From the Society for Vascular Surgery

Urgent endovascular repair of juxtarenal/pararenal aneurysm by off-the-shelf multibranched endograft

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ABSTRACT

Objective: To report outcomes of urgent juxtarenal/pararenal aneurysms (J/P-AAAs) managed by off-the-shelf multibranched thoracoabdominal endografts (Cook, T-branch).

Methods: In this observational, multicenter, retrospective study, patients with J/P-AAAs treated by urgent endovascular repair by T-branch in 23 European aortic centers, from 2013 to 2023, were analyzed. Contained J/P-AAAs rupture, presence of related symptoms, and aneurysm diameter of >70 mm were considered as indication for urgent repair. Technical success (TS), spinal cord ischemia (SCI), and 30-day/hospital mortality were assessed as early outcomes. Survival, freedom from reinterventions, and target artery instability (TAI) were evaluated during follow-up.

Results: Overall, 197 patients (J-AAAs, n = 64 [33%]; P-AAAs, n = 95 [48%]; previous failed endovascular aneurysm repair (EVAR), n = 38 [19%]) were analyzed. The mean age and aneurysm diameter was 75 ± 8 years and 76 ± 4 mm, respectively. The American Society of Anesthesiologists score was 3 and 4 in 118 (60%) and 79 (40%) patients. Rupture, symptoms, and diameter of >70 mm were present in 51 (26%), 110 (56%), and 53 (27%) patients, respectively. An adjunctive proximal thoracic endograft was used in 28 cases (14%). The mean aortic coverage between the upper portion of the endograft and the lowest renal artery was 154 ± 49 mm. Single-stage repair and cerebrospinal fluid drainage were reported in 144 (73%) and 53 (27%) cases, respectively. TS was achieved in 182 (92%) cases (rupture, 84% vs no rupture, 95%; $P = .02$). Failures consist of TA loss (11 [6%]: renal artery, 9; celiac trunk, 2), type I to III endoleaks (2 [1%]), and 24-h mortality (2 [1%]). Rupture was a risk factor for technical failure ($P = .02$; odds ratio [OR], 3.8; 95% confidence interval [CI], 1.1-12.1). Overall, 15 patients (8%) had persistent SCI (rupture, 14% vs no rupture, 5%) with 11 (6%) , of paraplegia (rupture, 10% vs no rupture, 5%; $P = .001$). Rupture ($P = .04$; OR, 3.1; 95% CI, 1.1-8.9) and adjunctive proximal thoracic endograft ($P = .01$; OR, 4.1; 95% CI, 1.3-12.9) were risk-factors for SCI. Twenty-two patients (11%) died within 30 days or during a prolonged hospitalization. Previous failed EVAR ($P = .04$; OR, 3.6; 95% CI, 1.1-12.3), paraplegia ($P < .001$; OR, 9.9; 95% CI, 1.6-62.2) and postoperative mesenteric complications ($P = .03$; OR, 10.4; 95% CI, 1.2-93.3), as well as cardiac ($P = .03$; OR, 8.2; 95% CI, 2.0-33.0) and respiratory ($P < .001$; OR, 10.1; 95% CI, 2.9-35.2) morbidities were associated with 30-day/hospital mortality. The mean follow-up was 19 ± 5 months. The estimated 3-year survival and freedom from reinterventions was 58% and 77%, respectively. TAI occurred in 27 patients (14%) (occlusion, 15; endoleak, 14) with an estimated 3-year freedom from TAI of 72%.

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Conclusions: Urgent repair of J/P-AAAs by T-branch is feasible and effective with satisfactory TS and 30-day/hospital mortality in high-risk patients. However, extensive aortic coverage is necessary, leading to a non-negligible SCI rate, especially in case of aortic rupture or when adjunctive thoracic endografts are necessary. Previous failed EVAR and postoperative mesenteric complications, as well as cardiac and respiratory morbidities were associated with 30-day/hospital mortality and should be subjected to more research for the purposes of improving outcomes. (J Vasc Surg 2024;■:1-14.)

Keywords: Urgent endovascular repair; Juxta/Pararenal aneurysm; Off the shelf endograft; Branched endograft; Thoracoabdominal

Fenestrated and branched endovascular aneurysm repair (F/B-EVAR) is an established endovascular solution to treat juxtarenal/pararenal (J/P-AAAs) and thoracoabdominal aneurysms (TAAAs) with proven early/mid-term outcomes in high-risk patients, when anatomically feasibile.[1-5] These treatments are carried out by patient specific or off-the-shelf (OTS) endografts, according to the clinical scenarios (elective vs urgent cases) and anatomical characteristics.[1-5]

Patient-specific F/B-EVARs are routinely used to manage J/P-AAAs and TAAAs in elective situations, however manufacturing delays and anatomical limitations reduce their efficacy in urgent cases.[6,7] In 2012, the Cook Zenith T-branch (Cook Medical, Bloomington, IN) became the first OTS multibranched BEVAR (m-BEVAR) TAAA endograft commercially available in Europe, showing worldwide reproducible results in patients who cannot be timely managed by a custom-made solution.[8-10] Potential OTS FEVAR solutions (Cook Zenith P-Branch) have been investigated for J-AAAs in preliminary experiences, even if they are not yet commercially available in Europe or the United States.[11,12]

Physician modified endografts (PMEGs) are another possible solution; however, their use is limited by their discordance from the instructions for use, longer operative time, and necessity for the highest level of expertise in their planning and preparation.[13]

If used in urgent J/P-AAAs, OTS m-BEVAR endografts carry an enhanced risk of spinal cord ischemia (SCI), owing to an extensive supra-celiac aortic coverage,[14-16] possible intra-operative target artery (TAs) loss owing to the narrow aortic lumen at the level of TAs and diminished TAs follow-up patency owing to a lower long-term performance of renal branches vs fenestrations.[17-20] However, this strategy has not been investigated in an urgent setting.[9]

The aim of the present study was to report the early and mid-term outcomes of urgent endovascular J/P-AAAs repair by Cook Zenith T-branch endografts in a multicenter European experience.

METHODS

Study design and patient selection. This is an observational, multicenter, retrospective study performed without fundings from companies or other organizations. All patients undergoing urgent endovascular repair of J/P-AAAs by Cook Zenith T-branch in European aortic centers from January 2013 to June 2023 were collected prospectively. Each patient signed a dedicated informed consent for the endovascular aortic repair and their anonymous data analysis for clinical studies. In accordance with the European General Data Protection Regulation, all cases were deidentified with a coding number and clustered in a shared electronic database. Anatomical, procedural, and postoperative data were analyzed retrospectively. Approval by local review boards was not required owing to the retrospective and anonymized nature of the study.

