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Clinical Outcome of Staged Versus Combined Treatment Approach of Hybrid Repair of Thoracoabdominal Aortic Aneurysm With Visceral Vessel Debranching and Aortic Endograft Exclusion

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Abstract

Although visceral vessel debranching and endovascular aneurysm exclusion represents a hybrid treatment approach in patients with thoracoabdominal aortic aneurysm, the effect of timing with regard to the visceral debranching procedure and endovascular aneurysm exclusion in this treatment strategy remains unclear. In this study, the authors analyzed their recent institutional experience of visceral debranching and aneurysm stent-grafting procedures. Specifically, the authors compared the effect of staged (n = 27) versus combined (n = 31) hybrid treatment in patients with complex aortic aneurysms. This study showed a higher incidence of renal insufficiency in patients undergoing a combined hybrid repair than the staged hybrid approach. The possibility of aneurysm rupture may exist in the staged treatment approach if the duration of staged repair is prolonged. The combined hybrid treatment strategy should be performed with caution as it is associated with significantly higher complication rates than the staged hybrid treatment modality.

Keywords

thoracoabdominal aortic aneurysm, abdominal aortic aneurysm, endovascular therapy, endovascular stent-graft, hybrid repair, debranching, visceral bypass

Introduction

Since Crawford et al[1] published their seminal report over 3 decades ago regarding the role of surgical treatment of thoracoabdominal aortic aneurysm (TAAA), the operative management of TAAA and pararenal aortic aneurysm has evolved remarkably. The impact of the improved treatment outcome regarding operative TAAA repair was due in part to anesthetic advancement as well as technical refinement in intraoperative organ protection.[2-6] Although clinical series from high-volume institutions have consistently reported remarkable outcomes of this operative challenge,[4,7,8] the management of these complex aneurysms remain a formidable undertaking in the hands of most surgeons. In fact, reported mortality rates for elective TAAA operations from statewide or nationwide databases ranged from 19% to 22%.[9-11] Additionally, collective operative morbidities related to this condition, including spinal cord ischemia, renal failure, and cardiopulmonary complications, can range as high as 40% to 75%.[9-12]

The approval of thoracic endovascular devices by the Food and Drug Administration in 2005 created a new

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treatment alternative in patients with thoracic aortic aneurysm.[13] Recommended anatomical criteria for thoracic endograft implantation included a minimum length of 15 mm of normal aorta proximal and distal to the aneurysmal segment, which represents the endograft landing zone for adequate device fixation and aneurysmal exclusion.[14] Although this prerequisite anatomical morphology is commonly encountered in patients with isolated descending thoracic aortic aneurysm, patients with complex aneurysms, such as TAAA or abdominal aortic aneurysm (AAA) involving the visceral vessels, are not candidates for endograft implantation because of lack of adequate aortic landing zone for device fixation.

In an effort to increase the endovascular treatment feasibility in patients with TAAA, physicians have reported a hybrid treatment strategy by performing adjunctive surgical bypasses of the abdominal visceral vessels to lengthen the aortic landing zone, which is followed by thoracic endograft implantation to exclude the TAAA or pararenal AAA.[15-21] We have previously reported our experience using this hybrid surgical and endovascular approach in patients with TAAA, and we found that this hybrid strategy has increased the endovascular applicability in patients with complex aortic aneurysms.[22] Proponents for this hybrid approach advocated that since the surgical incision does not involve a thoracotomy approach, this may reduce potential perioperative pulmonary complication associated with a thoracic incision.[23,24] The theoretical benefits are yet to be validated in the literature as reported series from the literature regarding this hybrid approach have noted a wide range of operative mortality from 0% to 38%.[15-21] The mixed results from various clinical series underscore the therapeutic complexity as well as the wide disparity in the hybrid treatment approach of this challenging condition. In this report, we examine the outcome of the hybrid approach of TAAA with a particular focus on the timing factor between the visceral bypass and endograft implantation. Treatment outcome was compared among patients who underwent a combined versus staged approach in visceral debranching operation and endovascular aneurysm exclusions.

