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A Single Center Review of a Total Transfemoral Approach to Upper Extremity Access in Branched and Fenestrated Physician Modified Endografts

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Abstract

Objectives: Aortic aneurysms are normally treated by an endovascular approach. Due to the lack of devices and increasing experience, there is a growing number of complex aneurysms undergoing repair by physician modified endografts (PMEGs). Previously, our practice was to target visceral vessels exclusively through upper extremity access. We have since shifted to an all transfemoral approach when possible. This study aims to show the operative benefits of transfemoral only approaches.

Methods: Patients who underwent a PMEG at a tertiary center between 2015–2020 were included. Patients were stratified into two groups based on branched vessel approach – transfemoral only versus axillary or composite (axillary and femoral). Forty-one patients had a pararenal or type IV thoracoabdominal aneurysms (TAAA) and 15 patients had more complex TAAA. Primary outcomes were operative time, radiation exposure, fluoroscopy time, contrast and blood loss. Secondary outcomes were 30-day mortality and major adverse events. Linear regression models were used to evaluate the association between approach type and the main outcomes.

Results: Fifty-six patients were included with 48% (n=27) in the transfemoral group and 52% (n=29) in the axillary/composite group. Baseline characteristics were similar between the groups. Intraoperative outcomes revealed significant increase in the average operative time (418 vs. 246min, p<0.001), in radiation exposure (2755 vs. 1740 mGy, p=0.03), in fluoroscopy time (108 vs. 74min, p=0.01) and in blood loss (579 vs. 202cc, p=0.002) in the axillary/composite group compared to the transfemoral group. There was no significant difference in 30-day mortality or major adverse events including stroke.

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The authors declare that there is no conflict of interest.

Conclusions: This study shows a transfemoral approach to complex endovascular aortic aneurysm repair as opposed to axillary/composite approach has decreased operative time, radiation exposure, and fluoroscopy time and no significant differences in 30-day mortality or major adverse events. When treating complex aneurysms, improving efficiency is important to minimize morbidity to patients and operators.

INTRODUCTION

Thoracoabdominal aortic aneurysms (TAAA) represent a subset of complex aortic aneurysms that comprise anywhere from the descending thoracic aorta with extension to the abdominal aorta and even to the iliac bifurcation. TAAA classification was first developed by Stanley Crawford based on open surgical approaches to identify proximal and distal anatomic landmarks of the aneurysm and later revised by Safi and Miller[1,2]. TAAAs are defined as dilation over 50% of the normal aorta and have an incidence of 10 per 100,000 person-years with a 10–20% five-year survival if left untreated[3]. Prior studies have shown the risk for rupture doubles for aneurysms over 5cm with an aneurysm of 6cm having a 7% risk of rupture or dissection and an aneurysm more than 7cm having a risk of 43%[4–6]. The first successful documented open repair of a TAAA was in 1953 by Michael DeBakey and Denton Cooley in Texas and ushered in an era of open surgical repair for complex aneurysms both in the United States and around the world[7,8]. As treatments for complex aneurysms became more popular, more postoperative data was collected and Rigberg et al assessed 1000 patients who underwent open TAAA repair in the state of California and found that 30-day mortality when stratified by age showed an increase in mortality as age increased[9].

Due to concern for an aging population with increased morbidities and the inability to tolerate an open operation, a minimally invasive endovascular approach was pursued after simple infrarenal aneurysms reported success with shorter hospital stay, small incisions, faster recovery and return to baseline functional activity sooner[10]. The transition to endovascular repair was mirrored in scientific literature as publications in both the United States and worldwide from 1994–1997 were less than 50 compared to almost 900 publications between 2013–2017[11].

Additionally, the Aortic Research Consortium was developed to study fenestrated and branched repairs[12]. Given the complex nature of TAAAs and the need for a proximal landing zone involving the mesenteric vessels, the advent of branched and fenestrated physician modified endografts (PMEG) allowed previously deemed inoperable endovascular aneurysms to be treated.

