Open Versus Endovascular Repair With Covered Stents for Complex Aortoiliac Occlusive Disease: Cost Analysis Results

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Background: The aim of this work is to value cost-effectiveness of complex aortoiliac occlusive disease (AIOD) revascularization, by comparing in-hospital clinical outcomes and detailed costs of hospitalization of open and endovascular techniques.

Methods: This observational single-center retrospective cohort study included all patients who underwent AIOD revascularization from May 2008 to February 2018 and met inclusion and exclusion criteria. Patients were divided into 2 groups: open surgical repair and endovascular repair. Inclusion criteria were type C and D AIOD, and type of intervention: aorto-bifemoral bypass and covered kissing stenting. Costs were directly compared between the 2 groups, and subsequently a multivariate logistic regression model was performed to define which group most influenced major in-hospital costs. Cox proportional hazard models were used to identify predictors of long-term mortality and primary patency (PP).

Results: The 2 groups included 50 patients each, and all patients had a bilateral iliac axis revascularization. Mean age was 67 ± 9 years and 71% of patients were males. The open surgical repair group had a significantly longer length of hospitalization ($P < 0.001$) and in-hospital medical complications rate (22%, $P = 0.003$). No differences were found in the total cumulative cost of hospitalization, including ward, intensive care unit, and operating room. In a multivariate logistic model, higher total hospitalization costs were not significantly associated with either one or the other type of treatment. We did not find any statistically significant differences in overall medium-term survival ($P = 0.298$) and PP ($P = 0.188$), which were not influenced by the type of revascularization on Cox proportional hazard models (overall survival: hazard ratio 2.09 confidence interval 95% [0.90–4.84] $P = 0.082$; PP: hazard ratio 1.82 confidence interval 95% [0.56–6.16] $P = 0.302$).

Conclusions: Total in-hospital stay cost analysis did not reveal significant differences between aorto-bifemoral bypasses and covered kissing stentings for AIOD revascularization.

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INTRODUCTION

Since the first aortic bifurcation replacement performed in 1950 by Jacques Oudot,[1] revascularization techniques for aortoiliac occlusive disease (AIOD) have progressively evolved. In fact, in the last 20 years, technology has allowed an enormous improvement in endovascular procedures, and arterial lesions once reserved to open surgery can now be treated with balloon angioplasty and stent deployment. Based on the Trans-Atlantic Inter-Society Consensus Document on Management of Peripheral Arterial Disease (TASC),[2] updated in 2007 (TASC II)[3] and 2015,[4] endovascular repair (ER) and open surgery were indicated as the treatments of choice for TASC A and D lesions, respectively.[3,4] The TASC II document[3,4] suggested also that teams should favor ER and open surgery for TASC B and C lesions, respectively, although decision-making must consider patients' comorbidities. ER has allowed high-risk patients to be considered for revascularization; however, these procedures begin to be proposed also in low-risk cases with complex diseases,[5] with encouraging long-term results; as an exception, it is suggested that in female sex surgery remains the preferable choice.[5] Of course, the optimal treatment should be selected based on the lesion anatomical features, patient's comorbidities and, last but not least, center's experience. Concerning ER, some studies have investigated which stent type was more suitable for complex aortoiliac lesions. The *Covered versus Balloon expandable stent trial*[6] demonstrated the superiority of balloon-expandable covered stents (CSs) over balloon-expandable bare metal stents (BMS) in complex aortoiliac lesions (i.e., TASC C and D) in terms of freedom from binary restenosis, while the two were comparable in TASC A and B. These results were confirmed on the long term with a follow-up of 5 years,[7] where CSs showed a significantly higher patency rate. In another study, authors evaluated factors that may influence stent patency[8] and identified iliac occlusion and BMS use for long iliac lesions involving the entire axis. Furthermore, specifically for iliac axis occlusions, both BMSs and self-expanding CSs were found effective, yet CSs showed better results for TASC D lesions, long occlusions, and important calcifications.[9]

Each procedure carries an economic burden and cost considerations are nowadays a part of everyday choices in the hospital management. Different factors may influence the overall cost of hospitalization, and a complete evaluation must be done to obtain an exhaustive picture. Endovascular techniques have the advantage of being less invasive and they guarantee a significant social gain, allowing an early return to everyday life and job activity. Other studies have compared costs of open and endovascular treatments for AIOD,[10,11] yet not focusing on all complex lesions nor comparing 2 specific types of revascularization. The purpose of this work is to analyze and compare in-hospital costs and clinical outcomes of aorto-bifemoral bypass (ABF) and kissing technique with CSs (covered kissing stenting [CKS]) performed in our center for complex AIOD lesions (TASC C and D).

