Outcomes and Economic Impact of Hypogastric Artery Management During Elective Endovascular Aortic Repair for Aorto-Iliac Aneurysms

Luca Attisani,[1] Federico Villa,[2] Raffaello Bellosta,[1] Luca Luzzani,[1] Matteo Alberto Pegorer,[1] Federico Fontana,[3] Filippo Piacentino,[3] Matti Jubouri,[4] Mohamad Bashir,[5] Gabriele Piffaretti,[2] and Marco Franchin,[6] Brescia and Varese, Italy, and York and Cardiff, UK

Background: To analyze clinical outcomes and perform a macro-costing evaluation of endovascular aortic repair (EVAR) for aorto-iliac aneurysms.

Methods: This is a retrospective, financially unsupported, physician-initiated observational cohort study. Patients with iliac artery involvement treated with EVAR between January 1st, 2014 and December 31st, 2021 were identified. Inclusion criteria were intact aneurysm, elective EVAR with at least 1 hypogastric artery (HA) treatment, use of bifurcated endograft (EG), and at least 6 months of follow-up. Primary outcomes of interest were overall survival, freedom from aneurysm-related mortality (ARM), freedom from EVAR-related reintervention, and overall EVAR(procedure)-related costs.

Results: We studied 122 (9.1%) patients: 119 (97.5%) were male and 3 (2.5%) females. Median age of patients was 76 years (range, 68.75–81). Overall, 107 (87.7%) patients had both HAs preserved according to following strategy: 45 (36.9%) with flared limbs, 13 (10.6%) with bilateral branched device, and 49 (40.2%) with a combination of flared limb on 1 side and branched device on the contralateral side. Bilateral overstenting was performed in 15 (12.3%) patients. Estimated overall survival was not different between groups of EVAR (Log-rank, $P = 0.561$). There was only 1 (0.8%) ARM ascertained during the follow-up. Estimated freedom from EVAR-related reintervention was not different among groups (Log-rank, $P = 0.464$). During the follow-up, 9 (7.4%) patients developed buttock claudication (Society for Vascular Surgery (SVS) grade 1, $n = 4$, SVS grade 2, $n = 5$), more frequently in HA overstenting (hazard ratio (HR): 3.6; 95% confidence intervals (CIs): 0.96–13.5, $P = 0.058$). When all cots were included, branched EVAR still carried the highest burden ($P = 0.001$) in comparison with the mixed subgroup, the overstenting subgroup, and the flared limbs subgroup.

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[1]*Vascular Surgery – Department of Cardiovascular Surgery, Fondazione Poliambulanza, Brescia, Italy.*

[2]*Vascular Surgery – Department of Medicine and Surgery, University of Insubria School of Medicine, Varese, Italy.*

[3]*Interventional Radiology – Department of Medicine and Surgery, University of Insubria School of Medicine, Varese, Italy.*

[4]*Hull York Medical School, University of York, York, UK.*

[5]*Vascular & Endovascular Surgery, Velindre University NHS Trust, Health Education & Improvement Wales, Cardiff, UK.*

[6]*Department of Cardio-Thoracic and Vascular Surgery of the ASST Settelaghi University Teaching Hospital, Varese, Italy.*

Correspondence to: Gabriele Piffaretti, MD, PhD, Vascular Surgery – Department of Medicine and Surgery, University of Insubria School of Medicine, Via F. Guicciardini 9, Varese 21100, Italy; E-mail: gabriele.piffaretti@uninsubria.it

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Conclusions: Early mortality and pelvic ischemic syndromes rate were acceptably low in all techniques. Hypogastric artery preservation showed lower complication rate in comparison with HA overstenting which, however, appears to be safe an effective for option with similar overall costs for patients who are not candidates for HA preservation based on aortic anatomy.

INTRODUCTION

Guidelines from different cardiovascular societies recommended blood flow preservation to at least 1 hypogastric artery (HA) during surgical or endovascular repairs.[1−3] The main reason for a high-grade recommendation lies in the fact that the sacrifice or loss of 1 or both HA may be associated with critical pelvic ischemic syndromes.[4,5] Another important point is the widespread use of endovascular aneurysm repair (EVAR) also in the thoracic area: in such contest, HA preservation may increase protection against spinal cord ischemia.[6,7] Therefore, the need to preserve the HA is of major importance and, for the moment, branched devices are the more reasonable solution with good clinical results.[8−10] Another critical aspect in EVAR is cost analysis that have for some time aroused particular interest, especially in cases where the medical devices employed are economically onerous due to complex endovascular repair. Not only cost analyses are among the most difficult evaluations to be performed, especially in vascular surgery; there are also lack of information regarding costs evaluation specifically focused on HA management during EVAR.[11−15] These aspects along with the variability of the follow-up programs, increase uncertainty on which solution may be better for aorto-iliac aneurysms.[16,17] Being alternative strategies for HA management so different in terms of technical aspects and costs, we aimed to perform an analysis of the clinical outcomes and a macrocosting evaluation of EVAR involving HA preservation or overstenting using different techniques.

MATERIALS AND METHODS

Study Cohort

This is a retrospective, financially unsupported physician-initiated observational cohort study that involves academic urban hospitals. Checklist of items followed the STROBE statement.[18] These 2 hospitals shared common clinical practice in terms of operative indications, as well as type of examination used during the follow-up windows. Clinical data were collected in a prospective manner at each center; once merged in a single database, all data were recorded and tabulated in a dedicated database and analyzed retrospectively. For this study, those patients with iliac artery involvement and treated with EVAR between January 1st, 2014 and December 31st, 2021 were identified (Fig. 1). Medical records for all cases were reviewed by 2 senior surgeons (LA and GP). Information collected includes demographics, co-morbidities, aortic disease extent and sizing, type of intervention, type of endograft (EG), as well as postoperative events (death, endoleaks, reintervention) during hospitalization and follow-up.