The first documented PMEG was in 1996 by Jae Hyung Park in Seoul, South Korea with a renal artery fenestration and inferior mesenteric artery fenestration[13]. Since the adoption of endovascular techniques for the thoracoabdominal space, there has been a rapid progression from Chuter et al. in 2001 successfully deploying a modular 3 component endograft; Greenberg et al. in 2004 conducting a prospective study of 32 patients and found visceral artery cannulation to be successful with a decrease in aneurysm sac to Starnes et al. in 2018, who used automated software in 30 patients to identify and plan visceral artery cannulation in fenestrated endografts[14–16]. Ultimately, this led the Society of Vascular Surgery (SVS) to create reporting standards for the different types of repairs and associated recommendations[17]. Traditionally, PMEGs with branches and fenestrations involve the antegrade cannulation of mesenteric and renal arteries through an upper extremity approach to optimize technical success. Additionally, current branched and fenestrated grafts in trial require upper extremity access for deployment. Current literature has shown this can be associated with strokes, access site hematoma or nerve damage[18–21]. Our study aims to show that accessing the branched vessels in a retrograde position from the groin is beneficial to both the surgeon and the patient.

METHODOLOGY

Study Population

All consecutive individuals who have undergone a PMEG at the University of California, San Diego and the Veterans Affairs San Diego Medical Center from 2015–2020 were included in our Institutional Review Board approved, retrospective study. These individuals were retrospectively reviewed from a prospectively collected local data base. Data includes preoperative variables, intraoperative data, 30-day postoperative care and long-term follow-up when available from most recent office visit. Inclusion criteria was any patient who had an aortic aneurysm ranging from pararenal to any thoracoabdominal aortic aneurysm or type I endoleak after previous failed EVAR in patients unfit for open repair. A total transfemoral approach using branches was limited to patients with true lumens larger than 25mm in the perivisceral segment due to the smallest device being 24mm in size. Commonly, dissection cases do not have a 25mm true lumen, however, when possible, attempts were made to STABILISE (stent-assisted balloon-induced intimal disruption and relamination in aortic dissection repair) and create a larger lumen to accommodate a transfemoral approach. There was no randomization that was performed between upper extremity and transfemoral access. Exclusion criteria was any patient that was considered medically and surgically fit for an open repair. All aneurysms repaired in our study were considered elective and met size criteria of greater than 5.5cm or had defined features for elective repair such as rapid expansion, endoleak from previous repair or symptomatic penetrating aortic ulcer[22](Supplemental Figure 1). Of note, a previous history of EVAR or open repair did not preclude a total transfemoral approach. After reviewing all patients who underwent a PMEG, a total of 56 patients fulfilled our inclusion criteria.

Measurements

This is a retrospective review of a prospectively maintained local database and includes the patient's age, sex, body mass index and medical comorbidities. We also documented the size of the aneurysm from imaging at the time of repair, extent/type of aneurysm, history of previous endovascular aneurysm repair or history of previous open aneurysm repair. Intraoperative variables included type of graft, need for femoral endarterectomy, number of fenestrations, number of branches, and how visceral vessels were accessed – whether it be through a total transfemoral (TTF) approach or an upper extremity mixed (UEM) approach – which consists of either axillary/brachial access alone or a composite axillary/brachial and femoral access.

Primary and Secondary Outcomes

Primary outcomes were intraoperative and 30- day postoperative data which included operating room time (measured by start and end times of anesthesia), volume of contrast administered during operation, radiation exposure measured by the absorbed dose in milligray (mGy), fluoroscopy time, estimated intraoperative blood loss and need for transfusion. Postoperative events in the 30-day postoperative period were pneumonia, stroke, ischemic neuropathy, need for fasciotomy, myocardial infarction, cardiac arrhythmia, return to the operating room, and death. We also documented overall length of hospital stay. Secondary outcomes included long-term follow-up, such as time to most recent CT scan for surveillance, most recent diameter of aneurysm, any evidence of endoleak on CT imaging, time to death if applicable, any reinterventions that occurred, and target vessel instability. Target vessels were defined as renal or mesenteric arteries. Vessel instability was defined as any branch related death, rupture, re-intervention for endoleak, stenosis, occlusion or disconnection[23].

