Postoperative fluid collection after hybrid debranching and endovascular repair of thoracoabdominal aortic aneurysms

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Objective: **Hybrid thoracic endovascular aneurysm repair (H-TEVAR) to include visceral and renal debranching has emerged as a potential therapeutic option for thoracoabdominal aneurysms (TAAA). This study was performed to characterize the frequently noted development of postoperative fluid collections surrounding the bypass grafts.**
Methods: **All patients undergoing H-TEVAR from 2000-2010 (n = 39, 43.6% male) were identified. One hundred thirty-two bypasses were constructed (median 4 per patient) using either polyester (30), thin-walled polytetrafluoroethylene (ePTFE, 100) or saphenous vein (2). Follow-up computed tomography (CT) imaging was routinely performed at 1 and 6 months, and annually thereafter.**
Results: **Of the 37 patients with one follow-up CT, 20 (54.1%) were found to have fluid collections. The natural history of the 17 patients with collections and further follow-up imaging was variable, with 2 resolving, 6 stable, and 9 enlarging. Two patients with collections developed evidence of graft infection requiring reoperation. Two patients with enlarging sterile collections required evacuation for symptoms. By multivariate analysis, both preoperative creatinine ($P = .005$) and number of bypasses constructed ($P = .04$) independently correlated with the development of a fluid collection.**
Conclusions: **Postoperative fluid collections following hybrid debranching procedures identified in this series represent a unique complication not previously described. The subsequent clinical course of these fluid collections is variable and ranges from benign to frank graft infection and relate both to patient factors, as well as specific operative strategies. Longer-term studies with more robust numbers of patient numbers are warranted to determine whether this complication may limit the long-term durability of this procedure. (J Vasc Surg 2011;54:1623-8.)**

The natural history of thoracoabdominal aneurysms (TAAA) is dismal with a 5-year survival rate estimated at 20% to 40% if left untreated.[1] Select centers have achieved excellent results with conventional open repair, although nationwide mortality rates remain approximately 20%.[2] With the introduction of endovascular approaches, the treatment of isolated thoracic aortic aneurysms has changed dramatically, incorporating this strategy with increasing frequency.[3] Endovascular approaches, however, have not been as prevalent in the treatment of TAAA secondary to the presence of critical branch vessels within treatment zones, as well as regulatory and logistic issues.[4] The slow rate of dissemination of fenestrated endograft technology in the United States has led to alternative methods to adapt endovascular techniques to repair of TAAA in patients not suitable for traditional open repair.[5-13] To avoid a thoracotomy and the need for extracorporeal bypass, hybrid thoracic endovascular aneurysm repair (H-TEVAR) was developed, whereby visceral and/or renal debranching is performed prior to endovascular aortic repair.[5,6] Based on our own observations and scattered case reports after open repair, we sought to characterize the frequently identified postoperative fluid collections surrounding the debranching grafts (Fig 1) and their implications in this report.[7-9]

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METHODS

This study was approved by the Institutional Review Board at the University of Michigan Hospitals (IRB # HUM00040465, informed consent requirements waived).

Data from all patients undergoing hybrid debranching procedures for thoracoabdominal aortic aneurysms from 2000-2010 were retrospectively reviewed. H-TEVAR was performed in patients considered high risk for conventional thoracoabdominal aneurysmectomy due to comorbid conditions in all but one who refused open repair. Technical success was identified in all patients, who underwent endograft placement. Devices utilized included TAG (W. L. Gore and Associates, Flagstaff, Ariz, n = 21), Zenith and TX2 (Cook Medical, Bloomington, Ind, n = 9 and n = 5, respectively), AneuRx and Talent (Medtronic Inc, Santa Rosa, Calif, n = 6 and n = 2, respectively) and custom fabricated.[1] Nine patients received multiple different endograft types.