MATERIALS AND METHODS

Patients and Definitions

From May 2008 to February 2018, all consecutive patients undergoing aortoiliac revascularization for chronic obstructive disease in our vascular unit were collected. Inclusion criteria were TASC C and D lesions with both common iliac arteries and aortic bifurcation involvement. We included 2 types of procedure: ABF and kissing technique with CSs (CKS). We included both balloon-expandable and self-expandable CSs. Exclusion criteria were cases with associated aneurysms and dissections, TASC A and B lesions, unilateral treatments, bilateral iliac revascularization with 2 different techniques (e.g., unilateral iliac stenting associated to a femoro-femoral bypass), bilateral common iliac artery stenting with BMS and/or without a kissing conformation, and patients with multilevel revascularizations during the same operative session and the same hospitalization.

Patients were divided into 2 groups: open surgical repair (OSR) included ABFs, and ER included CKSs. Hybrid procedures, such as common femoral artery endarterectomy associated with aortoiliac stenting, were counted as part of the ER group. The choice between treatments was based on the TASC II classification,[3] current guidelines,[12] and patient comorbidities.

We collected patients' demographics and cardiovascular risk factors, markers of operative risk, preoperative clinical status according to Rutherford,[13] anatomical extent of the obstructive disease according to the TASC II classification,[3] any other localization of the arterial disease, intraoperative details, and data regarding ward stay. The operative risk was calculated according to the Society for Vascular Surgery grading system (SVS score)[14] and the American Society of Anesthesiologists Physical Status Examination (American Society of Anesthesiologists score).

ABF and CKS techniques have been previously detailed.[5] All interventions were performed in a standard operating room by members of the

Vascular and Endovascular Surgery Unit, using a mobile C-arm unit for endovascular procedures. The technical success of CKS procedures was assessed with a 2-dimensional digital subtraction angiography. In the ER, arterial access was achieved with a surgical femoral approach during the first years of our study period, and with a percutaneous approach during the last years.

We reported the duration of each procedure in minutes as well as the total length of the patient stay in the operating room, because the effective period of work is different between surgeons and anesthesiologists or nurses. We reported the number of surgeons, nurses, anesthesiologists, and healthcare workers. Furthermore, we reported the type of anesthesia (general versus local); the mode of arterial access in endovascular procedures (percutaneous or open surgical access); the type of prosthesis; and the number, diameter, length, and type of stents.

Data on ward stay included number of preoperative, postoperative, and total days; number of blood transfusions; and number of postoperative days in the intensive care unit (ICU).

Reported surgical complications were arterial rupture or dissection, pseudoaneurysm or hematomas requiring intervention, thrombosis, intrastent stenosis, stent recoiling, and stenosis of the anastomosis.

Medical complications were reported as major adverse events, including myocardial infarction, dysrhythmia, heart failure, respiratory failure, pneumonia, renal insufficiency, cerebrovascular events, and intestinal ischemia. We used the Risk, Injury, Failure, Loss of kidney function and End-stage renal disease criteria for renal insufficiency;[15] cerebrovascular events were reported according to the World Health Organization with distinction between transient ischemic attack and stroke based on duration of symptoms.[16]

Economic Values

Costs of the in-hospital stay were divided in ward-related, ICU-related, and intervention-related, all further divided in direct costs (DCs) and indirect costs (ICs). DCs included the variable expenses, such as healthcare personnel salary, prosthesis and stents, laboratory analysis, diagnostic investigations, and medications. ICs were those concerning food, cleaning, maintenance, and heating, and did not vary based on length and complexity of each hospitalization.

Concerning the ward and the ICU, we calculated the cost of 1 day of hospitalization, which included DCs and ICs, only adding the economic value of blood transfusions.

Regarding the operating room, we actually divided the 2 types of costs. Therefore, DCs included the salary of surgeons, nurses, healthcare workers, and anesthesiologists, calculated per minute, and the cost of each prosthesis and stent. For ICs, these were synthetized in the per-hour cost of the operating room.

Costs were reported on a price base of the financial year 2018. Since this work is an in-hospital analysis, we choose not to quantify costs of healthcare outside the hospital.

Outcomes

Patients were systematically evaluated at 1/3, 6, and 12 months and then annually postintervention with a clinical examination, including lower limbs arterial pulse palpation, and imaging, such as computed tomography angiography and/or duplex ultrasound, as needed; in fact, computed tomography was usually preferred for endovascular procedures, even without iodinated contrast mean, to certify the correct positioning of the stents and to exclude any misalignment or compression.

We evaluated primary patency (PP), freedom from reintervention (FFR), and overall survival (OS), comparing the 2 groups.

We then confronted the 2 groups in terms of costs of hospitalization, distinguishing between ward and ICU; we calculated duration and costs of every intervention, focusing on implanted devices and salary of each participant in the operating room. The 2 groups were also compared in terms of clinical outcomes and in-hospital details, such as length of hospitalization and number of blood transfusions.

The cost of subsequent hospitalizations for medical and surgical complications and the evaluation of postoperative quality of life were not the purposes of this study.