Surgical Technique

The technique for a TTF PMEG begins with careful planning off of the preoperative CT scan to create a patient specific graft using a double taper thoracic device and 1.5-centimeter beveled Viabahn branches sutured with polytetrafluoroethylene (PTFE) to reinforce the fenestrations. The main body of the PMEG is deployed using overlay software that ensures proper orientation of the graft with radiopaque markers throughout deployment. The markers are used to confirm the graft is at the appropriate height and all branches are deployed superior to any associated target vessel origin in the direction of flow. Once the main body is deployed, the access site is downsized to a 12 French sheath by tightening two ProGlide devices to improve flow to the lower extremities while minimizing bleeding around the sheath. A morphable sheath (Nagare or Oscor) is then used to cannulate the most distal branch or fenestration first, which is then exchanged for a stiff wire and delivery of the stent. Once all branch extensions are complete, single fluoroscopic shots are performed to confirm appropriate overlap and flare. Finally, completion angiogram ensures target vessel flow, lack of dissection and lack of high pressure endoleak. All cases in this study were performed by the same surgeon with variable co-surgeons. Additional details regarding PMEG creation and back table preparation have been well documented and described in the literature[20,24,25].

Statistical Methods

The electronic medical record was queried for all patients who had undergone complex AAA or TAAA repair from 2015–2020 and a database was created using the aforementioned measurements. Less than 5% of the variables were missing from the database. For continuous variables, means and standard deviations were captured and statistical significance assessed through Student’s T-test and Wilcox rank-sum test for nonparametric variables. For categorical variables, sample size and proportions were obtained and statistical significance was determined with the Chi-Square test of independence.

The data was split in two groups based on access vessel for mesenteric stenting. This included TTF group and a UEM group. We used a multiple linear regression model to test clinically significant confounders and assessed long-term survival between the two groups with the Kaplan-Meier estimator. A 2-tailed alpha value of < 0.05 was considered statistically significant. All data analysis utilized R Studio (version R-4.1.0, Boston, MA).

RESULTS

Our total cohort consisted of 56 patients who underwent a PMEG between 2015 and 2020 at a large academic center. The mean ± SD age was 74.5 ± 8.7 years old and the cohort was 17.9% female. The cohort was split into two groups based on mesenteric vessel access. The first group was mesenteric approach via a retrograde TTF approach and represented 27 patients, or 48.2% of the cohort. The other group was mesenteric approach via an anterograde UEM access which together represented 29 patients, or 51.8% of the cohort. A TTF approach is the preferred method in all patients unless technically impossible due to a small true lumen. This was more likely in dissection cases with a true lumen less than 25mm necessitating UEM approach.

Table I represents the baseline demographic characteristics of both groups. The groups were not significantly different except for cardiac conditions and previous history of EVAR: 22.2% in the TTF group compared to 62.1% in the UEM group (p<0.01). The prevalence of CHF was 3.7% in the TTF group compared to 34.5% in the UEM group (p<.01), presence of pacemaker was 3.7% in the TTF group compared to 24.1% in the UEM group (p<.05), and history of CABG or PCI was 37.0% in the TTF group compared to 65.5% in the UEM group (p<.05).

Table II contains the anatomic characteristics of the aneurysms prior to operative intervention. There was no statistically significant difference in aneurysm size between the two groups. However, the type of aneurysm was significant with 3 longer extent type 1–3 TAAAs in the TTF group and 16 in the UEM group (p<.01) and remained significant even after breaking down the extent of TAAA based on the modified Crawford classification[1,2]. Figure 1 represents that temporally over the 6-year study, a near equal number of cases were performed from a TTF approach and UEM approach per year.

Table III represents our operative and 30-day outcomes and we found a significant decrease in operative time, radiation exposure, fluoroscopy time, estimated blood loss and need for transfusion in the TTF group compared to the UEM group. The average operative time in minutes was 246 versus 418 (p<.0001), radiation exposure was 1740 versus 2755 mGy (p<.05), fluoroscopy time was 74 versus 108 minutes (p<.05), blood loss was 203 versus 579cc (p<.01), and need for transfusion was 0.3 versus 1.2 units (p<.05) in the TTF compared to UEM group, respectively. Additionally, we created an index between the amount of radiation in mGy divided by each patient's BMI and found no significant difference, suggesting that greater radiation in the UEM group is not due solely to BMI. In terms of 30-day outcomes, we found a significant difference in length of stay, 4 days in the TTF group versus 10 days in the UEM group (p<.01). However, in terms of morbidities such as pneumonia, stroke, cardiac arrhythmia or 30-day mortality there were no significant differences. There were no upper extremity access site pseudoaneurysms, dissections, reinterventions or neuropraxias, however, there was one upper extremity access site hematoma that resolved spontaneously.