For the final analysis, we used the following entry criteria:

- intact aneurysm
- elective EVAR
- use of bifurcated EG
- at least, 6 months of follow-up.

Hence, attempting to create the more homogeneous cohort as possible, for the final analysis we excluded patients with:

- preservation on 1 side and overstenting of the contralateral side
- patients with preoperative chronic occlusion of the HA.

Owing to the retrospective nature of the present study based on anonymized data, in agreement with national law approval of the local Ethical Committee was not mandatory.

Indication for Interventions

Informed consent for data recording and intervention was signed by each patient at admission. Indications for EVAR of aorto-iliac aneurysms agreed with the guidelines of the Italian Society for Vascular and Endovascular Surgery (SICVE), that are in accordance with the most recent position statements of the European Society for Vascular Surgery (ESVS).[1,2] The type of technique and EG was left at the surgeons' judgment, but always in accordance with the Instruction For Use (IFU) of each device. Common indications for branched EVAR were common iliac artery aneurysm (CIA) extending to the bifurcation having a diameter $\geq$30 mm, and CIA

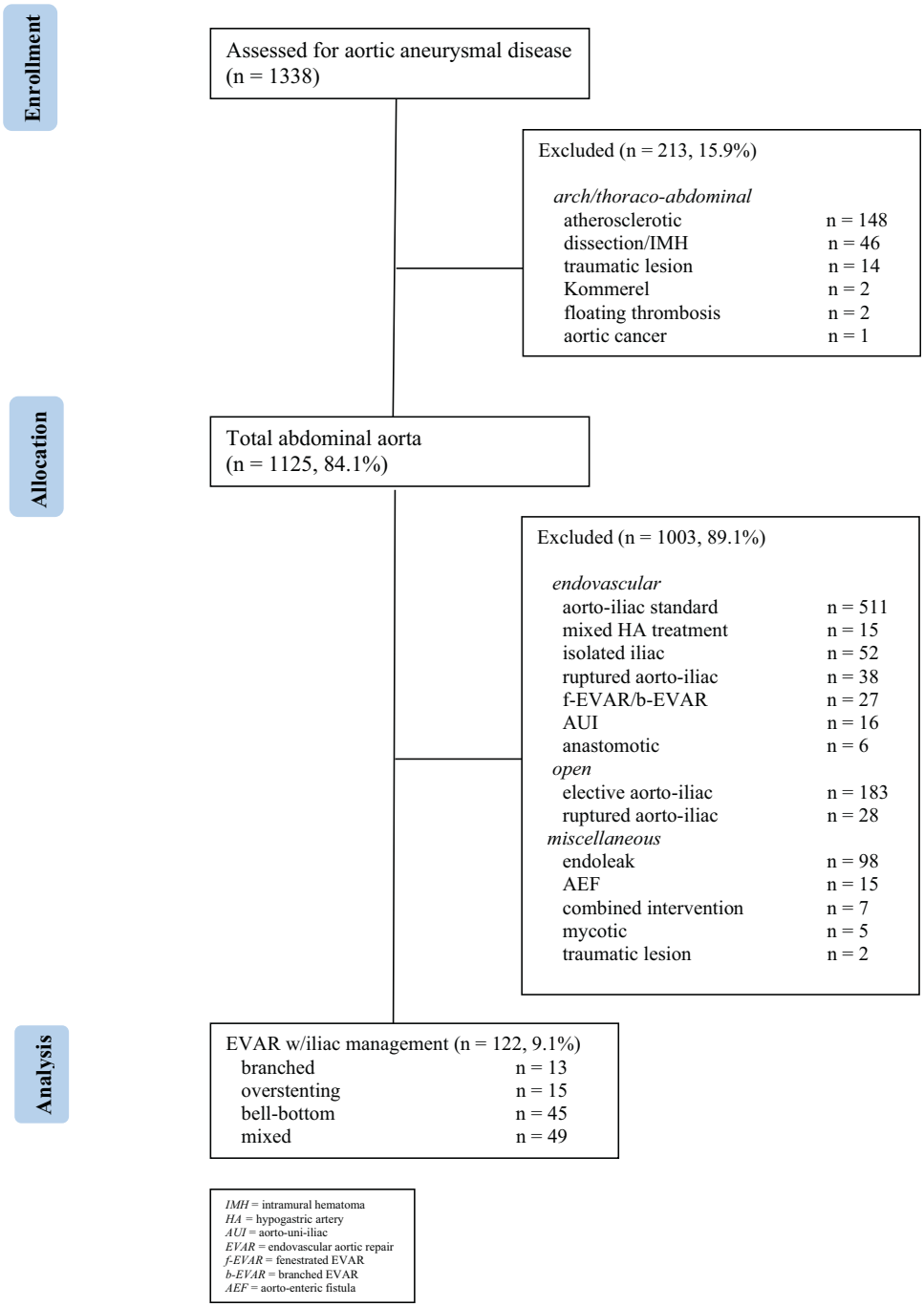


Fig. 1. Consort diagram of elective EVAR for aorto-iliac aneurysms during the period of study: January 1st, 2014 − December 31st, 2021. EVAR, endovascular aortic repair.