Primary outcomes were costs of hospitalization, while secondary outcomes included mortality, medical complications, and surgical complications listed in the ‘‘patients and definitions’’ paragraph, as well as factors that could influence mortality and patency on the long term.

Statistical Analysis

We used R 4.1.0 (R Foundation for Statistical Computing. Vienna, Austria) and Prism GraphPad 9.1.2 (GraphPad Inc, San Diego, California). Patients' baseline characteristics were reported as mean ± standard deviation or median + interquartile range, and frequency + percentage for continuous and categorical variables, respectively. Two-sided P values for continuous variables refer to unpaired t-test or Wilcoxon rank sum test, as appropriate. Two-sided P values for categorical variables refer to Chi-squared or Fisher's exact test.

Time variable was defined as the time between the intervention and date of the event or for subjects who did not experience the event, the date of the last available clinical follow-up. Kaplan-Meier survival curves were estimated for OS, PP, and FFR, and data with a standard error (SE) > 10% were censored.

Univariate analysis to identify predictors of overall mortality and PP was performed with Kaplan-Meier survival estimates and log-rank test. Associations with a P value < 0.2 were included in multivariate Cox proportional hazard models. Risks were reported as hazard ratios (HRs) along with their 95% confidence intervals (CIs).

Multivariate logistic regression models were used to identify associations between the type of treatment and the major in-hospital costs, identifying the SVS score and the TASC classification type as confounding factors.

A two-tailed P value < 0.05 was considered for statistical significance.

RESULTS

Demographics and Procedural Details

During the study period, 107 patients underwent aortoiliac revascularization with either ABF or CKS techniques, matching our inclusion criteria. Seven patients were excluded because a multilevel revascularization was performed during the same hospitalization. Therefore, our database included 100 patients, each further divided into 2 groups with 50 patients each: OSR and ER. All patients had a bilateral treatment.

The median follow-up was 37 months (range 0–126). Forty-one and 32 limbs, respectively, in the OSR and ER group were subjected to femoral endarterectomy during the same intervention ($P = 0.239$). Fifty percent of patients in the ER underwent the intervention under general anesthesia. Patients' demographics are listed in Table I: mean age was 67 ± 9 years. Aortoiliac TASC D lesions were more represented in the OSR group (43 vs. 28 in the ER group, $P = 0.001$); interestingly, in the ER group, TASC D lesions were more represented than the C ones (56% vs. 44%) (Fig. 1). Clinical preoperative condition was stated by the Rutherford classification, and the distribution of grade 3, 4, and 5 was not different between the 2 groups ($P = 0.446$) (Table I); no patient presented with a grade 6.

In-Hospital Details and Complications

The length of hospitalization (in the ward, in the ICU, and the total length), the length of surgery, and the number of patients undergoing blood transfusions were significantly higher in the OSR group, as expected (Table II). Patients experiencing medical complications and surgical complications requiring intervention showed a trend to longer in-hospital stay.

In the ER group, there were 6 in-hospital surgical complications, mainly represented by femoral pseudoaneurysms or hematomas requiring intervention, while the OSR group had 3 patients with complications, represented by 1 limb thrombosis, 1 proximal anastomosis thrombosis, and 1 paralytic ileus requiring an extension of the hospitalization; yet the difference between the 2 groups was not statistically significant ($P = 0.487$) (Table III). In-hospital medical complications differed between the 2 groups (OSR: 22%; ER: 2%; P value = 0.003); in the OSR group, they were mainly represented by acute renal failure (8% vs. 0% in ER, $P = 0.04$), and 3 patients had more than 1 type of complication. In the ER group, there was 1 case of sepsis related to a central venous catheter infection. No in-hospital deaths occurred in both groups.

Outcomes

The costs of the hospitalization in the ward and in the ICU were higher in the OSR group (Table II, Fig. 2). In fact, only 16% of patients in the ER group went to the ICU in the postoperative period, with a mean length of stay of 0.3 ± 0.7 days; the length of ward hospitalization in this group was 4.5 [interquartile range 2.7–6] days. Although less patients in the ER group received a blood transfusion (23 vs. 35 in the OSR group), the cost was not significantly different between the 2 groups ($P = 0.055$). The cost of 1 surgeon during an intervention was higher in the OSR group (277.17 ± 7.8 SEM vs. 216.9 ± 17.8 SEM, $P = 0.002$), yet it was not the same for nurses and healthcare workers. Finally, the cost of material, simplified in prosthesis, endoprosthesis, and stents, was significantly higher in the ER group (6,567 ± 413 vs. 220.8 ± 15 in the OSR group, $P < 0.001$). The comparison of total cumulative cost of hospitalization did not show any difference between the 2 groups ($P = 0.304$).

