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RANDOMISED CLINICAL TRIAL

Editor's Choice – Hybrid *vs.* Open Surgical Reconstruction for Iliofemoral Occlusive Disease: A Prospective Randomised Trial

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WHAT THIS PAPER ADDS

What is known? Hybrid procedures for co-existing aorto-iliac and common femoral artery occlusive disease (Trans-Atlantic Inter-Society Consensus C, D) are widely recommended without sufficient evidence comparing them with traditional aortofemoral bypass. What is new? This is the first prospective randomised trial comparing hybrid repair (HR) with open reconstruction in long iliofemoral occlusive lesions. The three year results suggest that HR for co-existing aorto-iliac and common femoral artery occlusive disease may be reasonable. What is next? Further randomised trials are needed to facilitate treatment decisions in long iliofemoral occlusive lesions.

Objective: The aim of this non-inferiority randomised trial was to compare the short and midterm safety and efficacy of hybrid repair (HR) and open reconstruction (OR) for patients with co-existing iliac and common femoral artery (CFA) occlusive disease.

Methods: The study was registered on the ClinicalTrials.gov register (identifier: NCT02580084). From 2015 to 2017, eligible patients presenting with combined iliac and CFA occlusive disease were randomised to either HR or OR. HR group patients underwent recanalisation and stenting of iliac arteries combined with CFA endarterectomy and patch angioplasty. The OR group underwent aortofemoral bypass with simultaneous CFA endarterectomy. Short (30 day) and midterm (36 month) outcomes including morbidity, mortality, and patency rates were compared between groups.

Results: Of 427 patients assessed, 202 were randomised (102 HR and 100 OR). The average hospital length of stay was shorter in the HR group (8.2 $\pm$ 4.2 days HR group *vs.* 15.7 $\pm$ 6.9 days OR group, $p < .001$); the 30 day peri-operative morbidity rate was 8.8% in the HR group *vs.* 21% in the OR group ($p = .030$). There was no significant difference in the 36 month mortality rate ($p = .16$). The cumulative primary patency rates were 93% (HR) *vs.* 93% (OR) at 12 months and 91% (HR) *vs.* 89% (OR) at 36 months ($p = .38$). The limb salvage rates were 99% (HR) *vs.* 99% (OR) at 12 months and 98% (HR) *vs.* 97% (OR) at 36 months ($p = .49$).

Conclusion: The results of this first non-inferiority randomised study support the safety and midterm efficacy of hybrid procedures for patients with iliofemoral peripheral arterial disease. HR patients had a shorter length of stay with reduced peri-operative morbidity and similar medium term patency rates.

Keywords: Aortofemoral, Iliac occlusive disease, Hybrid surgery, TASC II type C, D lesions bypass
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INTRODUCTION

The treatment of patients with combined iliac and common femoral artery (CFA) occlusive disease presents a dilemma for vascular surgeons.[1,2] Current guidelines recommend either open surgical reconstruction (OR) or hybrid repair (HR) combining iliac stenting with femoral endarterectomy.[3]

While traditional OR with aorto- or iliofemoral bypass is associated with excellent long term patency results,[4] it is associated with significant peri-operative morbidity with some studies citing mortality rates of up to 4% — 8%.[5—7] Furthermore, OR is associated with significant long term morbidity with 5.8% of aortofemoral bypass patients requiring future ventral hernia repair.[8] HR has, therefore,

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evolved as an attractive minimally invasive alternative to OR with the potential advantages of lower peri-operative morbidity and a shorter hospital stay.[9–11]

However, there are currently no randomised trials comparing both treatment modalities for patients with concomitant iliac and CFA occlusive disease.[12–15] Therefore, the aim of this randomised trial was to compare the short and midterm safety and efficacy of HR and OR procedures for patients with co-existing iliac and common femoral occlusive disease.

MATERIAL AND METHODS

Study design

A prospective single centre randomised trial was performed to compare the short and midterm safety and efficacy of HR and OR procedures for patients with co-existing iliac and CFA occlusive disease.

The study was registered on the ClinicalTrials.gov register (identifier: NCT02580084) and was approved by the Local Ethics Committee of the Siberian Federal Biomedical Research Centre, Ministry for Public Health Care of the Russian Federation. All patients provided informed consent for inclusion into the study.

Sample size calculation

The results of previous cohort studies[1,6,9,15] were used to base a non-inferiority margin of 10% with respect to 30 day combined morbidity and mortality for HR compared with OR. Assuming this, a total of 158 patients (79 per group) would be required to demonstrate statistical significance ($\alpha = 0.05$) at a power of 90%.