>24 mm, with an associated abdominal aortic aneurysm meeting the threshold for EVAR. Endovascular repair using flared iliac limb was considered suitable when there was a straight segment of common iliac artery of at least of 10 mm with a diameter ≤25 mm, allowing for an oversizing of 15% of the iliac component. Overstenting of the HA was performed in all those situations not amenable of branched EVAR or HA preservation using flared limbs due to aorto-iliac aneurysm extent. In these latter cases, HA was always embolized using an endovascular plug and preferentially limited to the main trunk of the HA. Postoperatively, per centers' policy intensive care unit (ICU) was never accessed by default but

used selectively after multidisciplinary preoperative and/or intraoperative case evaluation. The follow-up protocol included computed tomography-angiography (CT-A) at 30 days and at 1 year at least, for all patients at each center. Contrast-enhanced ultrasound (CEUS) was used for intermediate and long-term imaging follow-up. Generally, institutional indications for reintervention after EVAR were also aligned with clinical practice guidelines, for the following conditions: type 1 and 3 endoleaks, EG infection or significant structural issues (e.g., collapse, breakage, migration), and symptomatic EG-limb occlusion. Type 2 endoleak was treated in the presence of sac enlargement ($\geq$1 cm from the preoperative diameter), and/or if persisting $>$12 months or causing symptoms. Different types of standard EGs have been used throughout the entire experience: Zenith Alpha™ (Cook Medical, Bloomington, IN, USA), Endurant™/Endurant™ II (Medtronic Endovascular, Santa Rosa, CA, USA), Gore® Excluder®/Gore® C3® (W.L. Gore and Associates Inc, Flagstaff, AZ, USA). We adopted two types of iliac branched device, namely those from Gore® and Cook™.

Definition and Primary Outcomes

In agreement with the most recent guidelines of the ESVS, a CIA $\geq$18 mm in men and $\geq$15 mm in women was considered aneurysmal.[2] Medical comorbidity grading system and operative outcomes were described according to the Society for Vascular Surgery (SVS).[19] Specifically for this study, pelvic ischemic complications were classified as:

- mild (grade 1), if it has occurred but resolved spontaneously/did not prolong hospital stay/did not cause permanent impairment
- moderate (grade 2) when intervention/prolongation of hospitalization $>$24 hours, and/or at most, minor permanent disability did not preclude normal daily activity
- severe (grade 3), if it necessitated major surgical or medical intervention/prolonged convalescence/prolonged or permanent disability, and/or resulted in death.

As well, according to SVS reporting standards, we classified aneurysm-related mortality (ARM) as all deaths due to aortic rupture, or due to the consequences of both primary and secondary procedures, or open surgical conversion.[20] By reported standards, the cause of death was classified as verified if determined based on autopsy findings, direct surgical observation, or definitive imaging studies of the EG obtained during the patient's terminal illness.[20] When this level of information was unavailable, the cause and was classified as probable if the clinical picture was consistent and documented with reliable observations during the terminal illness. When these criteria were not met, the cause of death was considered indeterminate. Through December 2021, information on aneurysm-related reintervention, vital status, and date of death of individual patients were validated by death certificate, electronic charts managed by the regional health care system, general practitioner, or certified data from emergency department admission. The Follow-Up Index (FUI) describes follow-up completeness at a given study end dates ratio between the investigated and the potential follow-up period.[21] For this study, primary outcomes of interest were overall survival, freedom from aneurysm-related mortality (ARM), freedom from EVAR-related reintervention, and overall EVAR(procedure)-related costs. Specifically, EVAR(procedure)-related costs were evaluated either for the index procedure or for the follow-up. Macro-costing estimation included the price of the EG, costs of intensive care unit stay and standard hospitalization, as well as those of each single examination (e.g., CEUS and CT-A). Costs of the single component and variable for the index procedure are summarized in Table I

- preoperative CT-
- days of hospitalization
- days in intensive care unit stay after EVAR
- standard EG
- branched EG

Costs of the follow-up included:

- CEUS and/or CT-A
- days of hospitalization, and days in intensive care unit stay, for those who required reintervention.

All these outcomes were stratified according to the type of EVAR strategy (HA preservation versus overstenting), and/or type of EVAR performed [flared limbs versus branched device versus overstenting with embolization].

Statistical Analysis

Clinical data were recorded and tabulated in Microsoft Excel (Microsoft Corp—Redmond; Wash, USA) database: statistical analysis was performed by means of SPSS 26.0 for Windows (IBM SPSS—

Table I. Granular costs of the covariates

Macro-costs variables	Cost (euros)
Endovascular component	
bifurcated endograft	6.000−7.000
branched component	2.100
bridging stent-graft	2.900
hypogastric plug	800
Hospital component	
preoperative CT-A	116
day of hospitalization	254
day of intensive care unit	1.600
unit of transfusion	231
Follow-up component	
CEUS or CT-A	40
day of hospitalization	254
day of intensive care unit	1.600

CT-A, computed tomography angiography; CEUS, contrast-enhanced ultrasound.