We re-did our analysis of primary outcomes after adjusting for significant contributions in both the preoperative and intraoperative setting. This included controlling for the following confounders – history of CHF, history of EVAR, aneurysm extent, and number of fenestrations and branches performed. After controlling for these factors, we found a significant decrease in operative time ($p<.0001$), contrast use ($p<.0001$), radiation exposure ($p=0.016$), and fluoroscopy time ($p=0.002$) in the TTF group versus UEM (Supplemental Table I).

We had 100% technical success rate, defined by the SVS as access to the arterial system, deployment of aortic graft and all target branches, restoration of flow in all target vessels, absence of type I or III endoleak, and patency of all graft components, with four bail out snorkels or in situ fenestrations (one celiac artery in the TTF group, two superior mesenteric arteries in the UEM group and one renal artery in the UEM group) out of 185 vessels cannulated[17, 23]. Table IV has the remaining intraoperative characteristics and there was a significant difference between number of fenestrations; 22 in the TTF group, 12 in the UEM group ($p<.01$) and number of branches; 6 in the TTF group and 21 in the UEM group ($p<.001$), which remained even after breaking down by specific number of fenestrations ($p<.05$) or branches ($p<.01$).

In terms of the three 30-day mortality events there were no significant differences between the two groups, however, there were two deaths in the UEM group – one intraoperative death resulting from thoracic aortic dissection retrograde to the aortic valve after completion of the PMEG and a second from an embolic stroke in the post anesthesia care unit as well as one in the TTF group who a hemorrhagic stroke at home on the day of discharge. Of note, but not statistically significant, the two deaths in the UEM group were directly related to the operation and PMEG, while the death in the TTF group was not.

Long-term follow-up is captured in Table V with an average follow-up in the TTF group of 564 days and 372 days in the UEM group. There were some patients lost to follow-up, and complete data was obtained for 23/27 of the TTF group patients and 25/29 of the UEM group. There was no significant long-term morbidity, major adverse event, change in diameter of AAA, incidence of endoleak, or mortality between the two groups. Supplemental Figure 2 represents the Kaplan-Meier survival model of all-cause mortality between the two groups.

Supplemental Table II identifies any patient with target vessel instability and associated intervention or result. In the TTF group, one individual had a type 3c and 3d endoleak treated with angioplasty with stable aneurysm on follow-up imaging. Four individuals in the UEM group had endoleaks, one type 3d with a stable aneurysm and the patient passed after one year from other comorbidities, two individuals with type 3c which did not require intervention and have had stable aneurysms on surveillance and finally one type 1c with resolved after superior mesenteric artery extension. Overall, there was no difference in target vessel instability between the two groups.

DISCUSSION

Fenestrated and branched repairs can offer a minimally invasive, endovascular alternative to treat complex perivisceral or thoracoabdominal aneurysms. The endovascular approach for treatment of TAAAs has traditionally relied on upper extremity access for cannulation of mesenteric and renal arteries due to the ability to stage deployment of the fenestrated graft sequentially and obtain wire access to each visceral vessel to optimize technical success. This however, requires a longer time with a larger sheath in place, increasing risk of upper extremity complications such as proximal dissection and stroke[18–21]. In a TTF approach the groin sheath is able to be downsized early in the procedure, once the entire aortic main body has been deployed and prior to visceral vessel catheterization compared to UEM approach where the aortic main body is unsheathed one visceral vessel at a time to allow selective catherization. In our experience we observed the patients with aneurysm related mortality (ARM) in the upper extremity group were directly related to the procedure. One patient had a proximal dissection originating at the subclavian artery from sheath injury on post-mortem exam which was ipsilateral to the access site. The second patient and a major ischemic posterior stroke ipsilateral to the upper extremity access site in a vertebral artery distribution.