Methods

From July 2005 to July 2010, clinical records of all patients diagnosed with a TAAA who underwent a planned hybrid treatment of visceral vessel bypass and endovascular aneurysm exclusion procedures were reviewed. Additional clinical information based on a retrospective review of a prospectively maintained database was also reviewed. Appropriate institutional review board approval with waiver of consent was obtained for this study. Patients who were diagnosed with ruptured or leaking TAAA requiring urgent hybrid procedure were excluded from the study. Patients who required any arch vessel debranching involving the left subclavian artery or intentional endograft coverage of the left subclavian to facilitate proximal endograft fixation were similarly excluded from this analysis. The hybrid TAAA treatment strategy was offered to patients who were deemed too high-risk to undergo conventional open TAAA repair. Those patients with a Crawford classification of extent III or IV TAAA who underwent a hybrid visceral bypass and endovascular aneurysm exclusion procedures, based on an intent-to-treat basis, formed the basis of this study. For the purpose of this analysis, patients were separated into 2 groups based on the timing of the hybrid repair. The combined group consisted of those who underwent simultaneous visceral bypass and endograft exclusion. In contrast, the staged group included those who underwent an initial visceral debranching operation followed by a separate endovascular aneurysm repair procedure after an interval of recovery.

Clinical data including demographic information, operative variables, visceral bypass techniques, perioperative complications, and treatment follow-up were recorded. Clinical outcomes including relevant operative variables, morbidity, and mortality were compared between groups. We defined postoperative cardiac complications as follows: (*a*) myocardial infarction, (*b*) cardiac arrhythmias requiring pharmacological intervention, (*c*) cardiogenic shock requiring inotropic administration, or (*d*) electrocardiographic changes coupled by cardiac enzyme elevation, regardless of symptoms. Pulmonary complications were defined as follows: (*a*) postoperative pneumonia, (*b*) prolonged mechanical ventilation with an intubation period of greater than 72 hours, (*c*) need for postoperative reintubation, or (*d*) the need for tracheostomy. Ileus was defined as a delay in gut motility lasting for longer than 72 hours after surgery. Renal dysfunction was defined as (*a*) a rise in either serum creatinine or glomerular filtration rate (GFR) exceeding the baseline value by 30% or (*b*) any postoperative creatinine value surpassing 2.0 mg/dL. Renal failure was used to denote patients who required temporary hemodialysis because of renal dysfunction.[25] The normal serum creatinine was defined as 1.5 mg/dL or less. GFR was calculated by using the Cockcroft–Gault equation: $(140 - \text{age}) \times \text{weight}/(72 - \text{serum creatinine})$.[26] In this equation, age is expressed in years, actual body weight in kilograms, and serum creatinine in milligrams per deciliter. For female patients, GFR is multiplied by 0.85 as a conversion factor. GFR values are expressed as mL/min/1.73 m^2.[25] Preoperative and postoperative GFR values and trends up to day 5 after surgery were compared between the 2 groups.

Statistical analysis was performed between treatment groups in which categorical variables were analyzed using Fisher's exact test or Pearson's χ^2 test,

Table 1. Demographic Variables and Co-Morbidities of Patients in Combined and Staged Treatment Groups

	Combined Group (n = 27)	Staged Group (n = 31)	*P* Value
Mean age ± SEM (years)	75 ± 6.8	69 ± 8.2	.72
Men, n (%)	23 (85)	27 (87)	.82
Mean aneurysm size, mean ± SEM (mm)	6.7 ± 1.5	6.2. ± 1.46	.72
Crawford classification—extent III TAAA, n (%)	15 (56)	16 (52)	.68
Crawford classification—extent IV TAAA, n (%)	12 (44)	15 (48)	.66
Comorbidities			
Hypertension, n (%)	18 (67)	19 (61)	.69
Coronary artery disease, n (%)	11 (41)	14 (45)	.59
Hyperlipidemia, n (%)	9 (33)	8 (26)	.57
Chronic obstructive pulmonary disease, n (%)	8 (30)	7 (23)	.46
Obesity (BMI > 30), n (%)	3 (11)	2 (6)	.38
Renal insufficiency, n (%)	5 (19)	6 (19)	1.0
Prior aortic operation, n (%)	7 (26)	6 (19)	.57
Prior laparotomy or thoracotomy, n (%)	12 (44)	11 (35)	.62
Active cigarette smoking, n (%)	11 (41)	12 (39)	.85

Abbreviations: SEM, standard error of the mean; TAAA, thoracoabdominal aortic aneurysm; BMI, body mass index.

whereas continuous variables were analyzed using the Mann–Whitney test. Group comparisons were conducted using the log-rank test. Risk factors affecting postoperative renal dysfunction were analyzed using the univariate analysis, which was followed by multivariate stepwise logistic regression analyses. Kaplan–Meier life table method was used to calculate longitudinal survival rate. All statistical analyses were performed using a statistical software program (SAS; SAS Institute, Cary, NC). All values were expressed as mean ± SEM. Statistical significance was accepted with a *P* value of less than .05.