Follow-up computed tomography (CT) imaging was routinely performed at 1 month, 6 months, and annually to

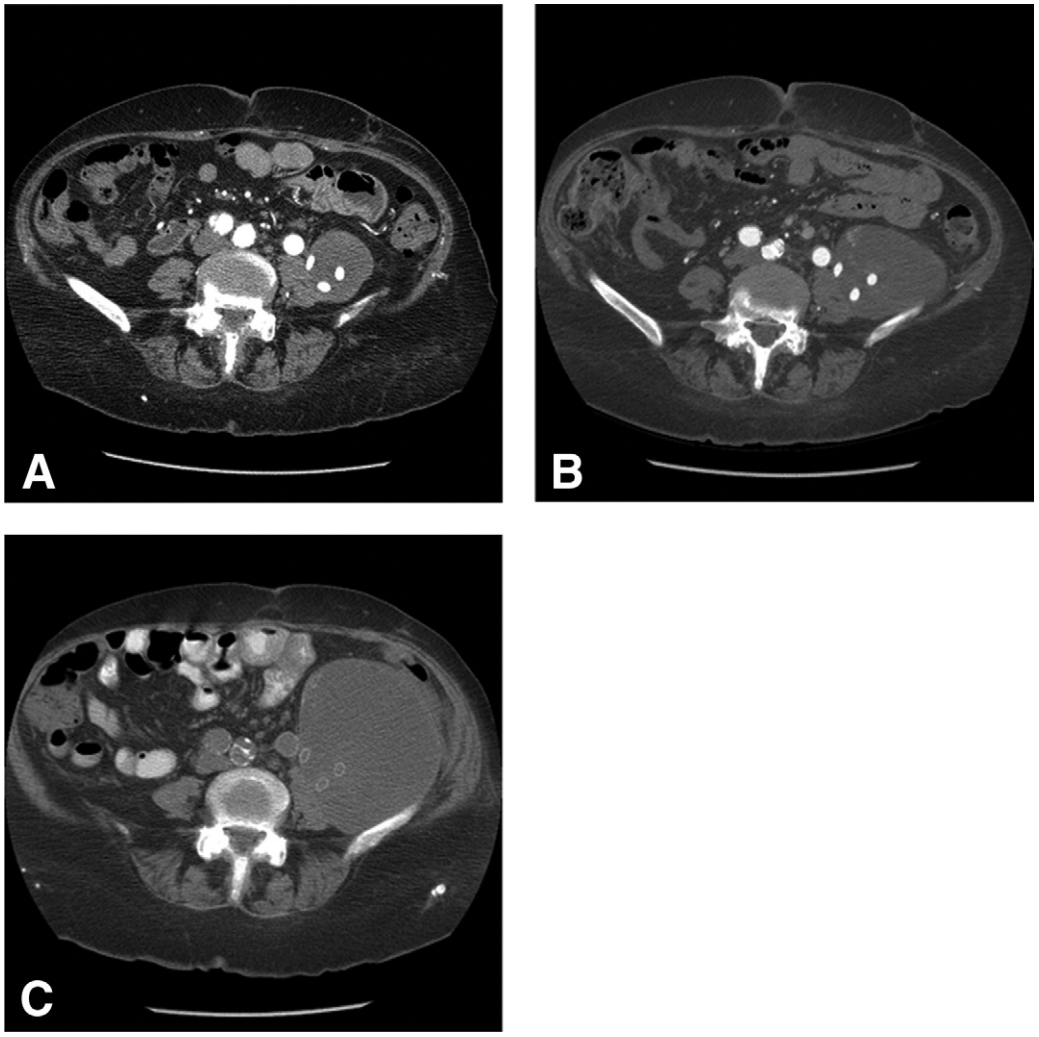

Fig 1. Typical postoperative imaging identifying perigraft fluid collection. These computed tomography (CT) scan images demonstrate the fluid collection with the *light arrow* at 6 **(A),** 18 **(B),** and 25 **(C)** months after concomitant debranching and endovascular repair for an aortoesophageal fistula. Note the homogenous nature of the collection surrounding the entire graft. This fluid collection grew in size to a maximum of 7.4 cm over the ensuing 25 months and required evacuation for symptoms. No evidence of infection was identified in this patient either preoperatively or with intraoperative findings and cultures. She remains asymptomatic at 12 months after evacuation.

evaluate the H-TEVAR repair (mean of three studies per patient). The primary outcome of this study was to characterize the frequency and course of identified postoperative fluid collections. The secondary focus of this study was to evaluate outcomes of patients undergoing H-TEVAR, in particular analyzing rates of early mortality, postoperative complications, and rates of endoleak. Data were collected from clinic visit notes, hospital charts, and imaging studies.