Inclusion and exclusion criteria. Inclusion criteria were urgent endovascular repair by Cook Zenith T-branch in J-AAAs, P-AAAs, proximal type I endoleak in previously failed EVAR or chimney EVAR without TAAA evolution. For the present study, urgent endovascular repair was defined as the presence of symptoms (acute pain/peripheral embolization), contained aortic rupture and asymptomatic aneurysm with diameter of $>$70 mm.

Exclusion criteria were hemodynamic instability defined as loss of, or reduced level of consciousness or systolic blood pressure of $<$80 mm Hg, according with the current European Society for Vascular Surgery guidelines for abdominal aortoiliac aneurysm management.[21]

End points and definitions. Technical success (TS), SCI, and 30-day/in-hospital mortality rate were assessed as early endpoints. Survival, freedom from reintervention (FFR), and TA patency/TA instability (TAI) rates were evaluated as follow-up end points.

Preoperative comorbidities and cardiovascular risk factors, anatomical and operative features, and postoperative results were reported according to the current Society for Vascular Surgery reporting standards for endovascular aortic repair of aneurysms involving the mesenteric and renal arteries.[1] In particular, the definition of TS includes successful access to the arterial system, deployment of the aortic/iliac endografts, TAs catheterization, and placement of bridging stents with restoration and maintenance of flow in all intended target vessels, absence of type I or type III endoleaks at completion angiography and confirmed at 30-day radiological examinations, and patency of all aortic modular stent graft and intended side branch components.[1] TAI

was defined as any branch-related complication leading to aneurysm rupture, death, occlusion, component separation, or reintervention to maintain TA patency or to treat TA-related component separation or endoleaks.[1] Reinterventions were defined as any procedure related to the aneurysm, device, TAs, or access occurring after the date of the index operation.

Statistical analysis. Continuous data were reported as the mean ± standard deviation. Categorical data were expressed as frequency. Risk factors for TS, SCI, and 30-day/in-hospital mortality rates were evaluated by univariate and multivariate analysis. Survival, FFR, and freedom from TAI were estimated by Kaplan-Meier analysis. Risk factors for follow-up mortality were investigated by Cox Regression. A *P* value was considered significant when less than 0.05. Statistical analysis was performed by SPSS 28.0 (SPSS Inc., Chicago, IL).

RESULTS

Patient selection. Overall, 197 patients were enrolled in 23 European aortic centers (Supplementary Table I, online only). The mean age was 76 ± 7 years, the American Society of Anesthesiologists score was 3 and 4 in 118 (60%) and 79 (40%) patients, respectively. Demographics, cardiovascular risk factors, and preoperative comorbidities are summarized in Table I. Rupture, symptoms, and diameter of >70 mm were present in 51 (26%), 110 (56%), and 53 (27%) patients, respectively.

Anatomical features, preoperative sizing, and endograft planning. Aortic pathologies were J-AAA, P-AAA, and previous failed EVAR in 64 (33%), 95 (48%) and 38 (19%) cases, respectively. In the latter group, four patients (2%) had a previous failed chimney EVAR. The mean aneurysm diameter was 76 ± 4 mm. The mean proximal oversizing was 15% (range, 95-27%), and in 28 cases (14%) an adjunctive proximal thoracic endograft was necessary to achieve an effective proximal sealing. The mean aortic coverage between the upper portion of the endograft and the lowest renal artery was 154 ± 49 mm (isolated T-branch, 146 ± 34 mm; proximal TEVAR + T-branch, 199 ± 42). There were 750 TAs accommodated by branches: 184 (25%) celiac trunks, 195 (26%) superior mesenteric arteries, and 371 (49%) renal arteries. Twenty-seven patients (14%) had ≥1 preoperative hypogastric artery occlusion, which was bilateral in 4 cases (2%). In 17 cases (9%), an iliac branch device was planned to manage concomitant iliac aneurysms maintaining the patency of the hypogastric artery. Anatomical, sizing, and planning details are reported in detail in Table II.

Procedure. All procedures were performed under general anesthesia. Single-stage repair and prophylactic cerebrospinal fluid drainage were reported in 144 (73%) and 53 (27%) cases, respectively. In the 53 cases (27%) managed by a multistage approach (symptomatic cases, 21; asymptomatic cases with an aneurysm diameter of >70 mm, 32), the mean interstep time was 5 ± 1 days, and in all cases the complete aneurysm exclusion was achieved in the same hospitalization. Supplementary Table II (online only) summarizes the different strategies of procedural staging. Femoral access was surgical, percutaneous or both surgical and percutaneous in 53 (27%), 137 (70%), and 7 (3%) cases, respectively. An axillary/brachial access was performed in 173 cases (90%). Catheterization and stenting of TAs was performed by transaxillary, transfemoral, or both transaxillary and transfemoral approach in 165 (84%), 24 (12%), and 8 (4%) cases, respectively. The partial deployment technique was adopted in 36 cases (18%) to allow the TAs cannulation when paravisceral aortic diameter was <25 mm. Supplementary Table III (online only) summarizes the types of bridging covered stents adopted in each TA. Relining by bare metal stents was performed in 89 of 750 TAs (12%) (celiac trunk, 23/184; superior mesenteric artery, 21/195; renal artery, 45/371) to correct compression of the covered stents (52%-58%), acute angulation between covered stent and native TAs (32%-36%), or a dissection (5%-6%).

ARTICLE HIGHLIGHTS

- **Type of Research:** Multicenter, observational, retrospective study
- **Key Findings:** One hundred ninety-seven urgent juxtarenal/pararenal aneurysms were treated by off-the-shelf multibranched thoracoabdominal endograft in 23 European centers. The mean aortic coverage between the upper portion of the endograft and the lowest renal artery was approximately 150 mm. Technical success, 30-day/in-hospital mortality, and spinal cord ischemia rates were 92%, 11%, and 6%, respectively. Estimated 3-year survival, freedom from target arteries instability, and freedom from reintervention rates were 58%, 72%, and 77%, respectively. Risk factors for technical failure, spinal cord ischemia, 30-day/in-hospital, and follow-up mortality were identified.
- **Take Home Message:** Urgent repair of juxtarenal/pararenal aneurysms by off-the-shelf multibranched thoracoabdominal endograft is feasible and effective with satisfactory technical success and 30-day/hospital mortality in high-risk patients. Extensive aortic coverage is necessary owing to device design, leading to a non-negligible spinal cord ischemia rate, especially in case of aortic rupture or when adjunctive thoracic endografts are necessary. Predictors of technical failure, spinal cord ischemia, and mortality were identified and should be considered for surgical indication and outcomes' optimization.