Results

During this study period, a total of 58 patients with extent III or IV TAAA who underwent a planned hybrid treatment of visceral vessel bypass and endovascular aneurysm repair were included in the study. Among them, 27 patients underwent a combined hybrid treatment strategy (combined group) while 31 underwent an intent-to-treat basis of visceral bypass with staged endovascular aneurysm repair (staged group). Pertinent clinical variables and demographic information are displayed in Table 1. All patients had degenerative aneurysms unrelated to chronic dissection. More than half of the patients in both groups were deemed high risk based on anatomical consideration alone for open TAAA repair. Specifically, prior aortic operation was a common anatomical risk factor in the combined and staged groups, which occurred in 26% and 19%, respectively. Similarly, many patients had a prior history of laparotomy or thoracotomy operations in both the combined and staged groups, which occurred in 44% and 35%, respectively. There was no difference in the comorbidities among the 2 groups.

Pertinent operative variables and postoperative complications are listed in Table 2. In the staged treatment group, 25 patients (81%) completed the staged treatment strategy, as their mean duration between the initial visceral bypass and subsequent endovascular aneurysm repair was 28 ± 12 days (range = 5-45 days). Six patients (19%) underwent the initial visceral bypass but failed to complete the staged endovascular repair because of reasons including the following: (*a*) patient refusal (n = 2, 6%), (*b*) postoperative stroke (n = 1, 3%), (*c*) death due to postoperative aneurysm rupture (n = 2, 6%), and (*d*) unknown cause of death (n = 1, 3%). Comparison of operative time and blood loss between the combined and staged treatment groups revealed a higher trend in both categories among the staged patient group. However, this difference was not statistically significant. In contrast, comparison of cumulative intensive care unit length of stay revealed a shorter duration in the combined group than the staged group, which was 5.8 ± 1.8 days and 9.3 ± 2.7 days, respectively (*P* = .04). Similarly, significantly shorter cumulative hospital length of stay was observed in the combined group when compared with the staged treatment group, which was 11.3 ± 3.2 days and 16.4 ± 3.5 days, respectively (*P* = .04).

Comparison of postoperative complications demonstrated that renal dysfunction occurred more commonly in patients in the combined group compared with the staged repair, which occurred in 59% and 10%, respectively (*P* = .01; Table 2). The disparity of this complication has correspondingly contributed to a higher incidence of cumulative postoperative complication rates in the combined group than the staged group, which was 85% and 48%, respectively (*P* = .02). There were 6 patients who developed renal failure requiring hemodialysis

Table 2. Perioperative Variables and Postoperative Complications of Patients Treated With Either Combined or Staged Hybrid Repair

	Combined Group (n = 27)	Staged Group (n = 31)	*P* Value
Operative variables			
Contrast injection volume (mL)	110 ± 20	100 ± 30	.95
Time period between staged repair (days)	N/A	28 ± 12	N/A
Cumulative operative time (min)	402 ± 120	465 ± 135	.37
Visceral bypass operative time (min)	N/A	385 ± 126	
Endovascular repair operative time (min)	N/A	102 ± 56	
Cumulative operative blood loss (mL)	2,632 ± 1,243	3,166 ± 1472	.58
Visceral bypass operative blood loss (mL)	N/A	2,541 ± 1219	
Endovascular repair operative blood loss (mL)	N/A	321 ± 238	
Cumulative ICU (median, days)	5.8 ± 1.8	9.3 ± 2.7	.04
Visceral bypass ICU (median, days)	N/A	5.3 ± 2.9	
Endovascular repair ICU (median, days)	N/A	1.5 ± 0.4	
Cumulative HLOS (median, days)	11.3 ± 3.2	16.4 ± 3.5	.04
Visceral bypass HLOS (median, days)	N/A	9.6 ± 2.7	
Endovascular repair HLOS (median, days)	N/A	5.3 ± 1.3	
Postoperative complications			
Cardiac complication, n (%)	3 (11)	2 (6)	.8
Pulmonary complication, n (%)	1 (4)	2 (6)	.8
Stroke, n (%)	1 (4)	1 (3)	1.0
Wound dehiscence/infection, n (%)	2 (7)	1 (3)	.8
Urinary tract infection, n (%)	1 (4)	2 (6)	.8
Renal dysfunction, n (%)	16 (59)	3 (10)	.01
Renal failure, n (%)	4 (15)	2 (6)	.6
Ileus, n (%)	2 (7)	3 (10)	.7
Mesenteric graft occlusion, n (%)	2 (7)	1 (3)	.8
Renal graft occlusion, n (%)	1 (4)	2 (6)	.8
Cumulative 30-day postoperative morbidity, n (%)	23 (85)	15 (48)	.02
30-Day postoperative mortality, n (%)	6 (22)	8 (26)	.7