Chicago; Ill, USA).[22] Categorical variables were presented using frequencies and percentages. Continuous variables were presented with mean ± standard deviation (SD), or median with interquartile range (IQR) and ranges, based on data distribution. Categorical variables were analyzed with the χ^2 test, and Fisher's exact test when appropriate. Continuous variables were tested for normal distribution by the Shapiro−Wilk's test and compared between groups with unpaired Student's *t*-test for normally distributed values; otherwise, the Mann−Whitney *U*-test was used. The Kruskall−Wallis honest significance test was used as single-step multiple comparisons to find significant difference among medians. Univariate analysis was used to identify potential predictors of ARM and EVAR-related reintervention during the follow-up. Associations that yielded a *P* value < 0.20 on univariate screen were then included in a Cox's regression analysis using the Wald's forward stepwise model. The strength of the association of variables with ARM and EVAR-related reintervention was estimated by calculating the hazard ratio (HR) and 95% confidence intervals [(95% CI): significance criteria 0.20 for entry, 0.05 for removal)]. Model discrimination was evaluated using the area under the receiver operating characteristic curve (AUROC), with >0.7 being considered significantly accurate. All survival analyses were estimated with the Kaplan−Meier test and reported as percentage ± standard error (SE) with 95% CI, and log-rank test for comparison. Additionally, to assess which covariate were associated with ARM, a proportional hazards model was implemented, to properly consider the presence of competitive risks. All reported *P* values were 2-sided; *P* value < 0.05 was considered significant.

RESULTS

Study Cohort

We studied 122 (9.1%) patients: 119 (97.5%) were male and 3 (2.5%) females. Median age of patients was 76 years (range, 68.75−81). Demographic data and comorbidities of the cohort are shown in Table II. The median SVS score was 6 (IQR, 3−11). The median maximum aorto-iliac aneurysm was 52 mm (IQR, 35.75−59); the median maximum right CIA was 27 mm (IQR, 19−38.25), and was 20 mm (IQR, 15−28) on the left CIA.

Operative Details

Overall, 107 (87.7%) patients had both HAs preserved according to following strategy: 45 (36.9%) with flared limbs, 13 (10.6%) with bilateral branched device, and 49 (40.2%) with a combination of flared limb on 1 side and branched device on the contralateral side. When HA was preserved using a branched device ($n = 63$), the distal landing zone was beyond the hypogastric bifurcation in just 2 (3.2%) cases. Bilateral overstenting was performed in 15 (12.3%) patients. In 13 (10.6%) patients, we performed an additional procedure as follows: pre-emptive inferior mesenteric artery embolization ($n = 7$), femoral endarterectomy ($n = 4$), and renal artery stenting ($n = 2$).

Early Results (≤30 days)

Primary technical success was obtained in 119 (97.5%) cases: type 1 endoleak [type a, $n = 1$; type b, $n = 2$)] was detected in 3 cases that were sealed off with coils embolization ($n = 1$, type 1a), or iliac limb extender into the external iliac artery ($n = 2$, type 1b). Operative mortality did not occur. No immediate conversion to open surgery was required. Intensive care unit stay was required in 8 (6.5%) patients: median hospital stay was 2 days (IQR, 1−3.5). There was no difference in ICU admission between treatment strategy ($P = 0.673$). Overall, 21 (17.2%) patients experienced a complication. Complication rate did not differ when stratified by treatment strategy [HA preservation, $n = 16$ (14.9%) versus HA overstenting, $n = 5$ (30.0%); OR: 2.8, $P = 0.135$]; of interest, patients in branched EVAR did not develop complication in comparison with other types of EVAR (flared limbs, 20.0% versus mixed group, 14.3% versus overstenting, 30.0%; $P = 0.113$). Early mortality was observed

Table II. Demographic data, comorbidities, and risk factors of the entire cohort (2014–2021, $n = 122$).

Covariate	Total cohort ($n = 122$)	HA preservation			HA overstenting ($n = 15$)	P
		Mixed cohort ($n = 49$)	Flared limbs ($n = 45$)	Branched device ($n = 13$)		
Demographics, *n* (%)						
Male	119 (97.5)	49 (100)	44 (97.8)	13 (100)	13 (86.7)	0.030
Age, mean (SD)	74 ± 8	74 ± 8	75 ± 8	65 ± 9	79 ± 4	0.001
>80 years	36 (29.5)	11 (22.4)	18 (40)	0 (0)	7 (46.7)	0.011
Comorbidity, *n* (%)						
Hypertension	74 (60.7)	36 (73.5)	19 (42.2)	8 (61.5)	11 (73.3)	0.013
CAD	35 (28.7)	13 (26.5)	17 (37.8)	3 (23.1)	2 (13.3)	0.277
COPD[a]	29 (23.8)	9 (18.4)	12 (26.7)	1 (7.7)	7 (46.7)	0.066
ESRD[b]	6 (4.9)	1 (2.0)	3 (6.7)	0 (0)	2 (13.3)	0.250
Diabetes	37 (30.3)	11 (22.4)	23 (51.1)	0 (0)	3 (20.0)	0.001
Risk factor, *n* (%)						
SVS score[c], median (IQR)	6 (3–11)	5.5 (3–9.75)	6.5 (3–12)	6.5 (3–12)	6.5 (3–12)	0.415
Oral anticoagulants	15 (12.2)	5 (10.2)	8 (17.7)	1 (7.7)	1 (6.7)	0.266
Previous aortic surgery	16 (13.1)	4 (8.2)	7 (15.5)	2 (15.4)	3 (20.0)	0.578

n, number; SD, standard deviation; HA, hypogastric artery; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; ESRD, end-stage renal disease; SVS, Society for Vascular Surgery.
[a]http://www.goldcopd.org.
[b]Ann Intern Med 2009; 150:604–612.
[c]J Vasc Surg 2015; 61:2S–41S.

in 3 (2.5%) patients (HA preservation, $n = 2$ versus overstenting, $n = 1$; OR: 3.7, $P = 0.328$): causes of death was acute coronary syndrome ($n = 1$), left heart insufficiency ($n = 1$), and SARS-CoV-2 related pneumonia ($n = 1$). Table III reports postoperative complications: colonic ischemia was never observed. Median hospitalization length was 6 days (IQR, 5–8.75): no significant difference between HA preservation groups and HA overstenting ($P = 0.199$) was observed.