Table I. Demographics, cardiovascular risk factors, and preoperative comorbidities

	No.	%
Male	165	84
Octogenarians	58	30
Hypertension	174	88
Smoking	77	39
Dyslipidemia	100	51
Diabetes	27	13
Chronic obstructive pulmonary disease	72	37
Coronary artery disease	87	44
Peripheral arterial occlusive disease	33	17
Atrial fibrillation	41	21
Oral anticoagulant therapy	81	41
Cerebrovascular disease[a]	27	14
BMI >31	34	17
Chronic kidney disease	59	30
Dialysis	6	3
Previous laparotomy	49	25
Previous aortic repair	72	37
Previous endovascular aortic repair	50	69
Previous surgical aortic repair	26	36
ASA score <3	118	60
ASA score >4	79	40

	Mean	Standard deviation
Age, years	75	8
Aneurysm diameter, mm	77	18
Creatine, mg/dL	1.3	0.4

ASA, American Society of Anesthesiologists Score; *BMI*, body mass index.
[a]History of stroke or transitory ischemic attack.

There were 38 renal/celiac arteries occluded preoperatively, and the respective branches of the T-branch were managed by cuff extension (balloon expandable covered stent) and plug.

Overall procedural and fluoroscopy time were 290 ± 117 and 80 ± 40 minutes, respectively. Iodinated contrast media volume and dose area product was 192 ± 89 mL and 236 ± 92 Gy/cm^2, respectively.

TS was achieved in 182 cases (92%) (rupture, 84% vs no rupture, 95%; $P = .02$). Failures consist of 11 TAs lost (6%) (renal artery, 9; celiac trunk, 2), 2 endoleaks (1%) (type Ib, 1; type Ic from renal artery, 1) and 2 cases (1%) of 24-h mortality.

TA patency at completion angiography was 99% (739/750). Both endoleaks were detected at the first postoperative CTA (before discharge, 1; at 30-day, 1) and were managed successfully (iliac branch device, 1; renal artery relining, 1). Rupture was a risk factor for technical failure ($P = .02$; OR, 3.8; 95% CI, 1.1-12.1). Procedural details and early outcomes were summarized in Table III.

Overall, 15 patients (8%) had persistent SCI (rupture, 14% vs no rupture, 5%; $P = .001$) with 11 cases (6%) of paraplegia (rupture, 10% vs no rupture, 5%; $P = .001$). Rupture ($P = .04$; OR, 3.1; 95% CI, 1.1-8.9) and adjunctive proximal thoracic endograft ($P = .01$; OR, 4.1; 95% CI, 1.3-12.9) were independent risk factors for SCI (Table IV). The mean hospital stay was 13 ± 3 days (single-stage approach, 8 ± 3 days; multistage approach, 17 ± 4 days).

Twenty-two patients (11%) died within 30 days or during a prolonged hospitalization. Previous failed EVAR ($P = .04$; OR, 3.6; 95% CI, 1.1-12.3), paraplegia ($P < .001$; OR, 9.9; 95% CI, 1.6-62.2), postoperative mesenteric complications ($P = .03$; OR, 10.4; 95% CI, 1.2-93.3), and cardiac ($P = .03$; OR, 8.2; 95% CI, 2.0-33.0) and respiratory ($P < .001$; OR, 10.1; 95% CI, 2.9-35.2) morbidities were independent risk factors for 30-day/hospital mortality (Table V).

Follow-up. The mean follow-up was 19 ± 5 months. Twenty-seven patients (14%) needed at least one reintervention (within 30-day, 4; after 30 days, 24) with four cases (2%) requiring multiple reinterventions. Timing, cause, treatment, and results of each reintervention are summarized in Supplementary Table IV (online only). Estimated FFR was 91%, 84%, and 77% at 1, 2, and 3 years, respectively (Fig, *A*).

TAI occurred in 27 patients (14%) (within 30 days, 3 [11%]; after 30 days, 24 [89%]) and in 8 (4%) cases >1 vessel was instable. There were 15 TA occlusions (renal arteries, 10; superior mesenteric artery, 3; celiac trunk, 2) and 20 TAs related endoleaks (renal arteries, 13; superior mesenteric artery, 3; celiac trunk, 4). Causes of the 35 TAIs are summarized in Supplementary Table V (online only). There was no difference in terms of patency between TAs with and without relining by bare metal stents (relining, 3/89 vs no relining, 12/661; $P = .41$).

The estimated freedom from TAI (patients) was of 93%, 85%, and 72% at 1, 2 and 3, years, respectively (Fig, *B*).

Overall, 60 patients (30%) died (within 30 days, 22; after 30 days, 38) with 2 cases (1%) of aortic-related mortality. Causes of mortality are summarized in Supplementary Table VI (online only). Estimated survival was 81%, 66%, and 58% at 1, 2, and 3 years, respectively (Fig, *C*).

DISCUSSION

In the present work, we report a series of 197 urgent J/P-AAAs treated over the last 11 years by T-branch in 23 European aortic centers.

TS, 30-day/hospital mortality, and SCI were 92%, 11%, and 8%, respectively, with an estimated 3-year survival, FFR, and freedom from TAI of 58%, 77%, and 72%, respectively. These results can be considered satisfactory,

Table II. Preoperative anatomical, sizing and planning details

Aortic lesion	No.	%
Juxtarenal AAAs	64	33
Pararenal AAAs	95	48
Proximal type I endoleak in previous failed EVAR	34	17
Previous failed Ch-EVAR	4	2
Overall	197	100
Clinical setting		
Rupture	51	26
Symptoms	110	56
Aneurysm diameter >70 mm	53	27
Aortic coverage	**Mean**	**Standard deviation**
From the lowest renal artery to bottom of the endograft, mm	154	49
From superior mesenteric artery to bottom of the endograft, mm	134	48
TAs	No.	%
Celiac trunk	184	25
Superior mesenteric artery	195	26
Renal arteries	371	49
Overall	750	100
Aortic diameter at the level of	**Mean**	**Standard deviation**
Celiac trunk origin, mm	32	10
Superior mesenteric artery origin, mm	32	13
Left renal artery origin, mm	30	17
Right renal artery origin, mm	30	18
Hypogastric artery status	No.	%
Bilateral patency	170	86
Unilateral patency	23	12
Bilateral occlusion	4	2
Endograft details		
Adjunctive thoracic endograft	28	14
Extra branches respect to preoperative target arteries[a]	38/788	5
Aortic bi-iliac abdominal endograft	176	89
Tube distal abdominal endograft	20	10
Aortic uni-iliac endograft	1	1
Iliac branch device	17	9

AAA, Abdominal aortic aneurysm; *Ch-EVAR*, chimney endovascular aneurysm repair; *TA*, target artery.
[a]There were 38 renal or celiac arteries preoperative occluded. The respective 38 branches of the T-branch were managed by cuff extension and plug.

especially if we consider that they were obtained in high-risk patients and an urgent clinical setting.