As the centre's catchment area incorporates a large area of Russia, it was anticipated that patient follow up could be difficult. Therefore, given the ease of recruitment at the centre, and to account for potential loss to follow up, the sample size was rounded up to 100 per arm (200 total).

Recruitment

From October 2015 to August 2017, adult patients aged 45 – 75 years with chronic limb ischaemia (Rutherford classification categories 2 – 5) caused by combined extensive iliac (Trans-Atlantic Inter-Society Consensus [TASC] II class type C/D disease) and CFA occlusive disease (stenosis $\geq$ 70% or occlusion) were considered potentially eligible for this study. In all cases the cause of the occlusive arterial damage was atherosclerosis. Patients aged 45 – 75 years were included in the study as the average life expectancy in Russia is approximately 75 and it is rare to encounter atherosclerotic disease below the age of 45.

Patients with intermittent claudication (Rutherford stage 2 – 3) were routinely initially offered conservative therapy with best medical therapy and a supervised exercise program prior to surgical intervention.[3,16] Therefore, only patients who had persistent severe symptoms with a subjective reduction in their quality of life following conservative therapy were considered for inclusion in this study.

Inclusion criteria.

1. Concomitant TASC II type C/D iliac segment disease and CFA lesions (occlusion/stenosis $\geq$ 70%).
2. Rutherford classification stage 2 – 5 chronic limb ischaemia.
3. Aged 45 – 75.

Exclusion criteria.

1. Aortic thrombosis, concomitant abdominal aortic or iliac aneurysms, acute limb ischaemia or vasculitis.
2. Refusal to participate in the study.
3. Stroke or myocardial infarction within the past three months.
4. Ischaemic heart disease with New York Heart Association functional class IV.
5. Malignant tumour with an estimated life expectancy of less than six months.
6. Previous ipsilateral or contralateral surgery (bypass, hybrid or stenting).
7. Hepatic or renal insufficiency (bilirubin $>$ 35 mmol/L, glomerular filtration rate $<$ 60 mL/min/1.73 m^2).
8. Severe calcification of the aorta and iliac arteries unsuitable for balloon angioplasty (as determined by the Peripheral Arterial Calcification Scoring System on computed tomography angiography as interpreted by a vascular radiologist):[17] unilateral calcification $\geq$ 5 cm (Grade 2), bilateral calcification $\geq$ 5 cm (Grade 4), or circumferential calcification, defined as 270° – 360° around the circumference of the aorta and/or iliac arteries.

Randomisation

Sealed envelope randomisation was used. Envelopes were sealed by a person independent of the recruiting team. All opaque envelopes were identical and not numbered (to exclude the possibility of marking). Once a patient had consented to enter the trial, an independent clinician provided the research clinicians with the sealed envelope and the patient was randomised to the appropriate group. This was typically performed the day prior to surgery.

In the HR group, all patients had to have undergone endovascular iliac revascularisation with simultaneous common femoral endarterectomy (CFE). Patients in OR group who required aortobifemoral or aortofemoral bypasses were included in this study only if simultaneous CFE was performed.

Outcomes

The primary outcomes included hospital length of stay; 30 day mortality/major adverse cardiac events (MACEs); 30 day morbidity/complication rate (including wound complications); 30 day graft/stent patency rates (evaluated

for the more severely affected limb); 30 day graft infection rates.

The secondary outcomes included 36 month graft infection, mortality, morbidity, graft/stent patency, limb salvage and amputation free survival (AFS) rates.

Operative technique

Before surgical reconstruction all the patients of both groups were investigated with duplex ultrasonography, ankle brachial pressure index (ABI) measurements, and multidetector computed tomographic angiography (MDCT).

In patients allocated to the HR group, local or spinal anaesthesia was used. All OR cases were performed under general anaesthesia. The HR operations were performed in an angiography suite (GE OEC 9900 Elite, USA).

Initially, for the HR group, an attempt was made to obtain retrograde access to the aorta via femoral access and secure aortic inflow before making the arteriotomy. Ipsilateral/contralateral femoral or brachial approaches were used depending on the clinical situation. After recanalisation and balloon angioplasty of the iliac artery, the procedure was completed with endarterectomy of the CFA. Once CFE was performed, the proximal and distal ends were secured with tacking sutures and the femoral artery was closed with standard bovine pericardial patch angioplasty. Subsequent access to the iliac arteries was performed through a central patch puncture with an 18 gauge needle and a 7F sheath was then placed over the wire. CFE was performed prior to iliac stenting because of easier access to the true lumen in a difficult CFA lesion. Primary stenting of common iliac artery lesions (with a severely calcified segment) was carried out with balloon expandable stents (Omnilink Elite, Abbott). Diameters ranged from 8 to 10 mm. Primary stenting of external iliac lesions and some long occlusions was performed with self expanding nitinol stents (PROTEGE™ EverFlex™, EV3; Absolute, Abbott) after iliac recanalisation. The diameters varied between 7 and 9 mm.[15] For long lesions of the external iliac artery, the practice was to extend the treatment zone with percutaneous transluminal angioplasty (PTA) or stenting down to the superior border of the inguinal ligament. Neither high pressure nor cutting balloons were used in the study.