Our study compared a TTF to UEM approach and found a decrease in operative time, radiation exposure, fluoroscopy time and contrast use from the TTF approach after controlling for history of CHF, previous EVAR, extent of preoperative aneurysm, and total number of vessels treated. Current literature supports an increased risk of stroke with upper extremity access and based off Vascular Quality Initiative (VQI) data, arm access is related to an 8.4 times higher risk of stroke and single institution studies have found stroke incidence to be as high as 5%[26–28]. Similarly, European registries have found a stroke rate of 3% in patients with endovascular repair of their thoracic aorta[29]. Additionally, O'Donnell et al. using VQI data found that patients who underwent a chimney or snorkel had a 3.3% chance of having a stroke compared to 0.9% for patients who had a PMEG[18]. It is thought that a significant risk for perioperative stroke in endovascular repair has to do with instrumentation and crossing of the aortic arch[30].

A recent meta-analysis of 500 patients found a complication rate of 8% with upper extremity access, including bleeding, stroke, stenosis and pseudoaneurysm[31]. Further studies have found an increase in upper extremity morbidity with literature indicating a 4% risk of brachial plexus injury[32]. However, the introduction of preloaded guidewires has been shown to decrease access site complications, owing to less manipulation of the catheter[33,34]. To address stroke risk, studies were conducted to compare right versus left upper extremity access. Mirza et al. looked at surgical exposure of the brachial artery for mesenteric vessel catheterization and found a significant difference with increased incidence of stroke with right upper extremity access compared to left upper extremity access[19].

Given the literature shows complications associated with upper extremity access, albeit small in percentage, some surgeons have opted for a retrograde TTF approach to avoid upper extremity access site complications and crossing the aortic arch. In Germany, 150 patients who underwent an EVAR repair with a custom made device (CMD) were split based on upper extremity versus TTF access. They found a significant decrease in radiation dose and operative time in the TTF group[35]. Our study shows similar advantages treating similar anatomical aneurysms and that TTF access for visceral vessel cannulation in complex aneurysms has benefit over the traditional upper extremity access. Additionally, Eilenberg et al found a 3% rate of brachial access complications, 8.6% stroke rate in the upper extremity group and no stroke occurrence in the TTF group[35]. At Southwestern Medical Center, 148 patients underwent a fenestrated endovascular aneurysm repair and 66% of patients had an upper extremity access site, while the remaining had a femoral access site. Four patients developed upper extremity access site complications including hematoma and neurological symptoms, however, there was no difference in stroke rate between the TTF versus upper extremity group[36].

Our study aims to show that a TTF approach to visceral vessel cannulation has less complications and benefits to both the patient and provider. Our study had an ischemic stroke rate of 3% and only occurred in the UEM access group, supporting current literature that crossing the arch is associated with increased stroke risk[26–28,37]. Furthermore, our incidence of upper extremity complications was 3% and is similar to current literature[32,38]. Finally, the decreased radiation exposure seen in our TTF group compared with UEM group supports currently literature of branched and fenestrated endografts[39]. Overall, our findings suggest that TTF access has potential benefit. We do acknowledge that there was a learning curve during this time period. The authors feel however that this is a field where approaches and techniques are continually evolving. We evaluated our evolution of approaches showing that year after year our overall volume increased, however, our percentage of TTF versus UEM remained unchanged. This is also due to treating more anatomically complex aneurysms over time with higher rates of patients with dissections having smaller flow lumens. Overall, it was surgeon preference to transition any possible case to TTF approach to avoid complications such as stroke, arch dissection, hematoma and neurapraxia. Even though future technologies will have delivery options to come from the upper extremity for access and branch stent placement, there will be methods that can be adopted to perform this from a TTF approach. These methods should be explored in order to save operative time, radiation exposure, contrast use, and fluoroscopy time.