As reported by the Society for Vascular Surgery practice guidelines on the care of patients with abdominal aortic aneurysm, perioperative mortality of open repair procedures can be predicted according to preoperative patient's and procedural characteristics.[22] For example, a patient >75 years old, with aneurysm diameter of >65 mm, preoperative chronic renal failure, severe chronic obstructive pulmonary disease, and need for suprarenal aortic cross-clamping has a predictive score of 11, corresponding with a prohibitive perioperative mortality rate of 31%.[22]

This risk increases further in urgent situations. Mortality after open repair of urgent complex aortic aneurysm can be as high as 32%.[21,23] Comparative studies between open and endovascular repair of ruptured complex AAAs are rare and possibly influenced by patient heterogeneity. In a propensity score analysis from the American College of Surgeons, open repair had a 1.75-fold higher risk of perioperative mortality compared with cases managed endovascularly.[21,24] Moreover, open repair was associated with higher pulmonary complications, bowel ischemia, and longer intensive care unit stays.[21,24]

A clear definition of urgent complex aneurysm repair is of paramount importance to obtain homogeneous data for further comparisons/analysis. According to our inclusion criteria, three different clinical situations are considered as urgent J/PAAAs: those with rupture (26%), those with symptoms (56%), and those >70 mm in diameter (27%). Each of these scenarios carries different risks, complications, and outcomes and should be considered separately as summarized in Table III. Ruptures and symptomatic J/PAAAs have worse clinical outcomes compared with asymptomatic large aneurysms. The latter should be considered relatively urgent cases, owing to the risk of acute aortic events occurring in the lead time of the device customization. Different clinical experiences have reported a mean waiting time of >3 months, with aneurysm rupture occurring in ≤3% of cases with an aortic diameter of >70 mm, which is an independent predictor of this risk.[6,7] Ruptures have the worst technical and clinical outcomes, even if cases with hemodynamic instability are excluded; it is likely that these cases had a less than ideal anatomical situation, associated with a highly fragile patients.

F/B-EVAR by patient-specific device should be the first endovascular strategy for elective complex aneurysms according to the current European Society for Vascular Surgery guidelines,[21] but in urgent cases other different OTS endovascular solutions should be adopted for a prompt repair.

A parallel graft technique and standard abdominal endograft plus endoanchors have been proposed for

Table III. Procedural details and early outcomes

Steps of repair	No.	%
Single	144	73
Multi	53	27
CSF drainage	53	27
Femoral access		
Percutaneous	137	70
Surgical	53	27
Both percutaneous and surgical	7	3
Axillary access		
Overall	173	100
Left	117	68
Right	56	32
Surgical	144	83
Percutaneous	29	17
TA cannulation		
Transaxillary	165	84
Transfemoral	24	12
Both transfemoral and axillary failure of cannulation from below with rescue maneuvers from above	8	4
Partial deployment	36	18
	Mean	**Standard deviation**
Overall procedural time, minutes	290	117
Fluoroscopy time, minutes	80	40
Dose area product, mGy/cm^2	235,722	92,379
Iodinated contrast media, mL	192	89
	No.	**%**
TS	182	92
Technical failure	15	8
Target visceral vessels lost (renal, 9; celiac trunk, 2)	11	
Endoleaks I-III	2	
Intraoperative/24 h death	2	
	Mean	**Standard deviation**
Intensive care unit, days	4	2
Postoperative hospitalization, days	13	3
30-Day/in-hospital outcomes	No.	%
Overall SCI	21	11
Permanent SCI	15	8
Permanent paraplegia	12	6
Cardiac morbidity	18	9
Respiratory morbidity	28	14
Acute kidney injury	44	22
New onset of dialysis	5	2
Mesenteric complication	8	4
Stroke[a]	2	1
Major adverse evets	69	35
Reintervention within 30 days	4	2
30-Day/in-hospital mortality	22	11

	Overall, No (%)	Ruptured aneurysm (n = 51), No. (%)	No ruptured aneurysm (n = 146), No. (%)	*P* value
Technical success	182 (92)	43 (84)	139 (95)	.02
Overall SCI	21 (11)	11 (22)	10 (7)	.006
Permanent paraplegia	12 (6)	5 (10)	7 (5)	.36
30-day/in-hospital mortality	22 (11)	8 (16)	14 (10)	.30

CSF, cerebrospinal fluid; *SCI*, spinal cord ischemia; *TA*, target artery; *TS*, technical success.
[a]Stroke: hemorrhagic (n = 1; upper extremity access for TA cannulations); ischemic (n = 1; transfemoral access for TA cannulations).

urgent JAAAs with specific anatomical characteristics and lack of other solutions.[21] Recently, we have demonstrated that they have an anatomical feasibility in 37% and 27% of cases if performed inside the instructions for use by CE mark materials.[25] Cherfan et al[26] reported an experience with 58 complex aneurysms managed in urgent and elective situations by chimney and periscope techniques. Fourteen cases (24%) developed endoleak, 11 (19%) required reinterventions for an endoleak and 10 (17%) for compression/occlusion of the parallel graft.[26] According with these data, the authors concluded that chimneys/periscopes lead to poor outcomes, owing to their low TS, high morbidity/mortality, and reintervention rates.

PMEGs have been widely reported by US surgeons in the last decades and are now gaining popularity in Europe as well. In urgent or even elective cases with complex aortic aneurysms, fenestrations or branches are customized over a standard thoracic endograft by the surgical team right before its deployment. Recently, Gouveia and Melo[13] performed a systematic review and meta-analysis on the PMEG's outcomes. Overall, 282 urgent cases showed 30-day mortality, SCI, and major adverse event rates of 10%, 4%, and 25%, respectively with 19% reintervention rate at the midterm follow-up.[13] This technique is attractive; however, the quality of available data are presently low, and results should be validated in larger and prospective studies. Several issues should be considered in this context. One or 2 hours are necessary to customize the graft, and this time is not always present in urgent or emergent situations. A dedicated learning curve is necessary, even for surgeons with much experience in F/B-EVAR procedures, and long-term results need to be validated, especially in terms of endograft integrity and component disconnection. Finally, possible legal controversies may arise owing to the uncontrolled endograft modification in countries where other validated OTS solutions are available commercially.