Statistical analysis. Data were analyzed using SPSS software (SPSS, Chicago, Ill). All data are expressed as mean ± standard deviation where applicable. Dichotomous variables were evaluated using χ^2 analysis; continuous variables using the *t* test. Multivariable models (binary logistic regression) were constructed using a forward conditional process to identify factors that were independently associated with the development of a postoperative fluid collection on last follow-up. Models were tested for goodness of fit using the Hosmer-Lemeshow statistic. Factors utilized in multivariable analysis included those with a $P < .1$ significance on univariate analysis. Survival was analyzed by Kaplan-Meier methods. All results with a $P < .05$ were considered statistically significant.

RESULTS

Thirty-nine patients (mean age 71.4 ± 8.7 years, 43.6% male) underwent H-TEVAR during the study period. Aneurysm size ranged from 5.2 cm to 9.4 cm with an average maximum diameter of 6.5 cm. Extent of repair by the Crawford classification included type II (11), type III (14), and type IV (10). An additional four patients underwent debranching procedures primarily for juxtarenal aneurysms. The endovas-

Table I. Demographics and comorbidities

Age (years)	70.8 ± 8.8
Male gender	17 (43.6%)
Prior aortic surgery	21 (53.9%)
Prior abdominal surgery	23 (59.0%)
Coronary artery disease	16 (41.0%)
Myocardial infarction	5 (12.8%)
Chronic obstructive pulmonary disease	15 (38%)
History of tobacco abuse	26 (66.7%)
Diabetes	7 (18.0%)
Hypertension	33 (84.6%)
Preoperative creatinine (mg/dL)	1.03 ± 0.36
Stroke	7 (17.9%)
Peripheral vascular occlusive disease	1 (2.6%)

cular portion of the procedure was primarily done in a delayed fashion (n = 34), but included concomitant endovascular repair in two patients with urgent symptoms. The mean time interval between debranching and endovascular portions of the procedure was 40 days, and ranged from 1 day to 142 days. Three patients expired prior to placement of an endograft. Demographics and comorbidities are listed in Table I.

A total of 132 extra-anatomic bypasses were constructed. Graft composition was polyester (30) or thin walled expanded polytetrafluoroethylene (ePTFE, 100) or saphenous vein (2). There were 67 bypasses to renal arteries, 34 bypasses to the superior mesenteric artery, and 31 bypasses to the celiac axis. Thirty-five patients underwent back-table construction of their grafts, while four were performed using prefabricated grafts. Four patients were approached through the retroperitoneum and required no additional graft coverage. Of the 35 patients with a transperitoneal approach, nine required bovine pericardium and five grafts were covered with omentum for inadequate graft coverage with native peritoneum. After recovery from the initial procedure, 36 of 39 (92%) of patients underwent endograft placement.

Early results. Early mortality (defined as either in-hospital or 30-day) was identified in four patients (10%) and was due to a variety of causes. One patient developed lower extremity weakness at home 4 days after discharge and subsequently expired at an outside hospital after undergoing an uneventful endovascular repair with a known type II endoleak. The second patient, who had a prolonged hospital course after debranching complicated by an open abdomen due to bowel edema, and prolonged ventilation requiring tracheostomy sustained a cardiorespiratory arrest after transfer from the intensive care unit after undergoing successful TEVAR. This patient was noted to have a type II endoleak and developed bowel ischemia prior to the family's request to withdraw care. The third patient was started on full anticoagulation secondary to findings of a small atrial thrombus and low ejection fraction. This patient developed a large retroperitoneal bleed as a result of this anticoagulation and not aneurysm rupture; this complication resulted in cardiac arrest and death. The final patient sustained multiple complications following the debranching portion of his procedure related to thrombosis of his renal and visceral bypasses, including gangrenous cholecystitis, necrotizing pancreatitis, and renal failure requiring dialysis.