Abbreviations: N/A, not applicable; ICU, intensive care unit; HLOS, hospital length of stay.

during the postoperative course. Among them, 4 patients (15%) had a combined repair while 2 patients (6%) underwent the staged repair. Mesenteric graft occlusion occurred in both the combined and staged groups, with an incidence of 7% and 3%, respectively. The diagnosis of mesenteric graft occlusion was established with computed tomography angiogram of the abdomen because of persistent abdominal pain and acidosis. All these patients underwent mesenteric graft thrombectomy and graft revision. In contrast, renal graft occlusion occurred in 4% of the combined group and 6% of the staged group. No patients with renal graft occlusion underwent thrombectomy or graft revision because the contralateral renal bypass graft remained patent. There was no difference in the 30-day postoperative mortality rate between the combined and staged treatment groups, which was 22% and 26%, respectively (nonsignificant).

Postoperative trends of GFR revealed a significant diminution in the combined patient group, which eventually returned to the baseline level by postoperative day 5 (Figure 1). In contrast, no change in GFR was observed in the staged group as this value remained consistently stable following either the initial visceral bypass or the subsequent endovascular aneurysm repair (Figure 1). Univariate analysis of relevant demographic, comorbid conditions, and treatment strategies in relation to postoperative renal dysfunction was performed. Univariate analysis showed increased age (>78 years old; P = .01), combined hybrid treatment strategy (P = .03), decreased preoperative GFR (<60 mL/min/1.73 m^2; P = .002), and high red blood cell transfusion requirement (>16 units on first postoperative day; P = .04) were associated with postoperative renal dysfunction (Table 3). Multivariate analysis revealed that increased age >78 and decreased preoperative GFR were predictors for postoperative renal dysfunction following either combined or staged hybrid repair.

The mean follow-up period was 27.3 months (range = 6-45 months) in this study. During the follow-up period,

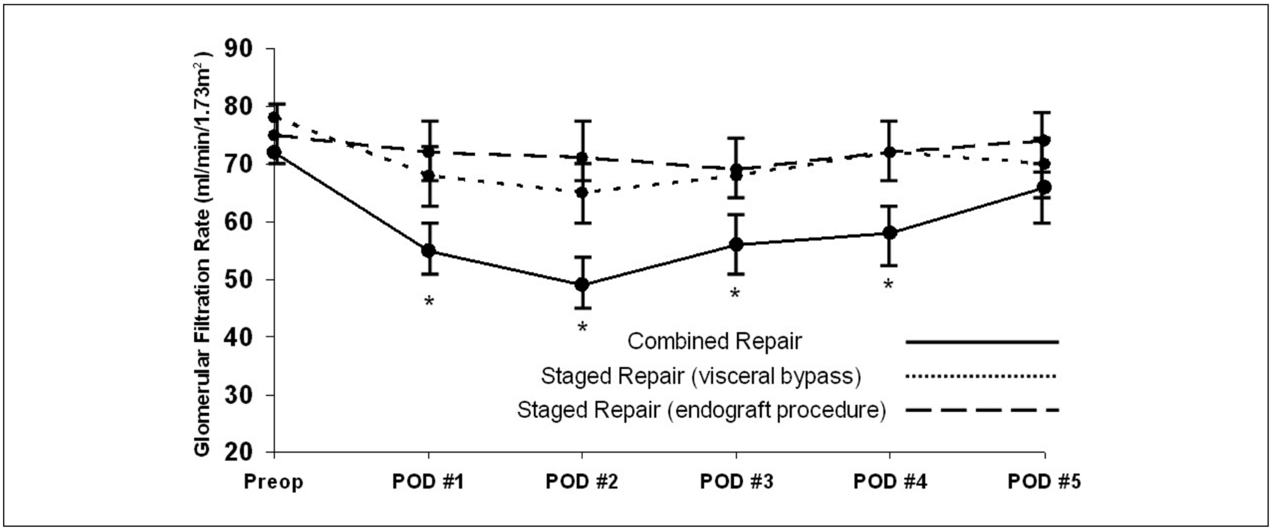

Figure 1. Postoperative trend of GFR in patients treated with either combined or staged hybrid repair
*$P < .05$ when compared with preoperative GFR baseline value.