The pivot branch (p-Branch) manufactured by Cook was proposed as potential OTS fenestrated solution in JAAAs and showed an anatomical feasibility of 70% in JAAAs managed by custom-made FEVAR and approximately 50% in ruptured JAAAs.[11,27] It is provided by a proximal OTS component incorporating a scallop for the celiac trunk, a fenestration for the superior mesenteric artery and two pivot fenestrations for the renal arteries. Different from a device with outer branches, an OTS endograft with fenestrations may be more difficult to adapt in urgent cases and the mismatch between the renal arteries take offs and the appropriate fenestrations was the most common reason of for nonuse.[11,27] Farber et al[28] reported a prospective multicenter experience with 76 cases managed in both urgent (11) and elective (65) situations. TS was 96% with no cases of 30-day mortality. The mean follow-up was 25 months with 26 patients (34%) requiring reinterventions, 2 cases (3%) of bowel ischemia, and 8 (11%) renal artery occlusions.[28] Sveinsson et al[29] reported a single-center experience including 23 patients with a mean follow-up of 45 months. TS was 92% and the estimated 5-year survival and TA patency rates were 76% and 91%, respectively.[29] The conclusions of both experiences suggest that OTS FEVAR with the p-Branch device may be safe and effective in anatomically selected JAAAs with acceptable early follow-up outcomes, being a reasonable option in cases where a custom-made solution is not available.[28,29] Despite these encouraging preliminary data, only few experiences have been reported and this platform is not commercially available in Europe yet.

Since 2012, the Cook T-branch was the first commercially available OTS m-BEVAR with an anatomical feasibility reported in ≤80% of TAAAs managed by custom-made F/B-EVAR.[8-10] It is a safe and effective solution for elective and urgent TAAAs repair with worldwide early and mid-term reproducible results published in the last 10 years.[8-10] Recently, in a multicenter collection of 100 endovascular repairs of ruptured TAAAs, 88 cases were managed by the T-branch with satisfactory results in terms of TS (88%), 30-day/hospital mortality (24%), and paraplegia (8%) rates.[30]

This device was designed to repair TAAAs, and no robust data are available for J/P-AAAs. However, OTS m-BEVAR technology has improved dramatically in the last decades, and it may be proposed as an effective solution in the urgent repair of J/P-AAAs owing to the lack of dedicated devices in this setting. Obviously, it cannot be considered a common solution; only 197 cases were

Table IV. Independent risk factors for spinal cord ischemia (*SCI*) at uni- and multivariable analysis

	Univariate	Multivariate		
	P value	*P* value	OR	95% CI
Preoperative factors				
Male	.23	-	-	-
Symptomatic aneurysm	.36	-	-	-
Ruptured aneurysm	.007	.04	3.3	1.1-8.9
Aortic diameter >7 cm	.06	-	-	-
Hypertension	1.0	-	-	-
Smoker	.75	-	-	-
Previous smoker	1.0	-	-	-
Dyslipidemia	.65	-	-	-
Diabetes	1.0	-	-	-
Chronic obstructive pulmonary disease	.82	-	-	-
Coronary artery disease	.49	-	-	-
Peripheral arterial occlusive disease	.05	.13	2.5	0.73-8.8
Atrial fibrillation	.58	-	-	-
Oral anticoagulant therapy	.25	-	-	-
Carotid artery stenosis >70%	.40	-	-	-
History of stroke/AIT	.75	-	-	-
BMI >31	.33	-	-	-
Chronic kidney disease	.62	-	-	-
Dialysis	.13	-	-	-
ASA 3	.40	-	-	-
ASA 4	.36	-	-	-
Juxtarenal aortic aneurysm	.81	-	-	-
Pararenal aortic aneurysm	.11	-	-	-
Endoleak IA in previous EVAR	.13	-	-	-
Previous failed Ch-EVAR	1.0	-	-	-
Both hypogastric arteries patent	.32	-	-	-
One hypogastric artery patent	.48	-	-	-
No hypogastric artery patent	1.0	-	-	-
Procedural factors				
Adjunctive proximal TEVAR	.04	.01	4.1	1.3-12.9
Multiple stages procedure	1.0	-	-	-
Aortobi-iliac endograft	.68	-	-	-
Tube endograft	.45	-	-	-
Aorto-uniliac endograft	1.0	-	-	-
Iliac branch devices	.1	-	-	-
Partial deployment	1.0	-	-	-
Transfemoral TAs cannulation	.48	-	-	-
Transaxillary TAs cannulation	.21	-	-	-
Intraoperative TVVs loss	.29	-	-	-
CSF drainage	.19	-	-	-
TS	.67	-	-	-
Postoperative factors				
Major adverse events	.003	.33	1.8	0.53-6.2
Stroke	.20	-	-	-
Cardiac morbidity	.42	-	-	-
Respiratory morbidity	.01	.73	1.28	0.30-5.4

Table IV. Continued.

	Univariate	Multivariate		
	P value	*P* value	OR	95% CI
Dialysis	.01	.65	.60	0.09-4.4
Mesenteric complications	.04	.60	1.95	0.02-13.8
30-Day/hospital mortality	.003	.30	2.2	0.50-10.1

ASA, American Society of Anesthesiologists Score; *BMI,* body mass index; *Ch-EVAR,* chimney endovascular aneurysm repair; *CI,* confidential interval; *CSF,* cerebrospinal fluid; *EVAR,* endovascular aneurysm repair; *OR,* odd ratio; *TA,* target artery; *TEVAR,* thoracoabdominal aneurysm repair; *TIA,* transitory ischemic attack; *TS,* technical success.

collected in 23 high-volume aortic centers over a 11-year period. Despite the overall satisfactory results, a series of concerns should be analyzed for this solution.

First, there is extensive proximal aortic coverage with a greater number of segmentary arteries sacrificed in comparison with patient-specific endograft or open repair, with a theorical increase in SCI.[14-16] This issue is critical, especially in J/P-AAAs treated by custom-made FEVAR, where the incidence of SCI is <1%.[4,5] However, the adjunctive risk of SCI may be balanced by the urgent setting of repair, where a lifesaving procedure is required quickly.