A simple logistic regression model underlined that patients with higher ICU-related costs were more likely to belong to the OSR group (estimate

Table I. Patients demographics and distribution of lesions according to the TASC II classification

Variable	OSR $n = 50$ Mean (± SD) or *N* (%)	ER $n = 50$ Mean (± SD) or *N* (%)	*P* value
Age	66.6 ± 7.8	68.3 ± 9.8	0.328
Male sex	36 (72)	35 (70)	0.825
Arterial hypertension	43 (86)	44 (88)	0.766
Smoking			0.076
Current	7 (14)	6 (12)	
Former	18 (36)	29 (58)	
Diabetes mellitus	19 (38)	12 (24)	0.269
Dyslipidaemia	40 (80)	26 (52)	0.698
Renal insufficiency	8 (16)	6 (12)	0.774
Coronary artery disease	20 (40)	22 (44)	0.685
COPD	4 (8)	6 (12)	0.740
Cerebrovascular disease	2 (4)	4 (8)	0.433
SVS total score	0.81 ± 0.46	0.97 ± 0.46	0.087
TASC C	7 (14)	22 (44)	**0.001**
TASC D	43 (86)	28 (56)	
Rutherford class[a]			0.446
3	55 (55)	50 (50)	
4	24 (24)	32 (32)	
5	21 (21)	18 (18)	
Femoral endarterectomy	41 (41)	32 (32)	0.239
Percutaneous femoral access	-	27 (54)	-
SFA occlusion[a]	29 (29)	33 (33)	0.646

Bold values indicate significative *P*-values.
OSR, open surgical repair; ER, endovascular repair; SD, standard deviation; COPD, chronic obstructive pulmonary disease; SVS, Society for Vascular Surgery; TASC, TransAtlantic Consensus Conference; SFA, superficial femoral artery.
[a]Values and analysis are intended per limb.

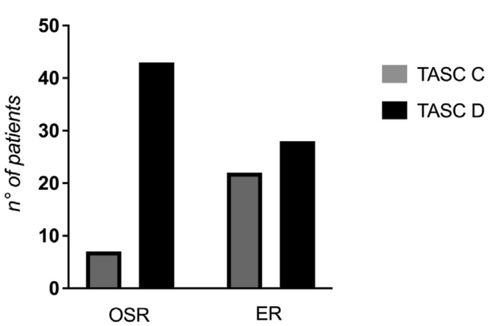

Fig. 1. Distribution of patients in the 2 groups according to the anatomic TASC II classification.

−0.05, SE 0.01, *P*= < 0.001), while patients with higher implanted material costs belonged to the ER group (estimate 0.11, SE 0.007, *P*= < 0.001). Conversely, the inclusion in either one group or the other did not depend on the total hospitalization cost (estimate 0.006, SE 0.006, $P = 0.279$). The multivariate model adjusted for the SVS score and the TASC type confirmed these results (Table IV).

OS, FFR, and PP at 3 years did not differ between the 2 groups ($P = 0.298$, $P = 0.350$, and $P = 0.188$, respectively; Figs. 3 and 4). Unadjusted univariate Cox survival analysis showed a trend to lower OS in the ER group (HR 1.94, 95% CI 0.88−4.30, $P = 0.099$). However, this was not significant even when the model was adjusted for age, diabetes, and preoperative SVS score in the multivariate model, as reported in Table V (HR 2.09, 95% CI 0.90−4.84, $P = 0.082$ for the ER group). Similarly, ER did not influence PP both in univariate (HR 2.01, 95% CI 0.69−5.87, $P = 0.199$) and multivariate analysis (HR 1.87, 95% CI 0.56−6.16, $P = 0.302$), while higher age and male sex were protective factors and occlusion of the superficial femoral artery was a risk factor, as reported in Table VI.

DISCUSSION

Although healthcare systems vary worldwide, they all face an increase in costs, especially for chronic diseases. The purpose of the Value-Based Health-Care, first introduced by Michael E. Porter in 2009,[17] is to redesign healthcare systems to estimate

Table II. In-hospital details and cost comparison between the 2 groups. Length of hospitalization is expressed in days, length of intervention in expressed in minutes, costs are reported in euros

Variable	OSR *n* = 50 Mean (± SD or SEM) or median [IQR]	ER *n* = 50 Mean (± SD or SEM) or median [IQR]	*P* value
Blood transfusions[a]	35 (70)	23 (46)	**0.015**
In-hospital total length of hospitalization	12 [9−19.25]	6 [4−10.25]	**< 0.001**
Postoperative ward hospitalization	7 [5.25−10]	4.5 [2.7−6]	**< 0.001**
Postoperative ICU hospitalization	2.7 ± 3.6	0.3 ± 0.7	**< 0.001**
Length of intervention (SEM)	258.8 ± 7.2	202.6 ± 16.6	**0.002**
Cost of blood transfusions	1,134 ± 231	940 ± 228	0.055
Cost of hospitalization in the ward	3,089 [2,163−4,711]	1,854 [1,236−2,935]	**< 0.001**
Cost of ICU hospitalization (SEM)	3,711 ± 698.4	412.4 ± 148.2	**< 0.001**
Cost of 1 surgeon during intervention (SEM)	277.2 ± 7.8	216.9 ± 17.8	**0.002**
Cost of 1 nurse during intervention	154.8 ± 30.2	143.2 ± 58	0.106
Cost of 1 healthcare worker during intervention	128.4 ± 25	118.7 ± 48	0.106
Cost of prosthesis and stents	220.8 ± 15	6,567 ± 413	**< 0.001**
Total cumulative hospitalization cost	10,636 [9,002−14,874]	12,234 [9,319−17,126]	0.304