In the OR group, aortofemoral or aortobifemoral bypasses were performed through a retroperitoneal approach with a bifurcated or straight Dacron graft sutured end to side proximally and distally. Concomitant CFE was performed in all patients who underwent OR.

For both groups, profundaplasty was performed when the profunda femoris artery had $>$ 50% stenosis on preoperative computed tomography scan, or at the time of operation if the orifice was not accessible with a 3 mm dilator.

After HRs, aspirin (100 mg per day) and clopidogrel (75 mg per day) were prescribed for six months. After six months, clopidogrel was stopped and long term aspirin (100 mg per day) was recommended. After OR, aspirin monotherapy (100 mg per day) was prescribed for life.

The post-operative follow up visits (at one, 12, 24, and 36 months post-procedure) consisted of physical examination, ABI measurement, and duplex scan of the bypass graft or iliac stent and CFE site. If there was a suspicion of stent, bypass, or CFE restenosis $\geq$ 70% or occlusion, MDCT was performed for further evaluation.

Statistical analysis

The Shapiro—Wilk test was used to verify the normality of the quantitative data distribution. Normally distributed quantitative data are presented as the mean $\pm$ standard deviation, and the non-normally distributed data are presented as a median with a 95% confidence interval (CI). The statistical difference between groups was determined with the Mann—Whitney U test and two sided F test. The Wilcoxon signed rank test was used for the paired intragroup analysis of dependent data and McNemar's test for paired nominal data. ABI before and after surgery (mean and standard deviation) between the two procedures were compared by a two sample *t* test. Kaplan—Meier survival curves for primary patency, primary assisted patency, secondary patency, and the log rank were estimated. A p value $<$ .050 was considered statistically significant. The Cox proportional hazards model was used to assess combined primary and secondary endpoint outcomes between the groups. In order to test non-inferiority for the primary outcome (complications in the 30 day post-operative period) of the HR group compared with the OR group, the 90% two sided CI for the hazard ratio was calculated. Statistical calculations were performed using MedCalc v15.2.2.

RESULTS

Demographics

From October 2015 to August 2017, 427 patients were assessed for randomisation, but 225 patients were excluded, due to concomitant presence of abdominal aortic aneurysm (n = 16), stroke or myocardial infarction within the past three months (n = 18), previous ipsilateral/contralateral bypass or hybrid surgery (n = 46), CFA stenosis $<$ 70% (n = 56), and no consent (n = 89).

Ultimately, 202 patients were included with 102 patients randomised to HR group and 100 to OR group. Atherosclerosis was the cause of occlusive disease in all cases. Figure 1 shows the CONSORT diagram detailing patient flow through the study. Patient demographic and clinical characteristics are shown in Table 1.

In the HR group, technical success was 98% with unsuccessful iliac artery occlusion recanalisation in two (1.9 %) patients. Both cases were managed with successful aortofemoral bypass (these two patients were included in HR group). In these two cases severe calcification (unilateral or bilateral calcification $\leq$ 5 cm; Grade 1 or Grade 3) was noted. No peri-operative complications developed in these two patients during three year follow up.

The mean length of stented segments in the HR group was 78.8 $\pm$ 6.3 mm (range 40 — 150 mm). Kissing stents in the HR group were used in 23 (23%) cases where the