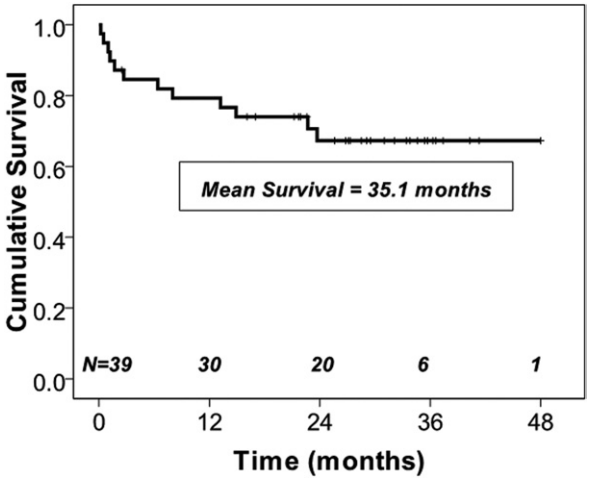

Fig 2. Kaplan-Meier survival curve. The patient cohort was primarily composed of those considered high risk for conventional open thoracoabdominal aneurysmectomy. This survival analysis confirms this preoperative assessment, and suggests that the 48-month actuarial survival of the entire cohort is 67.2% ± 7.9%.

Care was eventually withdrawn in this patient, who never underwent the endovascular portion of his procedure.

Prolonged intubation was required in eight (20.5%) patients, with three patients requiring tracheostomy. Renal failure needing dialysis was identified in five (12.8%) patients and was permanent in three (7.7%). Renal bypass thrombosis was the etiology in two of these patients. Temporary spinal cord ischemia was identified in two, with none sustaining permanent paralysis or paraplegia.

Late results. At a mean follow-up of 24 months, the crude mortality rate was 35.9% (n = 14 deaths, including four patients in the perioperative period). The causes of late mortality included aortic-related conditions in five patients. Two patients developed graft infection and will be discussed later given the association with fluid collection. Two patients died at home within 3 months of prolonged hospital stay, but with no definitive etiology for mortality. One additional patient expired due to pulmonary failure after undergoing surgery for a ruptured hypogastric artery aneurysm; this patient had pulmonary metastasis contributing to his pulmonary insufficiency.

The five remaining patients appeared to expire as a result of unrelated conditions. One patient developed a fatal acute myocardial infarction after placement of hemodialysis access. The other four patients expired at home without additional information. A Kaplan-Meier analysis of late survival is shown in Fig 2. As is evident from this figure, this cohort represented a high risk group with a mean survival <3 years.

Reoperation was required in 14 (35.9%) patients for infection (2), cholecystitis (2), pancreatitis (1), wound dehiscence (1), colectomy (1), iliac dissection (1), endoleak (6), and graft thrombosis (1). Two patients with type II endoleaks and sac enlargement were treated with endovascular reinterventions. One patient with a type III endoleak required an

Table II. Outcome of fluid collection requiring intervention

Initial size (cm)	*Maximum size (cm)*	*Outcome*
6.5 × 7	10 × 10	Seroma evacuation, hypogastric aneurysm rupture, death at 16 months due to cancer
4.6 × 4.1	7.4 × 5.6	Seroma evacuation, culture negative
4.4 × 4.7	6.8 × 7.2	Graft infection, culture negative, died at 7 months
5.5 × 4.1	5.0 × 4.9	Graft infection (Strep, Enterococcus), died at 13 months

endovascular reintervention and subsequently underwent open repair of a ruptured hypogastric aneurysm. One patient with a distal type I endoleak required "chimney snorkel" renal artery stent placement and distal endograft extension. Two patients with a proximal type I endoleak required stent graft extension.

Imaging results. Endoleak was identified in 17 of 36 patients with adequate follow-up CT scans and included types I, II, and III in 3, 11, and 3 patients, respectively. Reintervention for endoleak was needed in six patients as described above. At a mean follow-up of 24 months, graft patency assessed by CT scans was 91% overall, with most occlusions occurring in renal artery bypasses. The patency rates of the bypasses stratified according to vascular bed included: 89% for renal artery (55/62), 94% for superior mesenteric artery (31/33), and 93% for celiac artery (27/29).