In our series, the mean aortic coverage between the lowest renal artery and the top of the endograft was 154 mm, with a paraplegia rate of 6% (10% in ruptured cases vs 5% in not ruptured cases). Owing to the extensive aortic coverage, all these patients should be considered at high-risk of SCI and all the preventive medical, anesthesiologic and surgical measures should be adopted if possible. Possibly, by increasing the number of cases treated by multistaged approach (adopted in only 27%) and prophylactic cerebrospinal fluid drainage (adopted in only 27%), SCI may be decreased. These cannot be adopted safely in rupture cases, but in anatomical and clinical selected patients (symptomatic or large asymptomatic) they may be safe adjuncts in the prevention of SCI. Aneurysm rupture and adjunctive proximal thoracic endografts were independent risk factors for SCI. The first impacts 26% of our population and it may be related to the hemodynamic instability and low hemoglobin values. Unfortunately, these data are not available for all rupture cases, owing to the retrospective study design, and they were not considered in the univariable and multivariable analyses as potential risk factors for SCI. The second occurred in 27% of cases. and it is likely associated with the longer aortic coverage (mean adjunctive aortic coverage of 5 cm in comparison with isolated T-branch). The adjunctive proximal thoracic endograft was necessary owing to the standard proximal diameter (34 mm) of the T-branch which may need a more widely tapered thoracic endograft to achieve an effective proximal oversizing (15%-20%) in some instances. This endograft limitation should be corrected in future developments, with the availability of different designs in terms of proximal diameter (34-38 mm) and numbers of proximal sealing stents (1-3). Ferreira et al[31] proposed an easy and rapid physician-modified technique to decrease the aortic coverage, by cutting the first proximal sealing stent and creating a large fenestration in the posterior segment of the second sealing stent (fenestration for intercostal artery). However, it is important to emphasize that, in the first proximal stent, there are the active fixation barbs and leaving a T-branch without active fixation is not desirable, because it may result in its caudal migration and crushing of the bridging stents. The second concern is the risk of periprocedural TAs loss owing to the narrow paravisceral aorta, which would not allow the complete opening of the external branches or determine the compression of the bridging stent-grafts with possible early occlusion. Recently, Ferrer et al[32] reported that the use of the T-branch in cases of complex aneurysms with narrow paravisceral aorta can lead to results that are comparable with cases with paravisceral aortic lumen of >25 mm in terms of TS and mid-term clinical outcomes.

In our series, the mean aortic diameter at the level of the superior mesenteric artery and renal artery was 32 and 30 mm, respectively, and 22% of cases had an aortic diameter of <30 mm at the level of the renal arteries. In these cases, an important maneuver to guarantee safe TA cannulation and stenting is the partial deployment technique, adopted in 18% of cases in our cohort, and reported for the first time by Simonte et al and Timaran et al.[33,34] According to this technique, a partial endograft deployment (unsheathing the graft up to the outer branches origins and opening the proximal stent of the graft) is useful to save space and guarantee an easy cannulation of TAs from above to below with the distal part of the endograft still closed. The theoretical negative aspect of this technique consists of a prolonged pelvic and lower limb ischemia, which may be an adjunctive risk factor for SCI. Overall, TA patency at completion angiography was excellent (99%) with only 11 TAs (renal arteries, 9; celiac trunks, 2) lost among 750.

The incidence of TAs occlusion within 30 days was low (patients, 1%; TAs, 0.4%) and it is possibly the consequence of an aggressive approach in relining bridging stent graft by bare metal stent in case of any diagnostic

Table V. Independent risk factors for 30-day/hospital mortality at uni- and multivariable analysis

	Univariate	Multivariate		
	P value	*P* value	OR	95% CI
Preoperative factors				
Male	.48	-	-	-
Symptomatic aneurysm	.17	-	-	-
Ruptured aneurysm	.30	-	-	-
Aortic diameter >7 cm	.64	-	-	-
Hypertension	.30	-	-	-
Smoker	.56	-	-	-
Previous smoker	.25	-	-	-
Dyslipidemia	.82	-	-	-
Diabetes	1.0	-	-	-
Chronic obstructive pulmonary disease	.24	-	-	-
Coronary arteries disease	.17	-	-	-
Peripheral arteries occlusive disease	.22	-	-	-
Atrial fibrillation	.41	-	-	-
Oral anticoagulant therapy	.25	-	-	-
Carotid artery stenosis >70%	.70	-	-	-
History of stroke/TIA	.51	-	-	-
BMI >31	1.0	-	-	-
Chronic kidney disease	.046	.40	1.73	0.47-6.29
Dialysis	.14	-	-	-
ASA 4	.006	.07	3.1	0.89-11.1
Juxtarenal	.81	-	-	-
Pararenal	.43	-	-	-
Type Ia endoleak in previous failed EVAR	.03	.04	3.6	1.1-12.3
Previous failed Ch-EVAR	1.0	-	-	-
Both hypogastric arteries patent	.74	-	-	-
One hypogastric artery patent	.14	-	-	-
No hypogastric artery patent	.07	-	-	-
Procedural factors				
Adjunctive proximal TEVAR	.33	-	-	-
Multiple stages procedure	1.0	-	-	-
Aortic bi-iliac endograft	.70	-	-	-
Tube endograft	.47	-	-	-
Aortic mono-iliac endograft	1.0	-	-	-
Iliac branch device	.41	-	-	-
Partial deployment	.38	-	-	-
Transfemoral TAs cannulation	1.0	-	-	-
Transaxillary TAs cannulation	.54	-	-	-
Intraoperative TA loss	.09	-	-	-
Cerebral spinal fluid drainage	.45	-	-	-
TS	.016	.25	.34	0.025-3.41
Postoperative factors				
Postoperative MAEs	<.001	.40	1.8	0.41-8.3
Stroke	.21	-	-	-
SCI	.003	.06	3.6	0.7-12.1
Permanent paraplegia	<.001	.001	9.9	1.6-62.2
Cardiac morbidity	.001	.03	8.2	2.0-33.0

Table V. Continued.

	Univariate	Multivariate		
	P value	*P* value	OR	95% CI
Respiratory morbidity	<.001	<.001	10.1	2.9-35.0
Acute kidney injury	.11	-	-	-
Dialysis	.02	.30	.02	0.01-3.7
Mesenteric complications	.006	.03	10.4	1.2-93.3
Redo at 30 days	.06	-	-	-

ASA, American Society of Anesthesiologists Score; *BMI*, body mass index; *Ch-EVAR*, chimney endovascular aneurysm repair; *CI*, confidential interval; *CSF*, cerebrospinal fluid; *EVAR*, endovascular aneurysm repair; *MAE*, major adverse event; *OR*, odd ratio; *TA*, target artery; *TEVAR*, thoracoabdominal aneurysm repair; *TIA*, transient ischemic attack; *TS*, technical success.