Bold values indicate significative *P*-values.
SEM, standard error of mean; IQR, interquartile range; ICU, intensive care unit.
[a]Patients who underwent blood transfusion.

the right balance between expenses and outcomes. Cutting on devices and services may give the illusion to economize, but the principal way to contain costs is by improving outcomes.[17] Currently, there is no homogeneous evaluation system throughout the national Italian territory, with sometimes surprising differences between the various regional realities and also within the same region.

The vascular patient, from the onset of the disease and for the rest of his life, carries the burden of a chronic condition. Revascularization offers satisfactory results, but the inevitable progression of the disease often requires further interventions in more peripheral districts. Furthermore, these patients have multiple chronic comorbidities, such as diabetes mellitus, arterial hypertension, dyslipidaemia, cardiac, pulmonary, and renal diseases, besides age and frequent loss of autonomy.

To our knowledge, there is currently no study comparing in-hospital costs of 2 single types of aortoiliac revascularizations (i.e., ABF and CKS) for both TASC C and D occlusive disease. Our purpose was to analyze a real-life situation by comparing in-hospital expenses of open and endovascular AIOD revascularization for TASC C and D lesions, focusing on 2 specific types of techniques (ABF and CKS). We collected cost markers for individual procedures and hospitalization episodes. In the examined period, there was a progressive development of endovascular techniques that may now be considered as a first-line strategy even in complex lesions and in low-risk patients.[5] Furthermore, an ER does not hamper a subsequent open repair in case of failure, as validated by some authors.[18]

We observed longer hospitalizations with OSR, which was in line with Indes et al. analysis.[19] OSR group was associated with an increased need for ICU as well, with consequent higher ward and ICU hospitalization costs. Conversely, for ER the main item of expenditure regarded stents. The length of

Table III. Only in-hospital medical complications were significantly different between the 2 groups, mainly represented by acute renal failure in the OSR cohort

Variable	OSR $n = 50$ N (%)	ER $n = 50$ N (%)	P value
Overall in-hospital surgical complications	**3 (6)**	**6 (12)**	0.487
Limb/stent occlusion	1 (2)	1 (2)	>0.999
Proximal perianastomotic thrombosis	1 (2)	0 (0)	>0.999
Dissection of the artery	0 (0)	1 (2)	>0.999
Pseudoaneurysm	0 (0)	2 (4)	0.494
Hematoma	0 (0)	1 (2)	>0.999
Paralytic ileus	1 (2)	0 (0)	>0.999
Stent recoiling	0 (0)	1 (2)	>0.999
Surgical complications requiring intervention	**2 (4)**	**6 (12)**	0.268
Overall in-hospital medical complications[a]	**11 (22)**	**1 (2)**	**0.003**
Myocardial infarction	2 (4)	0 (0)	0.494
Heart failure	3 (6)	0 (0)	0.242
Arrhythmias	1 (2)	0 (0)	>0.999
Acute renal failure	4 (8)	0 (0)	0.117
Pneumonia	3 (6)	0 (0)	0.242
Bacteraemia	1 (2)	1 (2)	>0.999

Bold values indicate significative P-values.
[a]Patients with a medical complication.

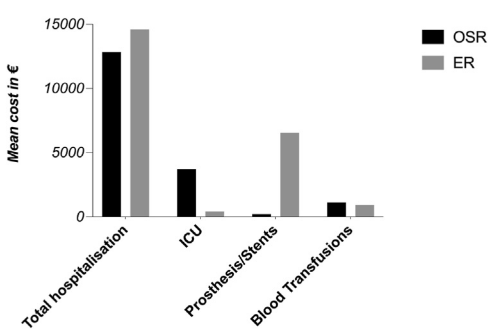

Fig. 2. Representation of mean values of principal costs. The differences between the 2 treatments are noticeable for implanted materials (prosthesis and stents) and ICU hospitalization. OR, operating room; ICU, intensive care unit.

procedures was higher for open surgical procedures, and consequently there was a significant difference in surgeons' salary between the 2 types of interventions. Nurses and healthcare workers usually spend an added amount of time with the patient right before and after the procedure itself, for patient preparation and assisting the anesthesiologist during awakening. We believe that this could be the reason why the comparison of their salary between the 2 groups did not show significancy. In the multivariate logistic regression model, higher total hospitalization

