ventilation >24 h	8 (34.8%)	Mortality, 30-day	3 (13.0%)
Visceral ischemia, 30-day	0 (0%)	Follow-up duration, days	
Spinal cord injury, 30-day	0 (0%)	*Median*	218 (85-494)
Stroke, 30-day		*Range*	(32-1226)
• Major**	1 (4.3%)	6-month survival (*n*=19)	78.90%
• Minor	2 (8.7%)	1-year survival (*n*=16)	75.00%
Acute kidney injury, 30-day	3 (13.0%)		
Renal failure (requiring dialysis)	1 (4.3%)		

*Continuous variables with normally distributed data reported as mean ± standard deviation, variables with skewed data reported as median with Interquartile Range (IQR)

**Defined as new assisted living requirements due to stroke-induced disability

needed in two patients, one for retrograde dissection and the other for pseudoaneurysm formation at the innominate artery anastomosis. Graft and stent patency was 100%.

Perioperative stroke occurred in three patients (13.0%), all of whom underwent one-stage thoracic debranching and stent graft deployment. This result is higher than seen in Benrashid et al. [9] where no patients suffered stroke (*n*=81), but less than the 20.0% seen in Quinones-Baldrich et al. (n=20) [17]. Two of the three strokes were minor and resolved without any long term sequelae. The major stroke resulted in assisted walking. All three patients suffered from multiple comorbidities (hypertension, coronary artery disease, chronic obstructive pulmonary disorder and hyperlipidemia). All patients underwent debranching in Zone 0, which has been reported in the literature as a high risk for stroke [18,19]. Therefore, careful patient selection and employing more effective cerebral protection methods may potentially decrease the stroke rate following these complex procedures.

One patient (4.3%) developed renal failure and required continuous renal replacement therapy in the setting of pre-existing renal disease (atrophic left kidney). This result is less than the 14.8% renal failure requiring permanent dialysis observed by Benrashid et al. [9] three patients had acute kidney injury (13.0%) that resolved completely by the day of discharge. Comparatively, Benrashid et al. [9] experienced 43.2% incidence of acute kidney injury in the hybrid repair group and 26.2% in the open repair group. However, the present study results are similar to those of Rosset et al. [12], who reported a 10.5% incidence of acute kidney injury. The lower rate of acute kidney in this study is likely due to reduced aortic clamp time and less need for full cardiopulmonary bypass and deep circulatory arrest.

The postoperative 30-day mortality of 13.0% seen in this study is within the range observed by: Lee et al. [15], 24% (*n*=17); Benrashid et al. [9], 12.3% (*n*=81); Massoni et al. [20], 24.4% (*n*=45); Rosset et al. [12], 34.2% (*n*=76) and van de Graaf et al. [21], 33% (n=15). Causes of death were: 1) Renal failure that led to abdominal compartment syndrome, 2) *Clostridium difficile colitis* that led to septic shock and multi-organ failure, and 3) Death due to cardiopulmonary arrest in the setting of coronary artery disease. Common characteristics in these patients were multiple comorbidities, higher than median contrast volumes and operative times (two were beyond the third quartile for these variables) and female gender [22].

The majority of patients (78.9%) survived at least 6 months following surgery. One-year survival was 75.0%. This rate is higher than reported by van de Graaf et al. [21], 47% (*n*=15), and comparable to Benrashid et al. [9], 69% (*n*=81); Massoni et al. [20], 67.4% (*n*=45) and Rosset et al. [12], 65.8% (*n*=76).

Katsargyris et al. [23] showed a strong relationship between aneurysm patient outcomes and the volume of such patients at a particular treatment center. Perioperative mortality in aortic aneurysm patients was reduced in high-volume hospitals, and explained by increased surgeon experience and better postoperative complication management. Therefore, it is recommended that patients with complex aortic disease be treated at centers of excellence with the experience and resources to achieve optimal outcomes. Additionally, future studies of hybrid open endovascular repair would benefit from analysis of a larger patient population and a normalization of factors including patient volume and surgeon experience.

Limitations to the study include its retrospective nature, a small number of patients, a short follow-up and analysis across a variety of aortic diseases and repairs. However, our focus is primarily the outcomes of using hybrid techniques in treating complex aortic disease.

Conclusion

Hybrid open-endovascular repair is a feasible alternative in high-risk patients. Solid conclusion of hybrid repair outcomes in treating complex aortic aneurysms requires studies with large number of patients or randomized controlled trials which would be challenging to achieve due to the dispersed nature of the these type of procedures.

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