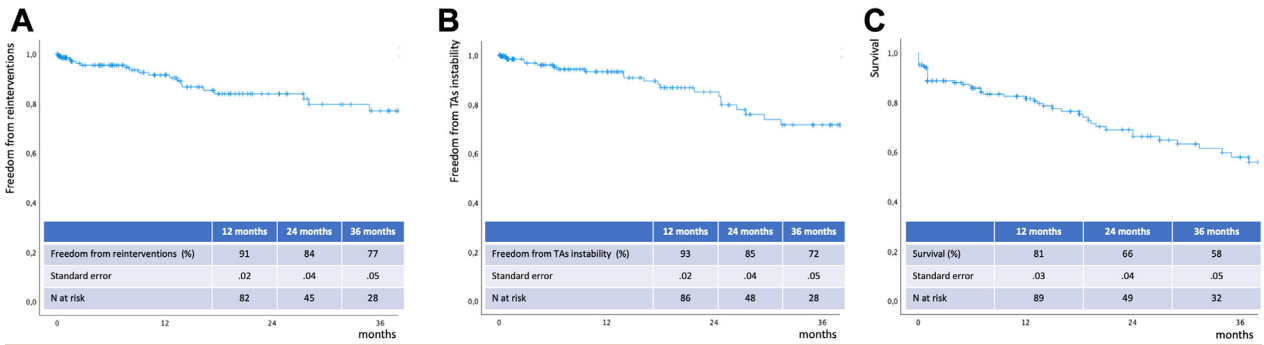

Fig. (A) Estimated freedom from reintervention (FFR) during follow-up by Kaplan-Meier analysis. **(B)** Estimated freedom from target artery (TA) instability during follow-up by Kaplan-Meier analysis. **(C)** Estimated survival during follow-up by Kaplan-Meier analysis.

doubts of compression (12% of TAs), as well as the intraoperative quality control by cone-beam computed tomography or intravascular ultrasound examination and the potential protective role of dual antiplatelet therapy in the first 6 postoperative months.

TA patency and instability should be evaluated during follow-up because the outer branches, especially those for the renal artery, have poorer clinical outcomes than fenestrations.[17-20] In these cases, we are accommodating some renal arteries with outer branches that should be managed by fenestrations in an elective setting. However, the rate of late renal artery events was not high and was comparable with cases managed by custom-made device.[2-5]

The choice of a correct bridging stent-graft plays a crucial role to obtain the effective aneurysm exclusion and durable TAs patency after F/B-EVAR. Even if new generation of covered stents were available in recent years, the absence of dedicated devices remains one of the main critical issues of this technology. In the present experience, we report the use of balloon-expandable, self-expandable, and a combination of balloon and self-expandable stents in 59%, 29%, and 12% of TAs, respectively (Supplementary Table III, online only). We did not analyze the outcomes of each single type or brand of covered stent because the different subgroups would be too heterogeneous owing to the long study period, important manufacturing innovations, and different physicians' preferences in 23 centers. Moreover, considering the number of TAI events (27/197 patients) and the different types of covered stents, we did not perform an analysis of potential risk factors for TAI because of poor predicted statistical significance.

Estimated 3-year freedom from TAIs and reinterventions were 72% and 77%, respectively. An important proportion of reinterventions (about 15%) occurs within 30 postoperative days, and it may be probably related to the urgent setting of the repair. In emergent cases, these procedures are focused to fix promptly the acute situation, optimizing technical details with early reinterventions.

Of 32 reinterventions, there were 4 (13%) femoral/iliac access-related events. One of the main theorical limitations of the T-branch is the presence of challenging access, because it has a delivery system requiring up to 8.5 mm (24F outer diameter).[8,9] Previous studies have demonstrated that hostile iliac access are associated with technical demanding F/B-EVAR procedures carrying need for adjunctive intraoperative maneuvers and increased mortality during follow-up.[35,36] Bertoglio

Table VI. Independent risk factors for follow-up mortality at the Cox Regression

	Univariate			Multivariate		
	P value	HR	95% CI	*P* value	HR	95% CI
Preoperative factors						
Preoperative chronic kidney disease	.001	2.4	1.4-4.2	.006	2.5	1.3-4.6
Type Ia endoleak in previous failed EVAR	<.001	3.1	1.7-5.4	<.001	3.3	1.7-6.3
Preoperative bilateral hypogastric occlusion	.01	3.8	1.3-10.8	.008	4.5	1.5-13.7
Postoperative factors						
Paraplegia	<.001	5.1	2.2-11.6	.01	3.4	1.3-8.8
Postoperative cardiac morbidity	<.001	3.5	1.7-7.1	.18	1.9	0.7-4.4
Postoperative respiratory morbidity	<.001	5.0	2.8-9.1	.04	2.3	1.1-5.0
Postoperative dialysis	<.001	4.6	1.9-11.1	.35	0.5	0.14-2.2
Postoperative mesenteric events	.002	4.3	1.6-11.0	.006	4.2	1.5-11.6

CI, Confidential interval; *HR*, hazard ratio; *EVAR*, endovascular aneurysm repair.

et al[37] reported that 18% to 22% of TAAAs should be excluded theoretically from OTS BEVAR for iliac access ineligibility. The availability of BEVAR with low-profile platform such as an OTS device may be an effective tool to manage urgent complex aneurysms in the presence of hostile femoral/iliac access, ensuring a safe and rapid life-saving repair and decreasing the risk of complications. Ramanan et al[38] in 2016 reported low-profile custom-made BEVAR with a similar configuration as the T-branch in elective J/PAAAs or TAAAs, decreasing the incidence of surgical/endovascular conduit and access artery injury. However, this experience is preliminary, with limited follow-up, and the results should be analyzed over a longer timeframe, especially regarding the low profile, fabric integrity, and TA patency. Finally, a dedicated consideration should be reserved on the follow-up survival because approximately 60% of patients are alive at 3 years. This value should be considered acceptable considering the patient's age at the time of repair, preoperative risk factors, and the urgent setting of procedures. Moreover, several predictors of mortality were identified (Table VI), and they should be taken in account during the decision-making process.

The present study has several limitations. It is a retrospective, multicenter experience, reporting <200 cases, managed in 23 centers over a 10-year period. The median number of cases per center and year is limited and the operator learning curve could not be considered. Moreover, during the study period, important improvements of the ancillary materials were achieved. The multicenter design may influence the study's outcomes because different techniques, and perioperative patient's managements, for example, SCI prevention protocols, were used in each center. The retrospective study design and the limited number of cases did not allow a specific analysis of each protocol. The small sample size and short-term follow-up limit the power of the study's conclusions. The urgent definition includes ruptured aneurysms, symptomatic cases, as well as asymptomatic patients with large aneurysms. Obviously, these are three different clinical scenarios, with different risks and outcomes. For these reason, the study's outcomes should be considered separately for each of the three clinical scenarios, even if it decreases the power of the statistical evaluation. Moreover, the time and entity of preoperative and postoperative hypotension, as well as hemoglobin levels, in cases of aneurysm rupture were not available for the analysis. Finally, it is a single brand experience and currently there are alternative OTS platforms with different endograft designs, proximal diameters, and numbers of sealing stents. All these factors may play a crucial role in the risk of SCI and should be considered.

CONCLUSIONS

Urgent repair of J/P-AAAs with the T-branch is feasible and effective with satisfactory TS and 30-day/hospital mortality rates in high-risk patients. However, a more extensive aortic coverage is necessary, leading to a non-negligible SCI rate, especially in aortic rupture or when adjunctive thoracic endografts are necessary. Predictors of TS, SCI, and mortality were identified, and they should be considered for surgical indication and outcomes' optimization.