Table IV. Multiple logistic regression on costs associated to treatments and adjusted for SVS score and TASC type. In this model, the type of treatment is the dependant variable

Variable	Estimate	Standard error	P value
Cost of ICU hospitalization	−0.050	0.011	**<0.001**
Cost of hospitalization in the ward	−0.004	0.014	0.751
Cost of blood transfusions	−0.013	0.031	0.677
Cost of prosthesis and stents	0.105	0.007	**<0.001**
Total cumulative hospitalization cost	0.009	0.006	0.129

Bold values indicate significative P-values.

costs did not suggest the belonging to one group or the other, indicating that the type of treatment did not influence final costs, comprehensive of ward, ICU, and operating room. On the other hand, OSR certainly influenced ICU costs, while ER was related to higher implanted material costs. Currently, literature is contradictory over cost-effectiveness of peripheral arterial disease revascularization. Doshi et al. have compared in-hospital expenses for

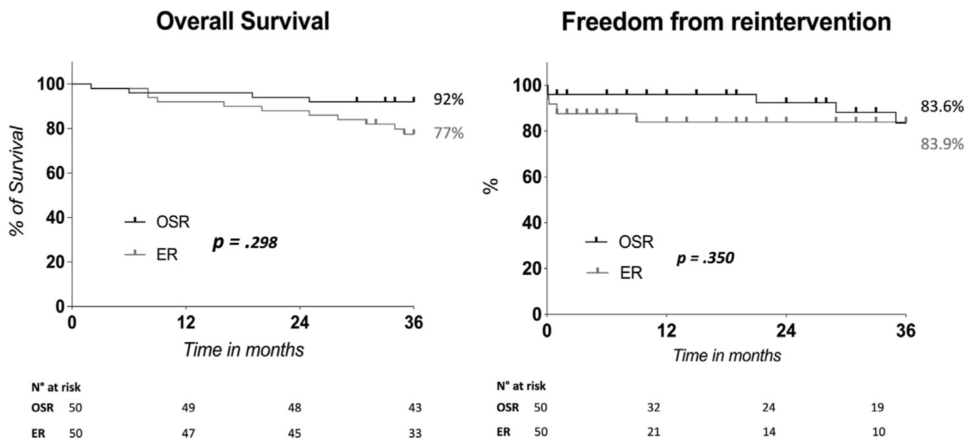

Fig. 3. Kaplan-Meier estimates on overall survival and freedom from reintervention in both groups, based on a time-to-event analysis. No difference was shown with the log-rank test, with a *P* value of 0.092 and 0.460, respectively. Standard error < 10%. OSR, open surgical repair; ER, endovascular repair.

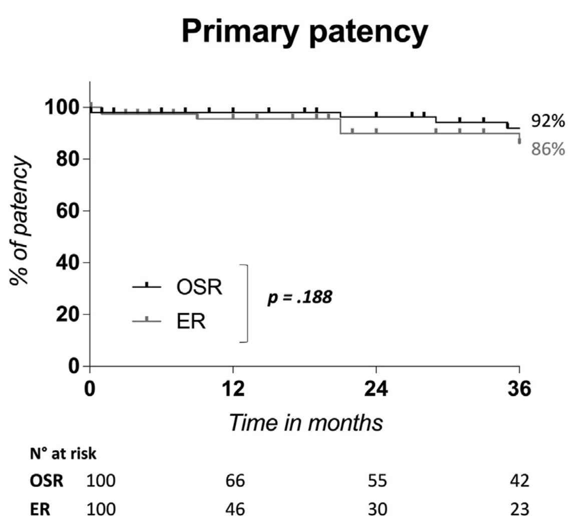

Fig. 4. Kaplan-Meier survival estimates on primary patency per limb at 3 years showed similar results of the 2 groups ($P = 0.188$ calculated with the log-rank test), based on a time-to-event analysis. Standard error < 10%. OSR, open surgical repair; ER, endovascular repair.

peripheral arterial disease,[20] finding lower related costs of endovascular procedures; however, these analyses did not focus on the aortoiliac district, where the need for CSs increases expenses. Sousa et al.[11] found that ER was significantly more expensive than open repair, yet only focusing the analysis on TASC D lesions. Conversely, Indes et al.[10] concluded that OSR had higher costs compared to ER, yet without making a distinction for procedure type and for disease localization: the OSR group included ABF, aortoiliac endarterectomy, femoro-femoral bypass, and axillo-femoral bypass, while the endovascular group included angioplasty or insertion of nondrug eluting stents. We believe that including different types of revascularizations in the same group would have created some consistent bias during cost-comparison, thus we decided to analyze only the most performed procedure for each cohort of patients.