Postoperative imaging identified perigraft fluid collections >1 cm in 20 (54.1%) of 37 patients with follow-up imaging. All but two patients with fluid collections had these present on the initial postoperative CT scan. These two patients had fluid collections identified at the 6-month CT scan; neither patient required evacuation at the time of last follow-up despite continued growth of the collection. Of the 17 patients with additional imaging, the natural history of these collections was variable. The two patients with polyester grafts had resolution of their fluid collection on subsequent imaging. Six patients had persistent collections that were stable or decreasing in size and were managed with observation. Nine demonstrated enlarging fluid collections with a variable clinical course. Four patients with enlarging fluid collections required re-exploration (Table II). Two of these patients developed frank graft infection requiring reoperation. The first patient underwent open drainage of a retroperitoneal abscess surrounding the grafts and subsequently expired 6 months later. The second patient developed a groin infection requiring drainage and sartorius muscle flap placement over her aortofemoral limb. She subsequently infected her intra-abdominal debranching grafts based off this aortofemoral limb and expired shortly thereafter. The remaining two patients with symptomatic (abdominal distension and pain) enlarging fluid collections underwent open drainage (Fig 1 shows the time course of one patient). Both patients were found to have culture negative fluid collections on evacuation. However, one of these patients subsequently went on to develop a retroperitoneal infection treated with drainage and lifelong antibiotics. This patient expired from a ruptured hypogastric aneurysm as described above.

Table III. Univariate analysis of fluid collections

	Collection	*No collection*	P *value*
Fluid collection at any time			
Age (years)	73.5 ± 7.7	67.5 ± 10.0	.05
Use of ePTFE grafts	18 (90%)	11 (68.8%)	.012
Preoperative creatinine (mg/dL)	1.2 ± 0.4	0.8 ± 0.2	.002
Use of bovine pericardium coverage of grafts	8 (40%)	1 (6.3%)	.026
Number of bypasses	3.7 ± 0.7	3.0 ± 1.1	.028
Fluid collection at last follow-up			
Age (years)	73.9 ± 8.0	67.7 ± 9.4	.043
Use of ePTFE grafts	18 (100%)	13 (72.2%)	.045
Preoperative creatinine (mg/dL)	1.2 ± 0.4	0.8 ± 0.2	.001
Use of bovine pericardium coverage of grafts	8 (44.4%)	1 (5.6%)	.018
Number of bypasses	3.7 ± 0.8	3.1 ± 1.1	.036
Use of iliac artery inflow	16 (88.9%)	10 (55.5%)	.06

ePTFE, Expanded polytetrafluoroethylene.

The development of a postoperative fluid collection at any time correlated on univariate analysis with increasing age, number of constructed bypasses, use of ePTFE, bovine pericardium for graft coverage, and preoperative creatinine (Table III). By logistic regression, only the number of constructed bypasses (P = .047, odds ratio [OR] 3.1, 95% confidence interval [CI] 1.2-9.5) and preoperative creatinine (P = .007, OR 216.4, 95% CI 4.3-10792.1) were independently associated with the occurrence of a fluid collection.

The presence of a postoperative fluid collection at last follow-up correlated with increasing age, preoperative creatinine, use of iliac artery as inflow source, coverage of debranching grafts with bovine pericardium, and with use of ePTFE as bypass graft material of choice (Table III). By logistic regression analysis, both the number of constructed bypasses (P = .044, OR 3.5, 95% CI 1.0-11.8) and preoperative creatinine (P = .005, OR 439.3, 95% CI 6.0-31965.4) independently predicted the presence of a postoperative fluid collection at last follow-up.

An analysis of factors associated with either the persistence or growth of fluid collections was performed with univariate analysis. Multivariate analysis was not feasible given the smaller patient numbers with multiple postoperative CT scans (n = 17). Again, impaired preoperative renal function assessed by glomerular filtration rate (GFR) was associated with this outcome (GFR decreasing fluid collection 100.7 ± 22.0 vs stable or increasing collection 59.4 ± 18.5, univariate P = .004). The use of polyester debranching grafts rather than ePTFE correlated with a reduced frequency of persistence of fluid collections (polyester 0% vs 87.5%, univariate P = .039). This