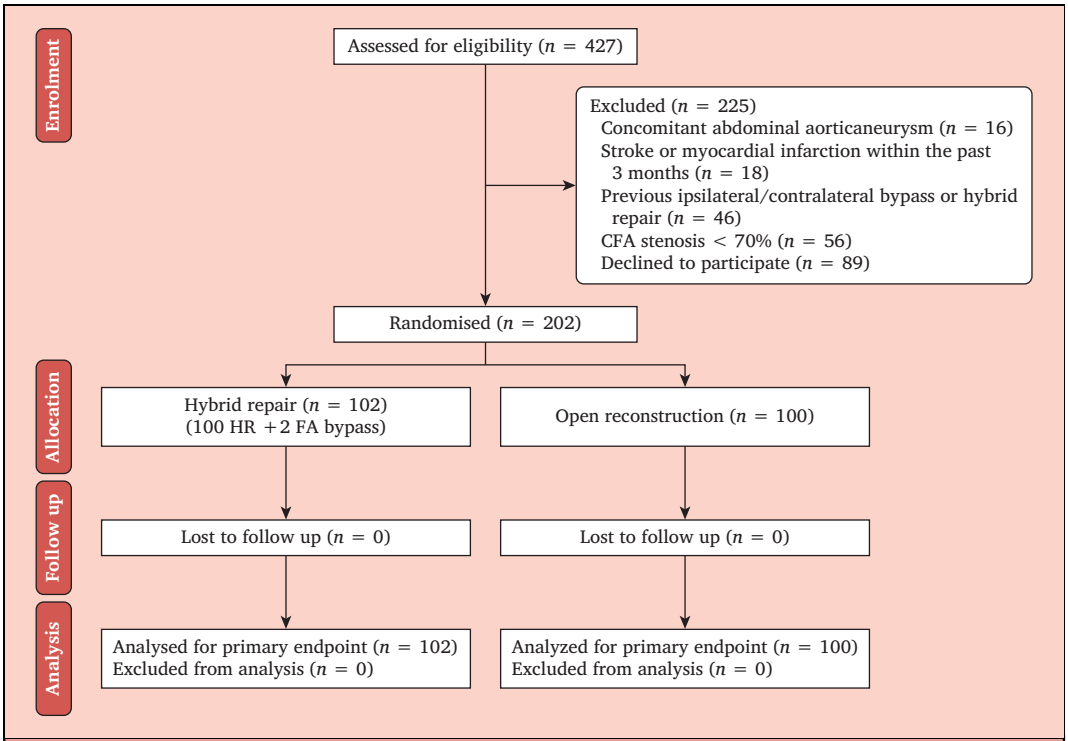

Figure 1. Consolidated Standards of Reporting Trials (CONSORT) study flow diagram detailing patient flow through the randomised trial comparing hybrid repair (HR) and open reconstruction for patients with co-existing iliac and common femoral artery (CFA) occlusive disease.

contralateral side was stenosed $\geq$ 60% (stenosis was diagnosed at surgery, severe calcification made it difficult to accurately assess stenosis on computed tomography angiography before surgery). All 23 cases had bilateral calcification $\leq$ 5 cm (Grade 3).[17]

Aortobifemoral bypass was performed in six (6%) OR group cases. In all six cases severe calcification (bilateral calcification $\leq$ 5 cm; Grade 3) was noted with contralateral iliac artery stenoses $\geq$ 60% (stenosis again diagnosed at surgery). All other HR and OR cases were technically successful.

Profundaplasty was carried out in 31 (30%) HR group cases and 28 (28%) OR patients ($p = .70$). None of these patients developed occlusive complications within 30 days. During the three year follow up, iliac segment restenosis $>$ 70% was determined in 4/31 (12.9%) HR group cases with profundaplasty. During the same period restenosis $>$ 70% of the distal aortofemoral bypass anastomosis was diagnosed in 3/28 (10.7%) cases in the OR group. For both groups, during the three year follow up no profunda femoris artery restenosis $\geq$ 60% was seen so no additional interventions were performed. There was no significant difference in restenosis between groups ($p = .56$). No patients from either group who underwent profundaplasty experienced stent/graft thrombosis.

Primary outcome

The average hospital length of stay was shorter in HR group (8.2 $\pm$ 4.2 days HR group *vs.* 15.7 $\pm$ 6.9 days OR group, $p <$ .010). There were no deaths, and no MACEs in either group within 30 days post-operatively.

Complications in the 30 day post-operative period are shown in Table 2. Overall, 30 day complications occurred in 8.8% of HR and 21.0% of OR cases ($p = .030$). In the HR group, there was one (1%) case of iliac artery perforation during stent pre-dilation which was treated successfully by stent graft implantation (Atrium Advanta V12, MAQUET).

Thirty day stent/graft thrombosis occurred in three (3%) HR group cases and six (6%) OR patients. Surgical thrombectomy was successful in all patients. Post-operative bleeding requiring surgical intervention occurred in one case (1%) in both groups (blood transfusion was not required).