Late Outcomes (>30 days)

No patient was excluded from follow-up analysis because definitively lost at a mean follow-up of 36.4 months ± 23 (range, 0–88); median of FUI was 0.9 (IQR, 0.4–1). There was no difference in follow-up length and FUI among groups ($P = 0.168$, and $P = 0.532$, respectively).

Survival. During the follow-up 31 (26.0%) patients died: the estimated overall survival was 94.0% (SE: 0.02; 95% CIs: 88.1–97.1) at 12 months, 78.0% (SE: 0.04; 95% CIs: 68.8–85.1) at 36 months, and 62.3% (SE: 0.06; 95% CIs: 50.6–72.7) at 60 months. Causes of death are reported in Table IV. Estimated overall survival was not different between groups of EVAR (Log-rank $\chi^2 = 2.757$, $P = 0.561$; Fig. 2A). At multivariate Cox's regression analysis early mortality risk was associated with age >80 years (HR: 2.1; 95% CIs: 1.05–4.2, $P = 0.037$), and history of previous aortic surgery (HR: 3.1; 95% CIs: 1.3–7.4, $P = 0.009$) (Table V). When adjusted by HA management, these covariates were still significantly associated with mortality risk. There was only 1 (0.8%) ARM ascertained during the follow-up: this was caused by secondary aortic rupture due to an undetected type 3 endoleak following a rare breakage of a main body EG.

Reintervention. Twelve (9.8%) patients underwent EVAR-related reinterventions during the follow-up; they are summarized in Table VI. Estimated freedom from EVAR-related reintervention 93.2% (SE: 0.02; 95% CIs: 87.2–96.5) at 12 months, 90.7% (SE: 0.03; 95% CIs: 83.4–95.0) at 36 months, and 88.5% (SE: 0.03; 95% CIs: 79.9–93.7) at 60 months; it was not different among groups (HA preservation versus overstenting: Log-rank $\chi^2 = 1.818$, $P = 0.561$; types of EVAR: Log-rank $\chi^2 = 2.565$, $P = 0.327$), as reported in Figures 2 and 3, respectively. At multivariate Cox's regression analysis necessity of reintervention was associated with aneurysm diameter (HR: 1.04; 95% CIs: 1.02–1.07, $P = 0.001$) (Table IV). Model discrimination for aneurysm diameter >60 mm yielded an AUROC of 0.72 being considered significantly accurate. When adjusted by type of EVAR, this covariate was still associated with necessity of reintervention (HR: 1.05; 95% CIs: 1.02–1.08, $P = 0.001$).

Endoleak. Overall, an endoleak was detected in 46 (37.7%) patients: the most frequent one was type 2 ($n = 40$, 33.6%); we detected 2 (1.7%) type 1a

Table III. Early postoperative complication and type of treatment

Complication	*n* (%)	Type of treatment
EG-related		
T1 endoleak	3	
proximal		coils embolization
distal		extender cuff (2)
access vessel pseudoaneurysm	2	surgical repair
occlusion		endarterectomy w/ patch
PIS	3	best medical treatment
peripheral embolization	4	embolectomy
Procedure-related		
TIA	1	
AKI	3	transient hemodyalisis (1)
atrial fibrillation	1	amiodarone
anemia	1	transfusion
acute coronary syndrome	1	
urinary tract infection	1	antibiotics
seizure	1	

n, number; T1, type 1; PIS, postimplant syndrome; TIA, transient ischemic attack; AKI, acute kidney injury.

Table IV. Follow-up: causes of mortality

Causes of death	*n* (%) (total = 31)
Respiratory	10 (32.2)
SARS-CoV-2 related	6
chronic respiratory insufficiency	4
Unknown	9 (29.0)
non−EVAR-related	8
indeterminate	1
Cardiovascular	6 (19.3)
LHF	3
acute coronary syndrome	2
AAA rupture	1
Neurologic	2 (6.4)
hemorrhagic stroke	2
Cancer	2 (6.4)
liver	1
colon	1
Other	
sepsis	1
road traffic accident	1

n, number; M, male; SARS-CoV-2, Coronavirus-19; EVAR, endovascular aortic repair; LHF, left heart failure; AAA, abdominal aortic aneurysm.