Limitations

Our study had several limitations including a heterogenous study group with more TAAAs in the UEM group. Inherently the retrospective review of our cohort has limitations that a prospective study would not have. Additionally, although our total sample size of 56 represents a large number of PMEGs based on the literature, each subgroup had approximately 20–25 patients and therefore regression model analysis created even smaller groups and a larger sample size for better power would be beneficial in the future. Additionally, due to anatomic limitations performing a TTF approach was not always feasible due to a small flow lumen at the level of the visceral arteries. In terms of concerns related to the team's learning curve, adoption techniques do not apply due to an equal number of patients in both the TTF and UEM cohorts each year (Figure 1). While we agree that our two cohorts are not identical, our analysis models attempted to address these factors as much as possible including demographic factors, aneurysm extent and procedural details such as fenestrations and branches. Finally, in order to see better long-term results on endoleak and target vessel instability, a longer follow-up interval is warranted.

CONCLUSION

We look forward to the Food and Drug Administration approval of off the shelf and/or CMD's for these pathologies, however, they will not meet the needs of all patients either due to anatomic issues or timing required for more urgent repairs. PMEGs may still be required for a significant number of these patients and therefore we seek to add to the literature reporting on improvements in the technique at our institution. Our retrospective cohort study of 56 patients at a large tertiary academic center who underwent PMEG for complex AAA and TAAA suggests that a TTF approach has benefit over a UEM approach for visceral vessel access when anatomically feasible. Current practice for vessel cannulation has focused on upper extremity access and an antegrade approach, however, as previously stated in the literature this can be associated with increased risk of stroke, hematoma, and neuropathy. Our study showed significantly less operative time, blood loss, radiation exposure, and fluoroscopic time for patients in the TTF group, which indicates a possible benefit to both patients and providers while preserving excellent technical success. Adopting a TTF approach in more patients where there is an adequately sized true lumen, whether that was created using the STABILISE technique or exists de novo, may improve operative and long-term outcomes. Further larger and prospective studies to expand on our findings that a TTF approach for PMEG may be preferred and better for both patients and providers compared to a UEM approach.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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- Transfemoral approach to visceral vessels in PMEGs can have operative advantages
- Transfemoral approach to visceral vessels in PMEGs can have clinical outcome advantages
- Single-center retrospective review of prospectively collected data
- When technically feasible, a transfemoral approach should be considered