Concerning clinical results, many studies have compared open and endovascular techniques in terms of complication rate and patency.[5,21–23] Our PP did not show a significant difference between the 2 groups, but with a better trend in OSR group. Multivariate Cox regression models pointed out that patency was not influenced by the type of intervention. In our analysis, patency was negatively influenced by superficial femoral artery occlusion, while higher age and male sex were protective factors. Dorigo et al.[21] only identified critical limb ischemia as an independent risk factor, while infrainguinal disease affected procedure durability also in Kashyap et al.[23] study. OS did not differ between the 2 cohorts, but the ER group had a low survival trend, and this was in line with other authors.[24,25] Yet, in multivariate survival analysis regression models, survival was not affected by the type of intervention.

In-hospital surgical complications were higher in the ER group, although not significantly, and were primarily represented by pseudoaneurysms and hematomas requiring surgical correction. The number of complications requiring an adjunctive procedure did not differ between the 2 groups. Conversely, medical complications were higher in the OSR group, as expected, mainly represented by acute

Table V. Multivariate Cox proportional hazard model for mortality in 100 patients

Variable	HR	95% CI	*P* value
ER group	2.096	0.908−4.840	0.082
Age	1.066	1.002−1.135	**0.043**
Diabetes mellitus	2.511	1.120−5.628	**0.025**
COPD	1.416	0.502−3.994	0.510
SVS score	4.008	1.523−10.544	**0.005**

Bold values indicate significative *P*-values.
ER, endovascular repair; COPD, chronic obstructive pulmonary disease; SVS, Society for Vascular Surgery.

renal injury. However, no in-hospital deaths occurred. Of course, complications occurrence lengthened in-hospital stays and thus raised costs of hospitalization in both groups.

Our study has several limitations. First of all, this is a retrospective nonrandomized study, reporting costs related to a single-center practice. A future multicenter cost evaluation would be advisable to allow a correct generalization of results. Second, the analysis examined a period of 10 years, with a progressive change in intervention indications and a continuous evolution in endovascular technologies: regarding our experience, in the first years of our decade, ER was achieved with a surgical femoral approach, while most accesses were percutaneous in the latest years. This could modify the length of hospitalization and, in some cases, even the need for ICU because of the avoidance of general anesthesia. By shortening the length of stay, an iliac recanalization with percutaneous access would have lower in-hospital costs. Furthermore, some results, such as blood transfusion costs, had a higher trend in the OSR group even if not reaching statistical significance: we suspect that this could be a consequence of a power problem and with a more consistent number of patients, this difference may become significative. Although BMS are less expensive, we only reported costs of ER with CS, because it is our preferred approach in aortoiliac revascularizations since they have shown better results in complex AIOD lesions, and thus this selection is more representative of clinical practice. Finally, in this article, we have concentrated on in-hospital costs, yet further analysis is warranted including reinterventions and their cost-comparison between open and endovascular techniques.

CONCLUSION

In our analysis, OSR group always required ICU stay, with higher related expenses, and presented more in-hospital medical adverse events. Conversely, ER group had lower hospitalization lengths, but higher implanted devices costs. All-inclusive hospitalization expenses were not different between the 2 groups, suggesting a cost balancing between the 2 revascularization procedures.

Open repair provided a better trend in PP and OS rates, although the difference between groups was not significant.

Future analysis is needed to validate our results and to evaluate the economic burden of subsequent hospitalizations for both medical and surgical complications, focusing on how quality of life could be affected.

Table VI. Multivariate Cox proportional hazard model for primary patency in 200 limbs' revascularization with open surgical or endovascular technique

Variable	HR	95% CI	*P* value
ER group	1.872	0.568−6.169	0.302
Age	0.933	0.872−0.997	**0.041**
Sex (male)	0.221	0.068−0.720	**0.012**
CLTI	2.546	0.788−8.221	0.118
SFA occlusion	4.255	1.235−14.653	**0.021**

Bold values indicate significative *P*-values.
CLTI, critical limb-threatening ischemia; SFA, superficial femoral artery.

REFERENCES

1. Oudot J. [Vascular grafting in thromboses of the aortic bifurcation]. Presse Med (1893) 1951;59:234−6.
2. Management of peripheral arterial disease (PAD). TransAtlantic Inter-Society Consensus (TASC). Eur J Vasc Endovasc Surg 2000;19(Suppl A):Si-xxviii, S1-250.
3. Norgren L, Hiatt WR, Dormandy JA, et al. Inter-society Consensus for the management of peripheral arterial disease (TASC II). J Vasc Surg 2007;45(Suppl S):S5−67.
4. Jaff MR, White CJ, Hiatt WR, et al. An update on methods for revascularization and expansion of the TASC lesion classification to Include below-the-knee arteries: a Supplement to the Inter-Society Consensus for the management of peripheral arterial disease (TASC II): the TASC Steering Comittee(.). Ann Vasc Dis 2015;8:343−57.
5. Antonello M, Squizzato F, Bassini S, et al. Open repair versus endovascular treatment of complex aortoiliac lesions in low risk patients. J Vasc Surg 2019;70:1155−1165.e1.
6. Mwipatayi BP, Thomas S, Wong J, et al. A comparison of covered vs bare expandable stents for the treatment of aortoiliac occlusive disease. J Vasc Surg 2011;54:1561−70.
7. Mwipatayi BP, Sharma S, Daneshmand A, et al. Durability of the balloon-expandable covered versus bare-metal stents in the Covered versus Balloon Expandable Stent Trial (COBEST) for the treatment of aortoiliac occlusive disease. J Vasc Surg 2016;64:83−94.e1.
8. Piazza M, Squizzato F, Spolverato G, et al. Outcomes of polytetrafluoroethylene-covered stent versus bare-metal