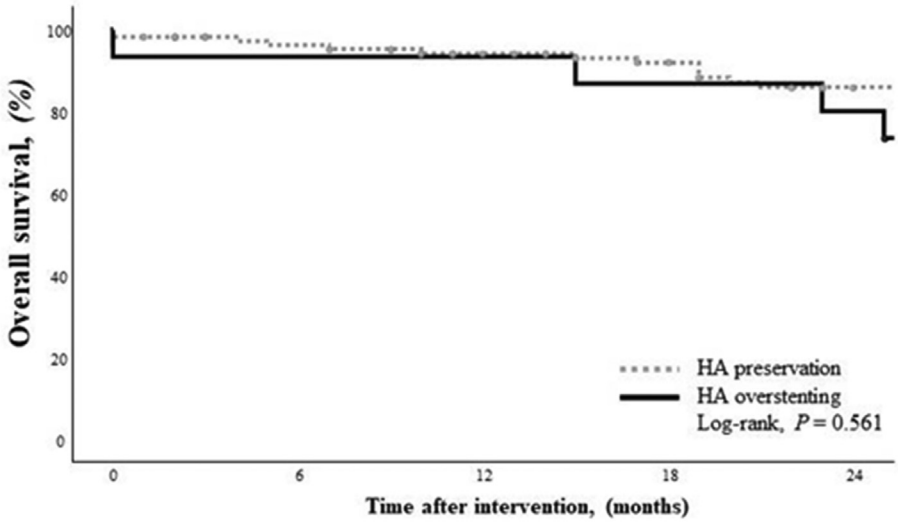
endoleak, 3 (2.5%) type 1b endoleak, and 1 (1.4%) type 3 endoleak. All these endoleaks were successfully treated and sealed off with additional extender cuff. Estimated freedom from endoleak-related reintervention was 95.8% (SE: 0.02; 95% CIs: 90.3−98.2) at 12 months, 94.1% (SE: 0.02; 95% CIs: 88.9−97.0) at 36 months, and 91.9% (SE: 0.03; 95% CIs: 84.0−96.1) at 60 months. There was no difference among groups in terms of endoleak-related reintervention (Log-rank $\chi^2 = 1.931$, $P = 0.587$).

Pelvic ischemic syndrome. During the follow-up, 9 (7.4%) patients developed buttock claudication (SVS grade 1, $n = 4$, SVS grade 2, $n = 5$); At multivariate Cox's regression analysis showed an increased risk of buttock claudication in patients who needed HA overstenting in comparison with other types of EVAR (HR: 3.6; 95% CIs: 0.96−13.5, $P = 0.058$). Patients treated with flared limbs did not develop buttock claudication complication in comparison with other types of EVAR (branched device, 15.4% versus mixed group, 6.1% versus overstenting, 26.7%; $P = 0.004$). No additional cases of pelvic ischemic syndromes were observed.

Macrocosting evaluation. Median total cost of hospitalization was 9,834 euros (IQR, 7040−12266): this was significantly different among the different types of EVAR with patients who received at least 1 branched device having the highest cost (10,501 euros, $P = 0.001$). This difference was not driven by the ICU admission whose median was not different among groups ($P = 0.828$), or by the cost of hospitalization ($P = 0.051$). Considering follow-up, the median cost was similar among groups ($P = 0.831$), despite there was an increased need of CT-A in the groups of patients with HA preservation ($P = 0.001$). Total cost during follow-up was significantly higher in patients who required reintervention (1,202 euros vs. 196 euros, $P = 0.005$), either due to endoleak-related reintervention (1,598 euros vs. 196 euros, $P = 0.005$) or EG-related reintervention (765 euros vs. 196, $P = 0.038$). When all cots were included, branched device still carried the highest burden (18,252 euros, $P = 0.001$; Fig. 4) in comparison with the mixed subgroup (13,261 euros), the overstenting subgroup (7,965 euros), and the flared limbs subgroup (7,258 euros).

DISCUSSION

The major finding emerging from our data analysis is that HA preservation and overstenting during EVAR for aorto-iliac aneurysms guarantee similar



Time window	1m	6m	12m	18m	24m
Survival %					
HA preservation	98.1	95.1	94.1	91.8	85.8
HA overstenting	93.3	93.3	93.3	86.7	80.0
SE					
HA preservation	0.01	0.02	0.02	0.03	0.04
HA overstenting	0.06	0.06	0.06	0.09	0.1
95%CI					
HA preservation	93.5-99.5	89.2-97.9	87.8-97.2	84.6-95.8	77.1-91.6
HA overstenting	70.4-98.8	70.4-98.8	70.4-98.8	62.1-96.3	55.7-92.7
@ risk					
HA preservation	105	96	86	77	66
HA overstenting	14	14	14	13	11

Fig. 2. Estimate of overall survival stratified by EVAR management **(A)**. Estimate of freedom from EVAR-related reintervention stratified by strategy **(B)**. EVAR, endovascular aortic repair; HA, hypogastric artery.

satisfactory clinical and technical results at early and mid-term provided that the anatomical indications and IFU are respected.

Pelvic ischemic syndromes during EVAR for aorto-iliac aneurysms cannot easily be predicted but they may lead to threatening complications such as colonic ischemia, or disturbing symptom such as buttock claudication.[2,23] These are the reasons why preservation of blood flow to at least 1 HA is recommended by different cardiovascular societies also during EVAR, and these are the reason why HA preservation in our EVAR cohort was accomplished in most of the situations.[1–3]

However, EVAR with HA preservation should be accomplished only if it does not compromise the primary treatment goal of aneurysm exclusion.[2] Considering that, in our series, only 57% of patients were treatable and treated with branched EG, in our opinion both the use of flared iliac limbs and overstenting still represent potential viable solutions when HA preservation may not be pursued with safe and durable results. Both flared iliac limbs and overstenting had similar survival and reintervention rates at lower estimated financial burden.[23]