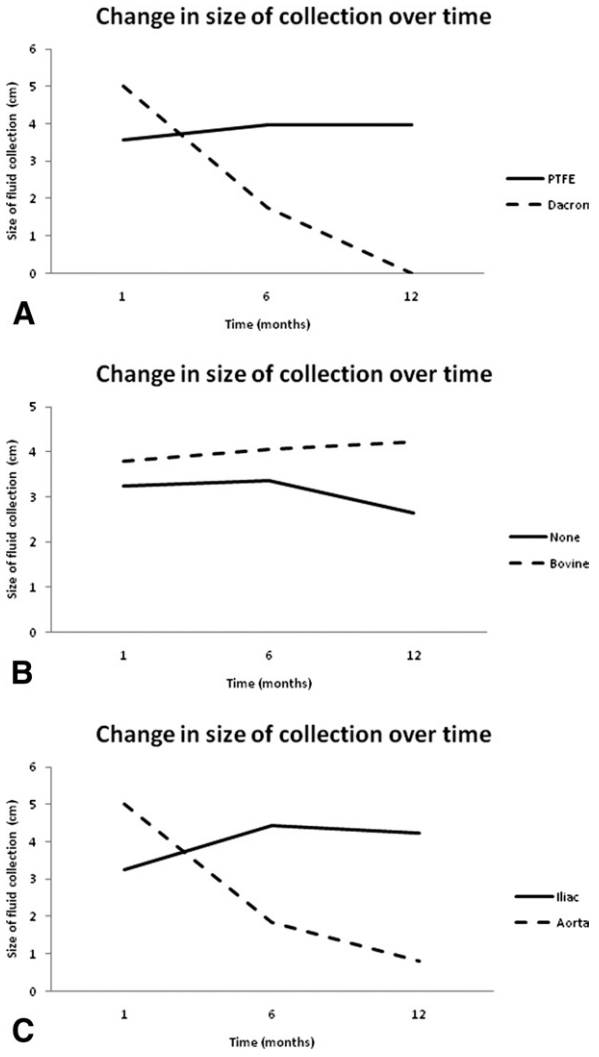

Fig 3. Change in average maximum diameter of fluid collection based on graft material **(A)**, debranching bypass coverage material **(B)**, and source of inflow **(C)**. In **(A)**, the *interrupted line* demonstrates the resolution of fluid surrounding polyester grafts while the *solid line* reflects the persistence of fluid surrounding PTFE grafts. In **(B)**, the average change in size of the fluid collection based on coverage material is depicted. The *interrupted line* represents graft coverage with bovine pericardium compared with patients without coverage. This suggests that bovine pericardial use may result in persistence or growth of fluid collections. Finally in **(C)**, the average change in size of fluid collection based on source of inflow is shown. The *solid line* represents grafts originating from the iliac arteries while the *interrupted line* represents grafts using the aorta as the inflow source, again suggesting the use of aortic inflow as protective against persistence of fluid collections.

is depicted in Fig 3, *A*, where a graph of fluid collection size as a function of time suggested the protective role of a polyester debranching graft. Both patients with polyester grafts had resolution of the collection on follow-up imaging. In stark contrast, none of the patients with thin walled ePTFE grafts resolved their fluid collections. Understanding the smaller patient numbers and their effects on valid statistical analysis, a similar assessment of fluid collection size as a function of time was also performed for patients with and without use of bovine pericardium coverage of debranching grafts (Fig 3, *B*), as well as use of iliac artery inflow (Fig 3, *C*), where a trend toward statistical significance was suggested (bovine pericardium $P = .09$, and aortic inflow source $P = .1$).

DISCUSSION

Endovascular therapy for the treatment of infrarenal and isolated descending thoracic aortic aneurysms has rapidly gained favor.[10,11] Despite a poor untreated natural history and the significant morbidity of conventional open repair, a parallel rise has not been seen in the treatment of thoracoabdominal aneurysms (TAAA). Likely reasons for this not only include logistic and regulatory issues, but also the long time delay (6-12 weeks) in acquisition of custom designed devices tailored for branch vessel anatomic variations seen with this pathology. In an effort to reduce the perceived morbidity of open repair, hybrid visceral and renal debranching with thoracoabdominal endovascular aortic repair (H-TEVAR) has emerged as a potential alternative to avoid concomitant thoracotomy and use of extracorporeal bypass support in these often elderly and debilitated patients.[6] The results of this therapeutic approach have been mixed, and comparisons to conventional open repair are limited to two series, including one from the authors' institution.[9,13] However, these midterm results suggested a higher risk for reintervention with the H-TEVAR group.