Table 3. Risk Factor Analysis for Postoperative Renal Dysfunction

Variable	*P* Value	Odds Ratio	95% CI
Univariate risk factor analysis			
Increased age (>78 years)	.01	7.34	1.2-5.89
Preoperative GFR <60 mL/min/1.73 m^2	.002	14.5	3.4-14.5
PRBC transfusion >16 units/POD 1	.04	2.1	1.2-4.5
Combined hybrid repair	.03	3.88	1.1-5.3
Multivariate risk factor analysis			
Increased age (>78 yrs old)	.03	3.64	1.1-6.87
Preoperative GFR <60 mL/min/1.73 m^2	.005	7.3	2.5-21.4

Abbreviations: CI, confidence interval; GFR, glomerular filtration rate; PRBC, packed red blood cell; POD, postoperative day.

cardiac adverse events were the cause for late death in both combined and staged groups, which occurred in 4 patients (15%) and 6 patients (19%), respectively. Two endoleaks occurred in the combined and staged groups, all of which resolved spontaneously within the first 12 months following the interventions. There was no aneurysm-related death among survivors in either group. There was no difference in the cumulative survival rate between the 2 groups. The cumulative survival rate at 42 months between the combined and staged groups was 62% and 65%, respectively (Figure 2).

Discussion

The concept of abdominal visceral vessel bypass grafting, or debranching, followed by thoracic endograft implantation for aneurysm exclusion has become an increasingly used treatment modality in the management of TAAA.[17,22,27]

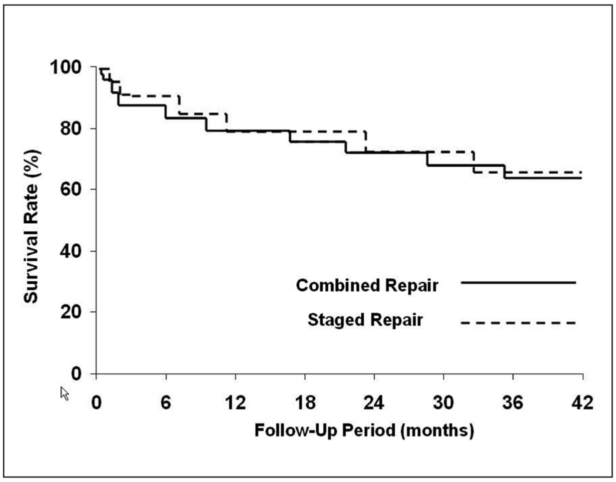

Figure 2. Kaplan–Meier life table curves for cumulative survival rates for patients treated with either combined or staged hybrid repair

In contrast to a conventional thoracoabdominal surgical repair in which both abdominal and thoracic cavities are exposed, physicians who favor this hybrid treatment approach suggest that the avoidance of a thoracotomy incision may lead to less perioperative morbidity.[23,28] Despite this seemingly logical theoretical benefit, many published studies regarding this treatment strategy continue to report a high incidence of perioperative morbidity and mortality,[15,16,18-21,28,29] whereas others advocated the safety and efficacy of this hybrid treatment approach.[17,22-24,27] The disparity of the widely reported treatment outcome may be due in part to the difference in patient selection, surgical technique, as well as the staged treatment strategy between the debranching operation and endovascular procedure. This study was undertaken in an effort to delineate whether staged versus simultaneous hybrid treatment would influence the treatment outcome. The findings of our study were notable because they showed that a greater incidence of renal dysfunction occurred in the combined group, while nearly 1 out every 5 patients undergoing the staged approach never completed the planned treatment strategy. Additionally, our results demonstrated that increased age and low preoperative GFR were independent predictors for postoperative renal dysfunction following hybrid TAAA treatment strategy.