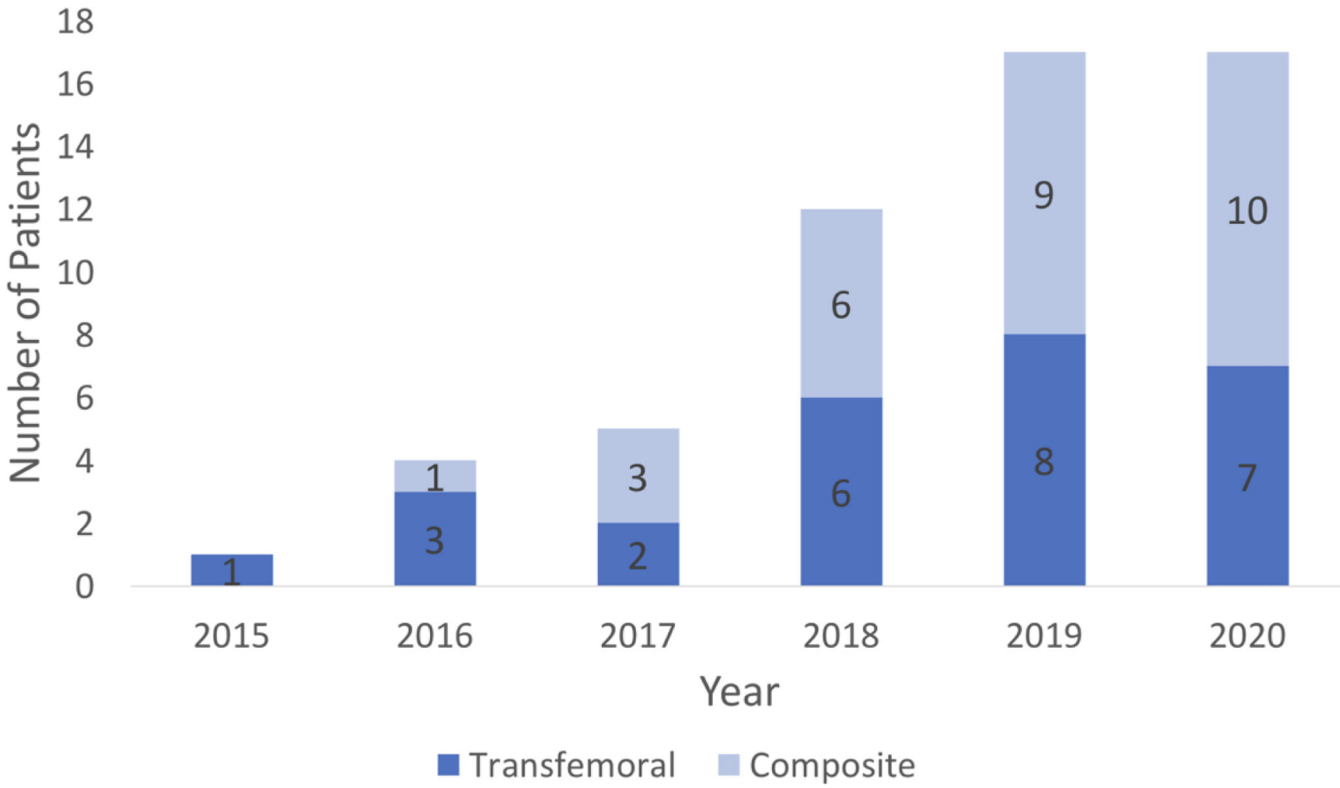

Figure 1:
Cases by Access Site Per Year

Table I:

Demographic and Clinical Risk Factors by Mesenteric Vessel Approach

Mean ± SD or N (%)	Total Transfemoral 27 (48.2)	Upper Extremity Mixed 29 (51.8)	P-Value
Age (years)	75.0 ± 6.9	74.0 ± 10.2	0.6778
BMI (kg/m^2)	25.1 ± 4.6	26.1 ± 5.7	0.4532
Female	4 (14.8)	6 (20.7)	0.5663
Atrial Fibrillation	6 (22.2)	8 (27.6)	0.6432
CHF	1 (3.7)	10 (34.5)	0.0038
PAD	7 (25.9)	7 (24.1)	0.8773
Cancer Diagnosis	8 (29.6)	8 (27.6)	0.8657
Pacemaker	1 (3.7)	7 (24.1)	0.0290
History of CABG or PCI	10 (37.0)	19 (65.5)	0.0331
OSA	3 (11.1)	4 (13.8)	0.7617
Type 2 DM	4 (14.8)	1 (3.4)	0.1361
History of stroke or TIA	5 (18.5)	5 (17.2)	0.9008
CAD	12 (44.4)	19 (65.5)	0.113
Smoker	22 (81.5)	23 (79.3)	0.8381
COPD	7 (25.9)	9 (31.0)	0.6724
History of DVT or PE	1 (3.7)	2 (6.9)	0.596
Hyperlipidemia	12 (44.4)	15 (51.7)	0.5859
Hypertension	23 (85.2)	27 (93.1)	0.3384
Chronic Kidney Disease	15 (55.6)	11 (37.9)	0.1864
History of EVAR	6 (22.2)	18 (62.1)	0.0026
History of open AAA repair	2 (7.4)	2 (6.9)	0.9409

BMI – body mass index

CHF – congestive heart failure

PAD – peripheral arterial disease

CABG – coronary artery bypass graft; PCI – percutaneous coronary intervention

OSA – obstructive sleep apnea

DM – diabetes mellitus

TIA – transient ischemic attack

CAD – coronary artery disease

Smoker – current or former

COPD – chronic obstructive pulmonary disease

DVT – deep venous thrombosis; PE – pulmonary embolus

Table II:

Aneurysm Characteristics Prior to Intervention

Mean ± SD or N (%)	Total Transfemoral 27 (48.2)	Upper Extremity Mixed[§] 28 (50.0)	P-Value
Aneurysm Size Prior to Repair (cm)	64.8 ± 11.1	73 ± 22.5	0.0927
TAAA	3 (11.1)	16 (57.1)	0.0003
TAAA by Extent			0.0104
0 (para/juxta renal)	24 (88.9)	12 (42.9)	
1	0	2 (7.1)	
2	2 (7.4)	3 (10.7)	
3	0	2 (7.1)	
4	1 (3.7)	4 (14.3)	
5	0	5 (17.9)	