AUTHOR CONTRIBUTIONS

Conception and design: EG, MG

Analysis and interpretation: EG, GF, MA, TK, NT, ND, GM, GS, AK, KO, KM, LMP, FC, SH, MG

Data collection: EG, GF, MA, TK, NT, ND, GM, GS, AK, KO, KM, LMP, FC, SH, MG

Writing the article: EG

Critical revision of the article: GF, MA, TK, NT, ND, GM, GS, AK, KO, KM, LMP, FC, SH, MG

Final approval of the article: EG, GF, sMA, TK, NT, ND, GM, GS, AK, KO, KM, LMP, FC, SH, MG
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DISCLOSURES

E.G., G.F., M.A., N.T., G.M., G.S., A.K., K.O., K.M., L.M.P., and M.G. are proctors for Cook Medical and received travel, educational grants, or speaker's fees. T.K., N.D., and S.H. are consultants for Cook Medical and they have intellectual property with Cook Medical and received speaking fees, and research, travel, and educational grants.

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On Behalf of the European Off-the-shelf Multi-branched thoracoabdominal Endograft for Juxta/para-renal aneurysms (EOMEJ) Study's group

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Supplementary Table I (online only). Cases enrolled in each participating center

No.	Center	Country	Cases	%
1	Munster	Germany	39	20
2	Hamburg	Germany	33	17
3	Bologna	Italy	16	8
4	Malmo	Sweden	12	6
5	Munich	Germany	12	6
6	Milan	Italy	11	6
7	Perugia	Italy	10	5
8	Rome. S Giovanni	Italy	8	4
9	Padova	Italy	6	3
10	Parma	Italy	6	3
11	Frankfurt	Germany	6	3
12	Athens	Greece	5	3
13	Porto	Portugal	5	3
14	Brescia	Italy	4	2
15	Uppsala	Sweden	4	2
16	Firenze	Italy	4	2
17	Verona	Italy	4	2
18	Genova	Italy	3	2
19	Paris	France	2	1
20	Trento	Italy	2	1
21	Trieste	Italy	2	1
22	Rome. Sapienza	Italy	2	1
23	Rome. Gemelli	Italy	1	1
Overall			197	100

Supplementary Table II (online only). Strategies of staging approach

	No.	%
First step: TEVAR; second step: T-branch + unibody + iliac legs	3	6
First step: T-branch with temporary sac perfusion branch + unibody + iliac legs; second step: connection of temporary sac perfusion branch	39	74
First step: T-branch + unibody + iliac legs; second step: iliac limb	11	20
Overall	53	100

TEVAR, Thoracoabdominal aortic aneurysm.

Supplementary Table III (online only). Type of bridging stent graft for type of target artery (TA)

	B Exp stent graft	S Exp stent graft	B + S Exp stent graft	TAs lost	Overall
Celiac trunk	125	46	11	2	184
Superior mesenteric artery	123	53	19	-	195
Renal arteries	192	115	55	9	371
Overall	440	214	85	11	750

TAs, Target arteries.

Supplementary Table IV (online only). Timing, cause, treatment, and results of each reintervention

Patient	Timing	Cause	Redo type	Outcome
1	>30 days	EL IIIc from SMA	Relining	Solved
2	>30 days	EL + thrombosis RRA	Relining	Solved
3				
I	<30 days	Brachial access hematoma	Surgical drainage	Solved
II	<30 days	Brachial access hematoma	Surgical drainage	Solved
4	>30 days	EL Ia	TEVAR	Solved
5				
I	>30 days	EL Ic from CT	Relining	Solved
II	>30 days	EL Ib from left iliac leg	Iliac limb extension	Solved
6	>30 days	Femoral pseudoaneurysm	Surgical correction	Solved
7				
I	>30 days	EL IIIc from LRA	Relining	Solved
II	>30 days	Thrombosis LRA	Thrombo-aspiration	Solved
III	>30 days	Thrombosis RRA	Thrombo-aspiration	Solved
8	>30 days	Femoral pseudoaneurysm	Surgical correction	Solved
9	>30 days	EL IIIc from SMA	Relining	Solved
10	<30 days	Thrombosis RRA	Thrombo-aspiration and relining	Solved
11	>30 days	Thrombosis SMA	Thrombo-aspiration, relining and hemicolectomy	Solved
12				
I	>30 days	Thrombosis SMA	Laparotomy and bowel resection	Solved
II	>30 days	Bowel ischemia	Re-laparotomy and resection	Death
13	>30 days	EL II	Laparoscopic clipping of accessory RA	Solved
14	>30 days	EL Ic from RRA	Relining	Solved
15	>30 days	Left iliac artery ruptured	Iliac limb extension	Solved
16	>30 days	CT stent graft crushing	Relining	Solved
17	>30 days	Thrombosis RRA + EL Ic from LRA	Bilateral RAs relining LRA	Solved
18	>30 days	EL Ic from LRA	Relining	Solved
19	>30 days	EL Ia	TEVAR	Solved
20	>30 days	EL IIIc from CT	Relining	Solved
21	>30 days	Femoral pseudoaneurysm	Surgical correction	Solved
22	< 30 days	EL Ib	Iliac branch device	Solved
23	>30 days	EL IIIc from LRA	Relining	Solved
24	>30 days	Femoral pseudoaneurysm	Surgical correction	Solved
25	>30 days	EL Ib	Iliac branch device	Solved
26	>30 days	EL Ic from RRA	Relining	Solved
27	>30 days	LRA occlusion	Thrombo-aspiration and relining	Unsolved

CT, celiac trunk; *EL,* endoleak; *LRA,* left renal artery; *RRA,* right renal artery; *RA,* renal arteries; *SMA,* superior mesenteric artery.

Supplementary Table V (online only). Target artery (*TA*) instability

Cause	No.	%
TA occlusion	15	43
Celiac trunk	2	5
Superior mesenteric artery	3	9
Renal artery	10	29
Endoleak TA-related	20	57
Celiac trunk	4	11
1c	3	9
3c	1	3
Superior mesenteric artery	3	8
1c	1	3
3c	2	5
Renal artery	13	37
1c	8	24
3b	1	3
3c	4	11
Overall	35	100

Twenty-seven patients (14%) had TA instability. In 8 patients (4%), there was >1 event for an overall of 35 events.

Supplementary Table VI (online only). Causes of mortality

Cause	No.	%
Aortic rupture	1	2
Bowel ischemia/perforation	4	6
Cancer	10	16
Cardiac morbidities	9	15
Cerebral Hemorrhage	2	4
COVID-19 infection	4	6
Endograft infection	1	2
Pulmonary morbidities	9	15
Sepsis/multiorgan failure	7	12
Unknown	13	22
Overall	60	100