Groin seromas occurred in four (4%) HR and seven (7%) OR patients ($p = .20$), all of whom were obese (body mass index [BMI] $>$ 30). Conservative treatment was performed in all cases (bandaging and local injection of Lipiodol). Superficial groin wound infections were diagnosed in one (1%) HR and one (1%) OR case ($p = .70$). Both cases were Grade 2 according to the Szilagyi classification and Group 2 according to the Samson classification. Both patients were obese (BMI $>$ 30) and required wound debridement with excision of necrotic wound edges. Vascular graft infection was not diagnosed.[18]

Acute renal failure, requiring renal replacement therapy[19] developed in one (1%) OR case ($p = .50$). Five (5%) OR cases developed ventral hernia within 30 days (all of these patients were obese with BMI $>$ 30). No other peri-operative complications developed in either group. Complications in early operative period in both groups are shown in Table 2.

Estimated hazard ratio of combined primary endpoint outcomes between the OR and HR groups was (hazard ratio 2.47; 95% CI 1.13 $-$ 5.40; $p = .020$).

Table 1. Baseline patient demographics and clinical characteristics of 202 patients randomised to hybrid repair (HR) or open reconstruction (OR) for co-existing iliac and common femoral artery occlusive disease in 2015–2017

Characteristics	HR group (n = 102)	OR group (n = 100)	p value
Male	89 (87)	88 (88)	.50
Age − y	62 ± 6.8	60 ± 6.7	.30
Rutherford classification			
Stage 2	28 (27)	27 (27)	
Stage 3	60 (59)	58 (58)	.50
Stage 4	10 (10)	11 (11)	.50
Stage 5	4 (4)	4 (4)	.48
Arterial hypertension	90 (88)	91 (91)	.34
Coronary heart disease	79 (77)	71 (71)	.40
Diabetes mellitus	11 (10)	10 (10)	.51
Obesity	31 (30)	33 (33)	.40
Dyslipidaemia	47 (46)	54 (54)	.26
Smoking history	102 (100)	100 (100)	NA
Ex-smoker, > 20 y	39 (38)	42 (42)	.34
Current smoker	63 (62)	58 (58)	.34
Aortic stenosis < 50%	102 (100)	100 (100)	NA
Iliac artery stenosis			
Ipsilateral stenosis ≥ 70% or occlusion	60 (59) / 42 (41)	58 (58) / 42 (42)	.50
Contralateral stenosis ≤ 60%	102 (100)	100 (100)	NA
Internal iliac artery stenosis			
Ipsilateral stenosis ≥ 70%	24 (23.5)	26 (26)	.68
Ipsilateral occlusion	10 (10)	11 (11)	.78
Contralateral stenosis ≤ 70%	31 (30)	38 (38)	.26
Calcification			
Unilateral calcification < 5 cm, Grade 1	39 (39)	42 (42)	.34
Bilateral calcification < 5 cm, Grade 3	28 (27)	21 (21)	.28
Unilateral calcification ≥ 5 cm, Grade 2	0	0	NA
Bilateral calcification ≥ 5 cm, Grade 4	0	0	NA
Circumferential calcification	0	0	NA
Mean length of ipsilateral iliac segment lesion − mm	131.4 ± 40.2	143.6 ± 36.5	.10
Common femoral artery stenosis			
Ipsilateral stenosis 70–99% or occlusion	62 (61) / 40 (39)	58 (58) / 2 (42)	.40
Contralateral stenosis < 70%	102 (100)	100 (100)	NA
Deep femoral artery stenosis			
Ipsilateral, patent / stenosis 50–99%	62 (61) / 40 (39)	55 (55) / 45 (45)	.25
Contralateral, patent / stenosis < 70%	55 (54) / 47 (46)	59 (59) / 41 (41)	.47
Superficial femoral artery stenosis			
Ipsilateral patent	25 (25)	28(28)	.34
Ipsilateral stenosis 50–99%	41 (40)	37(37)	.38
Ipsilateral occlusion	36 (35)	35(35)	.54
Contralateral patent	68 (67)	71 (71)	.50
Contralateral stenosis 50–99%	19 (18)	15 (15)	.50
Contralateral occlusion	15 (15)	14 (14)	.87

Data are presented as n (%) or mean ± standard deviation. NA = not available.

Secondary outcomes

In this study, no vascular graft infections were diagnosed during three year follow up. Midterm (36 month) post-operative complications and results are shown in Table 3. At 36 month follow up, three (3%) HR patients died (at eight, 12 and 26 months) compared with seven (7%) OR patients (at 9, 11, 12, 15, 18, 21, and 33 months). None of these patients had undergone re-interventions. The causes of death were not associated with the iliac occlusive disease and are detailed in Supplementary Table S1. Myocardial infarction, stroke, and malignancy were determined as causes of death. Figure 2 shows Kaplan–Meier survival curves in both groups (p = .16).