TAAA – thoracoabdominal aortic aneurysm

[§]N = 28 due to one patient with penetrating atherosclerotic ulcer

Table III:

Operative and 30-Day Outcomes by Mesenteric Vessel Approach

Mean ± SD or N (%)	Total Transfemoral 27 (48.2)	Upper Extremity Mixed 29 (51.8)	P-Value
Exposure to BMI Ratio	116.8 ± 112.5	148.8 ± 112.2	0.2916
Operative Time (minutes)	246.1 ± 80.8	418 ± 120.3	<0.0001
Amount of Contrast (cc)	172.1 ± 70	191.7 ± 96.8	0.3883
Exposure* (mGy) median (IQR)	1740 (1252–3351)	2755 (2005–5000)	0.0311
Fluoroscopy Time* (minutes)	74.2 ± 37.6	108.1 ± 61.2	0.0153
Estimated Blood Loss (cc)	202.6 ± 170.9	579.3 ± 582.7	0.0021
pRBC*	0.3 ± 0.7	1.2 ± 2.0	0.0227
Pneumonia	1 (3.7)	2 (6.9)	0.596
Access Site Hematoma	0	1 (3.4)	0.3302
Stroke	1 (3.7)	1 (3.4)	0.959
Fasciotomy	0	1 (3.4)	0.3302
Cardiac Arrhythmia	2 (7.4)	3 (10.3)	0.7001
Length of Stay (Days)	4.0 ± 2.6	10.0 ± 9.4	0.0023
30 Day Mortality	1 (3.7)	2 (6.9)	0.596

Exposure to BMI Ratio: ratio of radiation exposure in milligray to body mass index

Table IV:

Intraoperative Variables by Mesenteric Vessel Approach

N (%)	Total Transfemoral 27 (48.2)	Upper Extremity Mixed 29 (51.8)	P-Value
Femoral Endarterectomy	1 (3.7)	2 (6.9)	0.596
Presence of Fenestrations	22 (81.5)	12 (41.4)	0.0021
Presence of Fenestrations by Number			0.0212
0	5 (18.5)	17 (58.6)	
1	1 (3.7)	2 (6.9)	
2	5 (18.5)	4 (13.8)	
3	9 (33.3)	3 (10.3)	
4	7 (25.9)	3 (10.3)	
Presence of Branches	6 (22.2)	21 (72.4)	0.0002
Presence of Branches by Number			0.0071
0	21 (77.8)	8 (27.6)	
1	1 (3.7)	1 (3.4)	
2	1 (3.7)	4 (13.8)	
3	2 (7.4)	3 (10.3)	
4	2 (7.4)	12 (41.4)	
5	0	1 (3.4)	
Scallop	4 (14.8)	0	0.0315

Table V:

Long-Term Follow-up by Mesenteric Vessel Approach

Mean ± SD or N (%)	Total Transfemoral 23 (85.2)	Upper Extremity Mixed 25 (86.2)	P-Value
Time from Surgery to Most Recent Follow-up Visit (Days)	564.2 ± 528	371.7 ± 408.4	0.1532
Aneurysm Size on Most Recent CT Scan (cm)	58.4 ± 13.1	70 ± 26.3	0.0634
Change in Aneurysm Diameter Pre-op to Post-op (cm)	−5.6 ± 7.2	−5.3 ± 8	0.8716
Types of Endoleak on Most Recent CT Scan	N = 22	N=24	
1	0	1 (4.2)	0.333
2	5 (22.7)	5 (20.8)	0.8764
3	1 (4.5)	3 (12.5)	0.3389
5	0	1 (4.2)	0.333
Death (All)[§]	3 (11.1)	8 (27.6)	.121
Time from Surgery to Death (Days)	525 ± 526.5	372.7 ± 422.2	0.2402

[§]Transfemoral (N=27) and Composite (N=29)