Although the index case in our series suggested durability at 9-years follow-up (with death occurring in this patient with Marfan syndrome from an untreated aortic root aneurysm), a major uncertainty in the H-TEVAR procedure is its unknown late results. Questions remain regarding the durability of visceral and renal bypass patency often with orientation in a retrograde manner, as well as the potential for enteric-graft erosion or endoleak. There have been a number of case reports and small series documenting the development of perigraft fluid collections following extra-anatomic bypasses, femoral-popliteal bypasses, and aneurysm repair.[8,9,14-17] Anecdotally, we have noted the frequent development of postoperative fluid collections surrounding the debranching grafts. This led to the current review, which was performed to characterize these collections and describe their natural history.

Our results suggest that these postoperative fluid collections represent a unique complication not previously described in patients undergoing H-TEVAR yet occurring in 54% of patients. The subsequent clinical course of these fluid collections was variable and ranged from benign to frank graft infection. The formation of these collections was related both to intrinsic patient factors such as age or impaired renal function, as well as specific intraoperative strategies. Potentially modifiable factors associated with increased risk for fluid collection include the use of ePTFE grafts, bovine pericardial patch coverage to separate debranching grafts from adjacent viscera, and the use of iliac arteries as a source for inflow. The fluid collections associated with polyester grafts, even when large, tended to resolve over time. In contrast, fluid collections

associated with PTFE grafts required intervention in 20% of cases. This may not have been statistically significant because of small overall patient numbers. The apparent difference in frequency and clinical course of the fluid collections between patients with thin-walled PTFE and polyester grafts was striking. The difference appears to be corroborated in previous studies where persistent fluid collections were only found in patients with PTFE graft.[8,16] Variable sac regression after endovascular abdominal aneurysm repair has also been suggested with the thin walled original Excluder graft (W. L. Gore and Associates) implicated in sac growth in the absence of endoleak. In contrast, polyester-based endografts did not display sac growth as readily.[18] The finding in our study of the number of bypass grafts as an independent risk factor for fluid collections is likely a surrogate for increased PTFE graft surface area. PTFE was not identified as an independent risk factor in this study, potentially due to sample size. The identification of renal failure as a risk factor of development of fluid collections in this study is a novel finding that warrants further evaluation. A possible mechanism of perigraft seroma formation has been previously studied by Ahn et al.[14] They identified these sterile collections in up to 4% of extra-anatomic bypass grafts, and postulated the presence of a humoral fibroblast inhibitor preventing adequate incorporation of the grafts. This identified decrease in fibroblast activity was eliminated from the serum following removal of the graft suggesting a unique interaction between the graft and the patient.

We continue to believe that open thoracoabdominal aneurysmectomy remains the gold standard therapy for thoracoabdominal aneurysms. The high rate of morbidity seen by us and others has tempered our initial enthusiasm for H-TEVAR leading us to exercise caution when considering intervention.[5-7,10,13] However, we do recognize the morbidity inherent in open thoracoabdominal aneurysm repair and consider the H-TEVAR option as an alternative to optimal medical therapy in those considered too high risk for conventional repair.[10] In addition, we have changed our practice to avoid the use of thin-walled PTFE for bypass construction and bovine pericardium for graft coverage.

The major limitation of this study remains the small sample size. Although this report describes one of the largest cohorts of patients described following H-TEVAR, longer-term studies with more robust numbers of patients are warranted to determine whether this complication may limit the long-term durability of this procedure.

In summary, we have described midterm follow-up of a unique occurrence of the development of a fluid collection around bypass grafts following the hybrid repair of thoracoabdominal aneurysms. Both patient factors, as well as operative strategies, are implicated in its development, and suggest potential approaches to prevent its occurrence.

AUTHOR CONTRIBUTIONS

Conception and design: JH, HP, EC, JE, GD, GU
Analysis and interpretation: JH, HP
Data collection: JH, HP
Writing the article: JH, HP
Critical revision of the article: JH, HP, EC, JE, GD, GU
Final approval of the article: JH, HP, EC, JE, GD, GU
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Overall responsibility: HP

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