We postulate several factors that are accountable for the high incidence of renal dysfunction in patients treated with the combined modality. First, the obligatory renal ischemia created by renal artery clamping and bypass in both kidneys represents a major physiologic insult to the renal parenchyma. This is compounded by the additional parenchymal stress induced by contrast injection during the endograft implantation. Although the mean volume of contrast injection between the combined and staged groups was similar (Table 2), we believe that the nephrotoxic effect of contrast agent combined with operative renal ischemia for renal artery bypass resulted in an insurmountable physiologic injury, which accounted for the high incidence of renal dysfunction in the combined treatment group. In contrast, those patients treated with the staged approach had an ample amount of time for hydration and renal recovery before enduring contrast administration for subsequent endograft implantation. A confounding variable that may be attributable to the higher incidence of renal dysfunction is the operative time in the combined group, which is longer when compared with either the debranching or endograft procedure alone in the staged patient cohorts. The prolonged operative time of an abdominal laparotomy undoubtedly can lead to greater evaporative fluid loss, hypothermia, and subsequent intravascular fluid shifting with resultant dehydration. This finding was consistent with previous reports that established the correlation between these operative variables and postoperative renal dysfunction following aortic aneurysmorrhaphy.[30,31]

Of interest in our findings was that the degree of creatinine elevation was similar in either group following the hybrid procedure. However, this finding provides little scientific value since serum creatinine represents an inaccurate marker reflecting renal dysfunction.[32,33] Several researchers have previously reported the unreliability of serum creatinine in predicting postoperative renal function in patients undergoing aortic aneurysmorrhaphy.[34-38] We assessed renal dysfunction using the Cockcroft–Gault formula, which represents one of most accurate diagnostic methodology in determining GFR.[39] When comparing the perioperative alteration of GFR in the 2 groups, patients in the combined group experienced a significantly longer period of postoperative GRF reduction before returning to the baseline value. In contrast, no postoperative GFR reduction was observed in patients who underwent the staged treatment strategy, regardless of the initial visceral debranching operation or the staged endovascular exclusion procedure (Figure 1). Our findings were supported by Walsh et al,[38] who showed that perioperative renal dysfunction as defined by impaired GFR correlated with poor outcome and greater mortality following open AAA repair, while serum creatinine failed to yield any predictive value. In a study that analyzed the clinical outcome of more than 1100 patients with thoracoabdominal aneurysms, Huynh et al[35] similarly noted that impaired GFR was predictive of postoperative mortality and poor outcome following surgical aneurysm repair. Similar correlation of impaired GFR and poor clinical outcome was also recently reported in patients undergoing endovascular AAA treatment.[34]

Our findings also highlighted a disadvantage of the staged treatment strategy, which relates to the possibility that the staged endovascular procedure may either be delayed or postponed indefinitely following the visceral bypass operation. Six patients (19%) did not undergo the endovascular procedure as planned. Among them, 2 patients simply refused due in part to the operative pain and in-hospital anxiety they endured from the first operation. One of them died at home whereby the cause of death was presumably caused by a ruptured aortic aneurysm. Another patient developed an unexpected stroke 5 weeks following his laparotomy, which precluded a subsequent endografting procedure. Ironically, 2 deaths were caused by aneurysm rupture following their initial visceral bypass operation, as confirmed by postmortem examination. The implication of incomplete hybrid repair was resonated in a recent study by Lee et al,[27] who reported a series of 17 TAAA patients undergoing an initial visceral bypass followed by endovascular aneurysm exclusion.[27] Nearly one third of these patients never completed their second staged endovascular repair because of either postlaparotomy death or patient refusal.[27] We recently highlighted the significance of postlaparotomy aneurysm-related deaths in a report that described a series of patients who developed aneurysm rupture following abdominal laparotomy for colon cancer resection.[40] Other researchers have similarly emphasized the possibility of aneurysm rupture following a laparotomy operation, particularly in patients who underwent an abdominal operation for gastrointestinal malignancy followed by a staged open aneurysm repair.[41-44] Given the potential risk of aneurysm rupture following an abdominal operation as well as unforeseen adverse clinical events that may preclude patients from undergoing a timely staged endovascular procedure, patients who undergo a staged hybrid repair must be cognizant of the possibility of aneurysm rupture if there is a significant delay before the staged endovascular repair.