During 36 month follow up stent/graft stenosis ≥ 70% and CFA/distal anastomosis stenosis ≥ 70% were detected in 11 (11%) HR group patients and nine (9%) OR patients (p = .43). Endovascular re-interventions were performed in four cases in the HR group. Hybrid operations (aortofemoral bypass stenting with reconstruction of the distal anastomosis) were carried out in two OR cases.

The cumulative primary patency rates at 12 and 36 months were 93% and 91% in the HR group and 93% and 89% in the OR group, respectively (Fig. 3A, p = .38). Secondary patency rates at 12 and 36 months were 99% and 98% in HR group and 99% and 97% in OR group, respectively (Fig. 3B, p = .58).

Table 2. Complications in the early operative period (30 day follow up) of 202 patients randomised to hybrid repair (HR) or open reconstruction (OR) for co-existing iliac and common femoral artery occlusive disease

Complications	HR group (n = 102)	OR group (n = 100)	p value
Stent/graft thrombosis	3 (3)	6 (6)	.20
Bleeding/haematoma	1 (1)	1 (1)	.70
Groin seroma	4 (4)	7 (7)	.20
Superficial groin wound infections	1 (1)	1 (1)	.70
Acute renal failure	0	1 (1)	.50
Post-operative ventral hernia	0	5 (5)	NA
Myocardial infarction/ stroke/mortality	0	0	NA

Data are presented as n (%). NA = not available.

Table 3. Late post-operative complications (at three year follow up) in 202 patients randomised to hybrid repair (HR) or open reconstruction (OR) for co-existing iliac and common femoral artery occlusive disease

Complications	HR group (n = 102)	OR group (n = 100)	p value
Myocardial infarction	3 (2)	5 (5)	.30
Stroke	0	2 (1.9)	.20
Death	3 (2)	7 (7)	.20
Stenosis > 70 %	11 (11)	9 (9)	.43
Thrombosis	3 (3)	4 (4)	.49
Major amputation	2 (2)	3 (3)	.50

Data are presented as n (%).

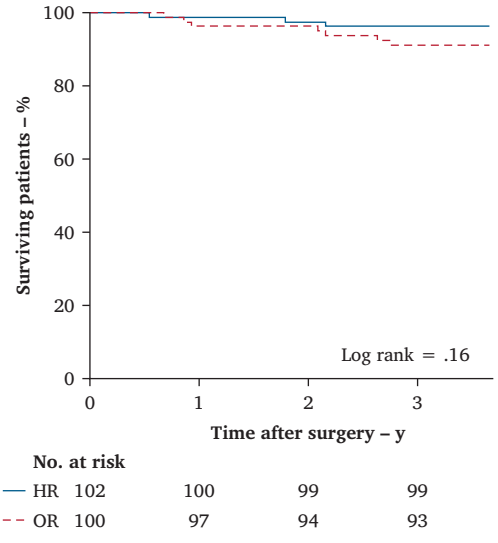

Figure 2. Cumulative Kaplan–Meier estimate of survival of 202 patients randomised to hybrid repair (HR) or open reconstruction (OR) for co-existing iliac and common femoral artery occlusive disease in 2015 – 2017.

While probably an underpowered analysis, the primary patency and secondary patency rates for patients with intermittent claudication (IC, Rutherford stage 2/3) were compared with those with chronic limb threatening ischaemia (CLTI, Rutherford stage 4/5). The primary patency and secondary patency rates at 36 months in the HR group patients with IC *vs.* CLTI were 90% and 94% *vs.* 79% and 90%, respectively. There was no significant difference in the primary patency and secondary patency rates in patients of the HR group (p = .96 and p = .66, respectively). In OR patients, rates were 94% and 95% *vs.* 85% and 90%, respectively. There were no significant differences in the primary and secondary patency rates in the OR patients (p = .27 and p = .13, respectively).

During the three year follow up, major amputations (ipsilateral) were performed in two patients of the HR group (above knee amputation) and three patients in the OR group (one below and two above knee amputations). The limb salvage rates at 12 and 36 months were 99% and 98% in the HR group and 99% and 97% in the OR group, respectively (p = .49).

The AFS and overall survival (OS) for patients with IC (Rutherford stage 2/3) were compared with those with CLTI (Rutherford stage 4/5). There were no significant differences in AFS and overall survival in the HR group patients (p = .14 and p = .38, respectively) but there was a significant difference in these parameters (AFS and overall survival) for OR patients (p < .010 and p = .010, respectively).

There was no significant difference in AFS in the HR cohort when comparing CLTI and IC patients, with three year estimates of 94% and 95%, respectively (p = .14). Similar rates of OS were determined in the HR group between CLTI and IC patients, with three year estimates of 95% and 96%, respectively (p = .040).