Favoring HA preservation may be an intuitive and clinically reasonable solution to limit the onset of pelvic ischemic syndromes. In the analysis of the Vascular Study Group of New England, Ultee et al.[24] identified that unilateral interruption of the HA was an independent risk factor for postoperative colonic ischemia. In a systematic review, Kouvelos et al.[8] found that unilateral or bilateral HA occlusion during EVAR seems to carry a substantial risk of significant ischemic complications in nearly one-quarter of patients. However, more recent studies proved exactly the opposite one: Bennett et al.[4]

Table V. Univariate screen a multivariable analysis for overall survival and EVAR-related reintervention

	Univariate		Multivariate		
Covariate	Log-rank	*P*	HR	95% CI	*P*
Age ≥80	3.4	0.063	2.1	1.04−4.2	0.037
Gender	0.7	0.397			
CAD	2.8	0.092			
COPD	4.1	0.042			
History of aortic surgery	6.1	0.014	3.1	1.3−7.4	0.009
Endoleak	3.7	0.054			
EVAR-related reintervention					
Aneurysm diameter >60 mm	5.4	0.020	3.7	1.1−12.1	0.030
Postoperative complication	4.8	0.027			
HA overstenting	1.8	0.178			

HR, hazard ratio; COPD, chronic obstructive pulmonary disease; CAD, coronary artery disease; HA, hypogastric artery; EVAR, endovascular aortic repair.

did not find a reduced incidence of postoperative ischemic colitis in patients who received a concomitant pelvic revascularization procedure. Our results are consistent with the conflicting nature of existing published evidence: on 1 side, HA occlusion was associated with the development of buttock claudication which occurred in nearly 27% of the cases close to the 32% reported in a large meta-analysis of comparative studies; on the other side, colonic ischemia did not develop even when HA was bilaterally overstented.[9] Giving unquestionable explanations for such conflicting data is currently unfeasible: at least, on the colonic ischemia side of the story, embolization limited to the main trunk of the HA may have reduced ischemic complication rate, as also demonstrated in published literature in studies that compared this technical alternative with a more distal embolization.

Readmission for complication and reintervention pose challenges for surgeon and patient and may negatively impact the financial burden on healthcare system.[25] Currently, there are scant of data reporting cost analysis of complex aortic EG technology. Lockman et al.[12] showed that total cost of fenestrated EVAR was significantly higher compared with standard EVAR, and likely driven by the additional cost of fenestrated EG as well as by reinterventions. Our experience adds to the literature an unprecedented comparative cost analysis of EVAR for aorto-iliac aneurysms performed with different techniques.[26,27] We observed higher cost of initial hospitalization in the branched EVAR in comparison with overstenting group, mainly driven by the cost of branched EG. However, it is interesting to note that there was a significant increase in overall costs for patients who needed reintervention; not only the subgroup of branched EVAR did not need reintervention at all, but also reintervention never occurred on the branched side in the subgroup of EVAR that comprised branched on 1 side and flared limb on the contralateral side. Also, the 2 groups (flared versus branched) have different anatomical indication: the flared up to 25 mm CIA and the branched from 24 mm to larger CIA. Although costs analysis between these 2 types of EGs cannot be directly compared with the purpose to drive the choice, we would not simply confirm the well-known higher costs for the branched technology. Debating the use of more expensive technology such as branched EG for HA preservation, we prefer to consider that the application of the higher prized device helped us to increase the rate of HA preservation that would have potentially increased the rate of pelvic ischemic syndromes. Despite larger aneurysm size has been consistently reported to predict worse reintervention rate after EVAR, there is not unquestionable diameter threshold to contraindicate EVAR in anatomically feasible aneurysm.[28,29] Therefore, the true benefit and appropriate selection of patients for EVAR may be evaluated through risk stratification. In our analysis, diameter ≥65 mm was associated with the highest need of reintervention, independently of the type of EVAR performed. This specific data find support in a recent analysis of the Vascular Quality Initiative (VQI) registry data that showed that aneurysm diameter ≥65 mm is independently associated with reinterventions after EVAR.[30] There is consistency in literature, larger

Table VI. Follow-up: type of complication and correlated reintervention

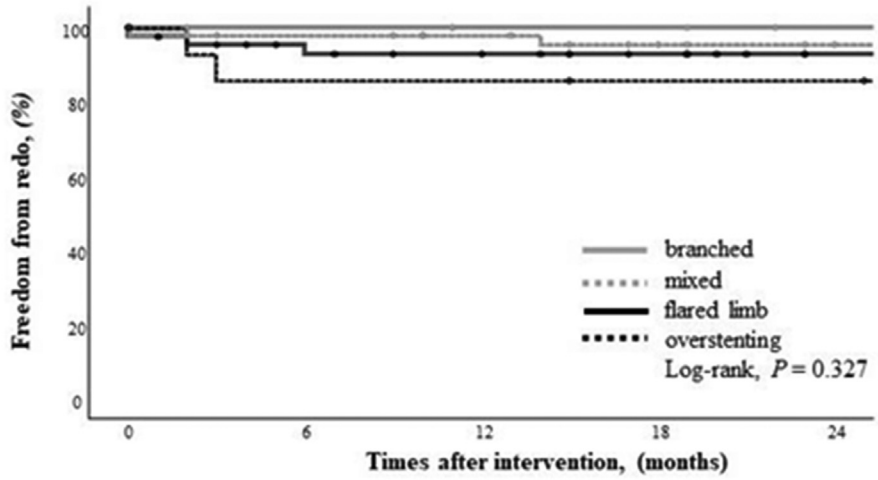
Type of EVAR, (*n*)	Endoleaks			Limb occlusion	Femoral PSA	Total, (%)
	T1a	T1b	T2			
Mixed group, ($n = 49$)	1 explant	1 EIA extender + HA embolization	1 coils embolization	1 thrombectomy	0	4 (8.2%)
Flared limbs, ($n = 45$)	1 TAAA parallel grafts	2 EIA extender + HA embolization	1 coils embolization	0	1 surgical repair	5 (11.1%)
Branched device, ($n = 13$)	0	0	0	0	0	0 (0)
Overstenting, ($n = 15$)	1 explant	0	1 coils embolization	2 thrombectomy + iliac stent	0	4 (26.7)