When comparing the finding of our study in the same context with other series using the hybrid approach in the treatment of TAAA, there were many similarities with regard to the treatment outcome. In a study that included 17 patients undergoing the hybrid TAAA treatment strategy, researchers reported that their mortality rate, based on an intent-to-treat basis, was 24%. The mean delay between their staged procedures was 27 days (range = 6-99 days), which was similar to our series. In another study that reported a series of 29 patients with complex aortic pathologies who were treated with the hybrid strategy, Black et al[15] reported an operative morbidity and mortality rate of 39% and 23%, respectively. These researchers also reported that 10% of their patients did not complete the second staged endovascular repair, because of either postlaparotomy death or morbidities. Several other smaller case series of TAAA hybrid repair similarly reported high operative mortality rates, which ranged from 25% to 33%.[16,19,20]

The findings from our series as well as those reported by others beg the question: "Is the hybrid treatment strategy a truly less-invasive treatment of TAAA?" Considering the technical steps involved in a hybrid approach, there are clearly limitations that may preclude its wide adaptation in all patients with TAAA. First, the abdominal visceral revascularization is a major surgical undertaking that typically involves more than 8 anastomoses in various vascular structures. The mean operative time of our abdominal visceral reconstruction was more than twice longer compared with the mean operative time of conventional TAAA repair previously reported from our institution.[4] The prolonged operative time of a hybrid repair was similarly resonated from other series, which ranged from 385 to 752 minutes.[15,16,18-21,28,29] This remains considerably longer compared with the operative time of open TAAA series from large tertiary institutions.[2,4,6-8] Second, the high number of anastomoses as well as the long length of visceral bypass graft inevitably increases the likelihood of technical error or graft occlusion. Moreover, the visceral or renal bypass graft frequently originated from the common iliac artery, which may be affected by the progression of underlying aortoiliac atherosclerosis or post–endografting aneurysm remodeling with resultant limb occlusion. In fact, our previous report has shown that renal graft occlusion, caused in part by a technical problem, was one of the most common perioperative complications in TAAA patients undergoing the hybrid procedures.[22] The clinical implication of this challenge is underscored by the 1-year primary patency rate of 83% in all visceral grafts in our series, which is considerably less compared with other contemporary open TAAA series.[2,4,6-8] The clinical sequelae of visceral graft occlusion can be devastating, as mesenteric ischemia can lead to ominous consequences in these elderly patient cohorts. All 3 patients in our series who developed mesenteric graft occlusion had to undergo urgent exploratory laparotomy for graft thrombectomy and revision. All 3 patients suffered prolonged hospital course because of gastrointestinal-related sequelae. More studies with long-term follow-up of this hybrid treatment are clearly needed to better delineate patient cohorts who will benefit from this treatment strategy.

Admittedly, there are several limitations related to our study. First, the heterogeneity and complexity of a hybrid TAAA treatment strategy precludes an accurate outcome comparison given the limited number of patient cohorts in each group. Additionally, the decision to perform either a combined or staged repair was largely based on the treating physician's preference rather than an objective treatment algorithm or a randomized process. Similarly, the decision regarding the timing between staged procedures was partly affected by the preference of not only the physician but also the patient. We further acknowledged that socioeconomic consideration may have played a role in the therapeutic planning process. Due in part to the tertiary referral nature of our institution, many patients routinely traveled from a far away distance or out-of-state regions seeking surgical treatment of their aneurysms. Patients and their families often desired expedited treatment processes in an effort to reduce costly travel expenditures associated with multiple or prolonged hospitalizations. These factors may have favored a combined treatment strategy or shortened time delay between staged operations in an effort to complete the hybrid treatment during a single hospital course. Taken together, these considerations have undoubtedly contributed a bias in both patient selection and treatment outcome.

In conclusion, management of TAAA remains a formidable challenge. The availability of thoracic endograft coupled with a visceral vessel debranching approach has created a novel treatment strategy in the treatment of complex aortic aneurysms. Although this hybrid treatment strategy has enabled treatment of TAAA without a thoracotomy exposure, our study revealed significant perioperative morbidities related to this hybrid treatment strategy albeit devoid of a thoracoabdominal incision. Our study also underscored the risk of renal dysfunction when visceral bypass grafting and endovascular aneurysm exclusion are performed in a combined setting. In patients undergoing a staged repair, on the other hand, potential aneurysm-related death can occur if the staged endovascular procedure is either delayed temporarily or postponed indefinitely. Last, the findings of our study further highlights that many unanswered questions remained regarding the optimal patient selection and the ideal treatment approach in terms of timing of the staged repair. In the end, the utility of this hybrid repair must be compared with the conventional open repair with regard to morbidity and mortality in order to validate its therapeutic benefit in the treatment of TAAA.

Declaration of Conflicting Interests

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