AFS in the OR group was lower for patients treated for CLTI compared with IC, with three year estimates of 84% and 93%, respectively (p < .010). The study also demonstrated a significant different of OS in the OR group between CLTI and IC patients, with three year estimates of 89% and 96%, respectively (p = .010).

ABI significantly increased in all the patients after their operations. In the HR group the pre- and post-operative ABIs were 0.33 ± 0.05 and 0.72 ± 0.16 (mean ± standard deviation, ipsilateral), respectively (p < .010). In OR group the pre- and post-operative ABIs were 0.35 ± 0.07 and 0.76 ± 0.13 (ipsilateral), respectively (p < .010). After three years, 29 (29%) patients of the HR group and 27 (30%) patients of the OR group did not complain of claudication (p = .56).

No additional cases of post-operative ventral hernia were diagnosed. During the three year follow up, no ventral hernia repairs were performed in the five patients who developed this complication.

Estimated hazard ratio of combined secondary endpoint outcomes between the OR group and the HR group was (hazard ratio 2.453; 95% CI 0.94-6.39; p = .070). Estimated hazard ratio of the death between OR group and HR group was (hazard ratio 2.57; 95% CI 0.67 – 9.95; p = .17).

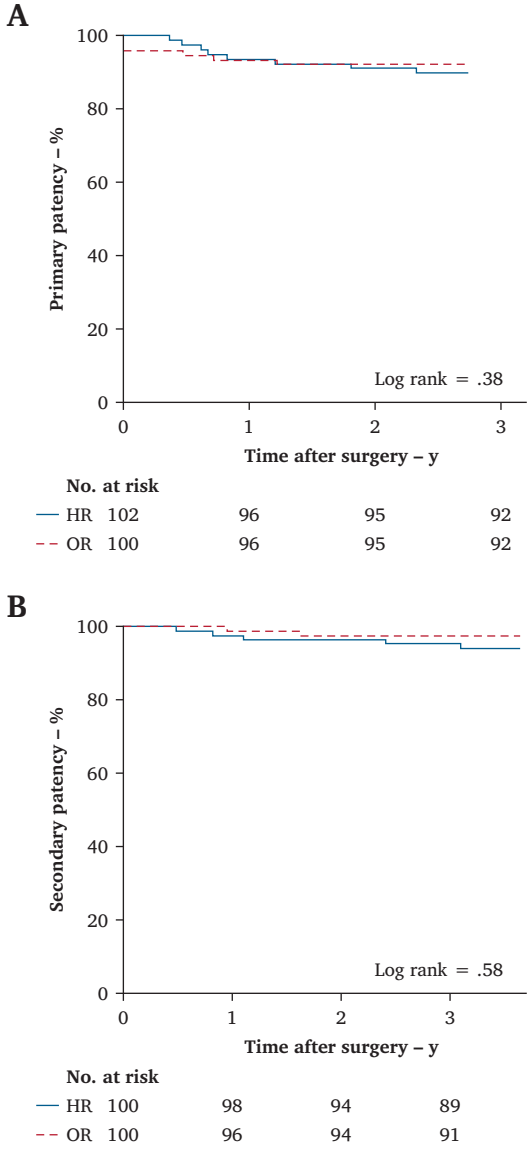

Figure 3. Cumulative Kaplan–Meier estimate of (A) primary patency and (B) secondary patency between 202 patients randomised to hybrid repair (HR) or open reconstruction (OR) for co-existing iliac and common femoral artery occlusive disease in 2015 – 2017.

Late post-operative complications are presented in Table 3. Long term results and the improvement of patient symptoms in three years (as determined by proportions within each Rutherford class) are detailed in Table 4.

Table 4. Long term results and symptom improvement in 202 patients randomised to hybrid repair (HR) or open reconstruction (OR) for co-existing iliac and common femoral artery occlusive disease

Long term results and the improvement of patient symptoms	HR group (n = 102)	OR group (n = 100)	p value
Statin therapy	39 (38)	43 (43)	.29
Smoking rate	58 (57)	49 (49)	.16
*Rutherford classification**			
Stage 0	29 (29)	27 (30)	.56
Stage 1	25 (25)	28 (31)	.26
Stage 2	27 (27)	21 (23)	.30
Stage 3	16 (16)	14 (16)	.51

Data are presented as n (%).
* n = 97 for HR group; n = 90 for OR group.

DISCUSSION

This was a randomised trial to compare HR with OR for patients with combined iliac (TASC C/D) and femoral occlusive disease. It has been demonstrated that HR is associated with a significantly shorter length of hospital stay and lower rates of peri-operative morbidity whilst maintaining patency rates comparable to that of OR up to 36 months.