n, number; T1a, type 1a endoleak; T1b, type 1b endoleak; T2, type 2 endoleak; PSA, pseudoaneurysm; EIA, external iliac artery; TAAA, thoraco-abdominal aneurysm; HA, hypogastric artery.

experiences are awaited to assess whether this diameter (≥65 mm) threshold may be considered, even in patients who are surgically fit, a better indication for open repair even for those patients with suitable anatomy for EVAR. In fact, not only 93% of patients with large (≥65 mm) were protected from aorta-related mortality at 5 years, but reintervention did not translate into higher risk of mortality.

Limitations

This study has several limitations. First, the analysis is essentially retrospective in nature. Large databases rely solely on accurate site reporting: thus, it is possible that investigators might have not identified all morphologic variables correlated to the aorto-iliac anatomy especially correlated to the hypogastric arteries. However, missing data were not defaulted to negative, and denominators reflect only reported cases: out of the 122 patients, 8,418 overall data were collected through 69 variables, with an overall missing data rate of 0.4%. Moreover, multiple review auditing was performed by the leading author at each center to limit major inconsistencies. Second, it has sampling bias because patients undergoing open repair were not included for comparison, as well as the small number of patients included in this cohort may introduce a serious bias in the ascertainment of findings. Third, this type of analysis should benefit from some measure of effectiveness, usual quality-adjusted life-years, to be plotted against costs to derive the incremental cost effectiveness ratio of these 2 specific different treatment modalities; the retrospective nature of this study did not allow for such type of important evaluation. Fourth, micro-costing analysis would have more insightful though demanding and difficult to be realized. Fifth, while we attempted to correct for potential confounders using multivariate analyses, the small number of patients and events makes results of multivariate models not generalizable, and absence of statistically significant differences could reflect a type-II error. Lastly, quality of life has not been performed, but owing to the retrospective nature of this study it was not possible to run such type of data. All these limitations may not allow for generalizability of our findings, especially in terms of costs because they are quite different across world countries. Notwithstanding, our data compare well with the available literature because of the lack of data correlated to costs of EVAR for aorto-iliac aneurysms, to consistency of follow-up, and data validation by official health documents.



Time window	1m	6m	12m	18m	24m
Free from redo %					
branched	100	100	100	100	100
mixed	95.9	95.9	95.9	93.4	93.4
flared limb	95.7	90.9	90.9	90.9	90.9
overstenting	100	85.7	85.7	85.7	85.7
SE					
branched	0.00	0.00	0.00	0.00	0.00
mixed	0.03	0.03	0.03	0.04	0.04
flared limb	0.03	0.04	0.04	0.04	0.04
overstenting	0.00	0.09	0.09	0.09	0.09
95%CI					
branched	99.4-100	99.4-100	99.4-100	99.4-100	99.4-100
mixed	86.4-98.9	99.4-100	99.4-100	82.2-97.7	82.2-97.7
flared limb	86.7-98.7	70.9-96.4	70.9-96.4	70.9-96.4	70.9-96.4
overstenting	100	59.9-96.0	59.9-96.0	59.9-96.0	59.9-96.0
@ risk					
branched	13	13	13	13	13
mixed	47	43	39	34	31
flared limb	42	37	37	37	37
overstenting	14	12	12	11	11

Fig. 3. Total costs stratified by EVAR strategy. EVAR, endovascular aortic repair.

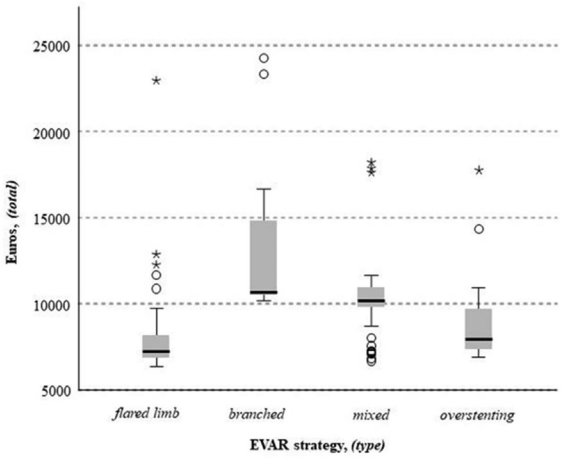


Fig. 4. Total costs stratified by EVAR strategy.

CONCLUSION

In our experience, major aortic-related outcomes and pelvic ischemic syndromes were acceptably low in all different types of EVAR techniques for aorto-iliac aneurysms, with equally excellent freedom from ARM. Overall, HA preservation with branched device showed better results in terms of postoperative complications in comparison with HA overstenting which, however, appears to be safe and effective option for patients who are not candidates for HA preservation based on aortic anatomy and IFU. While costs were significantly higher in patients receiving branched device, and in those needing reintervention, reintervention rate never required in iliac segments treated with branched device.

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