stent in the primary treatment of severe iliac artery obstructive lesions. J Vasc Surg 2015;62:1210−1218.e1.
9. Piazza M, Squizzato F, Dall'Antonia A, et al. Editor's choice - outcomes of self expanding PTFE covered stent versus bare metal stent for chronic iliac artery occlusion in matched cohorts using propensity score modelling. Eur J Vasc Endovasc Surg 2017;54:177−85.
10. Indes JE, Mandawat A, Tuggle CT, et al. Endovascular procedures for aorto-iliac occlusive disease are associated with superior short-term clinical and economic outcomes compared with open surgery in the inpatient population. J Vasc Surg 2010;52:1173−9. 1179.e1.
11. Sousa J, Neves J, Ferreira A, et al. Comparaison between endovascular approach and aorto-bifemoral bypass for Tasc D aorto-iliac disease patients treated between 2011-2017. Rev Port Cir Cardiotorac Vasc 2017;24:107.
12. Aboyans V, Ricco J-B, Bartelink M-LEL, et al. Editor's choice - 2017 ESC guidelines on the diagnosis and treatment of peripheral arterial diseases, in collaboration with the European Society for vascular surgery (ESVS). Eur J Vasc Endovasc Surg 2018;55:305−68.
13. Rutherford RB, Baker JD, Ernst C, et al. Recommended standards for reports dealing with lower extremity ischemia: revised version. J Vasc Surg 1997;26:517−38.
14. Chaikof EL, Fillinger MF, Matsumura JS, et al. Identifying and grading factors that modify the outcome of endovascular aortic aneurysm repair. J Vasc Surg 2002;35:1061−6.
15. Bellomo R, Ronco C, Kellum JA, et al. Acute renal failure - definition, outcome measures, animal models, fluid therapy and information technology needs: the Second International Consensus Conference of the Acute Dialysis Quality Initiative (ADQI) Group. Crit Care 2004;8:R204−12.
16. Aho K, Harmsen P, Hatano S, et al. Cerebrovascular disease in the community: results of a WHO collaborative study. Bull World Health Organ 1980;58:113−30.
17. Porter ME. A strategy for health care reform–toward a value-based system. N Engl J Med 2009;361:109−12.
18. Patel AP, Langan EM 3rd, Taylor SM, et al. Has the emergence of endovascular treatment for aneurysmal and occlusive aortic disease increased the complexity and difficulty of open aortic operations? Ann Vasc Surg 2004;18:212−7.
19. Indes JE, Pfaff MJ, Farrokhyar F, et al. Clinical outcomes of 5358 patients undergoing direct open bypass or endovascular treatment for aortoiliac occlusive disease: a systematic review and meta-analysis. J Endovasc Ther 2013;20:443−55.
20. Doshi R, Changal KH, Gupta R, et al. Comparison of outcomes and cost of endovascular management versus surgical bypass for the management of lower extremities peripheral arterial disease. Am J Cardiol 2018;122:1790−6.
21. Dorigo W, Piffaretti G, Benedetto F, et al. A comparison between aortobifemoral bypass and aortoiliac kissing stents in patients with complex aortoiliac obstructive disease. J Vasc Surg 2017;65:99−107.
22. Squizzato F, D'Oria M, Bozza R, et al. Propensity-matched comparison of endovascular versus open reconstruction for TASC-II C/D AortoIliac occlusive disease. A ten-year single-center experience with self-expanding covered stents. Ann Vasc Surg 2021;71:84−95.
23. Kashyap VS, Pavkov ML, Bena JF, et al. The management of severe aortoiliac occlusive disease: endovascular therapy rivals open reconstruction. J Vasc Surg 2008;48:1451−7. 1457.e1-3.
24. Sachwani GR, Hans SS, Khoury MD, et al. Results of iliac stenting and aortofemoral grafting for iliac artery occlusions. J Vasc Surg 2013;57:1030−7.
25. Premaratne S, Newman J, Hobbs S, et al. Meta-analysis of direct surgical versus endovascular revascularization for aortoiliac occlusive disease. J Vasc Surg 2020;72:726−37.