Traditionally, OR has been deemed the most durable intervention for the treatment of combined aortoiliac and common femoral occlusive disease with excellent long term patency.[4]

However, older age and patient comorbidity are associated with poor outcomes which has driven the search for less invasive interventions over the past few decades. Given the theoretical hazards associated with endovascular CFA stenting,[20] interest in HR has grown.

Furthermore, long term patency data are lacking for HR treated patients. In the trial, the cumulative primary patency rates at 12 and 36 months were 93% and 91% in HR group and 93% and 89% in OR group, respectively (p = .38). These results compare closely to the previous literature which report primary patency rates of 84% – 95% at 36 months in patients with TASC C/D lesions.[6,15] Chang *et al.* reported five year primary, primary assisted, and secondary patency rates of 60%, 97%, and 98%, respectively for HR, suggesting that these patients have a reasonable chance of requiring future re-interventions to maintain patency.[7]

Severity of disease is also likely to have an impact on HR durability. A previous study investigating the treatment of patients with TASC D lesions showed the primary patency rate for HR at 24 months to be only 70%.[12] Therefore, it is possible that OR may represent a more durable option for those with advanced disease.[13] From a clinical severity perspective, the study did not identify any significant differences in primary or secondary patency rates in either group when comparing patients with claudication or CLTI. Previous study of HR has shown claudicants to have better primary patency rates[12] and have identified major tissue loss (Rutherford class 6) as a predictor of decreased long term patency in patients undergoing HR (but not in those undergoing OR).[6] Limb salvage rates at 36 months of 98% were reported in the HR group and 97% in the OR group (p = .49) which compares well with the previous literature.

A major attraction of HR is the potential for improved peri-operative outcomes. Indeed, mean length of hospital stay was significantly shorter in the HR group (almost halved at 8.2 days *vs.* 15.7 days in the OR group, $p < .010$). Furthermore, the 30 day post-operative complication rate was significant lower in the HR group (8.8% *vs.* 21.0%, p = .030).

Interestingly, this mainly seemed to be due to wound complications such as ventral hernia development rather than post-operative medical complications (e.g., pneumonia). Five (5%) patients with obesity in the OR group developed an incisional ventral hernia within 30 days. None of these patients underwent hernia repair during the three year follow up. Previous studies have shown rates of incisional ventral hernia following aortofemoral bypass were 1.8%, 8% and 9.4% at one, five, and 10 years post-operatively.[8]

Previously reported rates of peri-operative morbidity following HR appear to differ considerably with figures ranging from 3% to 22%.[6,7] Interestingly, peri-operative morbidity and mortality following HR is not always lower than that for OR, however, length of stay is consistently shorter.[6]

The sequence and stages of HR are often debated. Some authors recommend initial endovascular stenting followed by a staged surgical repair with an interval of one to two weeks.[21] Alternatively, some surgeons perform the reverse HR sequence with a shorter interval of one to two days.[22] In this study, as many others recommend, one stage HR was performed.[23] The immediate technical success of HR in the study was 98%.

The limitations of this study include the fact that it was a single centre study, which carries an inherent risk of selection bias. No information was collected regarding buttock claudication, impotence, or lower limb neuropathy and no exercise testing was performed pre- or post-operatively. A range of Rutherford classes were included, and the study is underpowered for their subgroup analysis. Surgeons were necessarily unblinded. There was no standardised pre-operative exercise programme. This study did not use any high pressure or cutting balloons and patients with severe calcification intolerant of balloon angioplasty were excluded. Further, the HR group was initially prescribed dual antiplatelet therapy whilst OR group was only prescribed aspirin. Finally, the centre is a large referral centre with many patients from different regions of Russia making thorough follow up difficult. However, all patients were evaluated within the three year follow up. The aim is to conduct a further analysis after five years. The large geographical area also means that patients are kept in hospital for longer periods of time than seen in many other countries.

Conclusions

The results of this first non-inferiority randomised study support the safety and midterm efficacy of hybrid procedures for patients with iliofemoral peripheral artery disease. HR patients demonstrated reduced peri-operative morbidity and similar medium term patency rates.

CONFLICT OF INTEREST STATEMENT AND FUNDING

None.

APPENDIX A. SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejvs.2022.02.002.

REFERENCES

1 Morris-Stiff Gareth, Ogunbiyi Samuel, Winter Richard K, Brown Russell, Lewis Michael H. Aortic replacement in aorto-occlusive disease: an observational study. *BMC Surg* 2008;**8**:19.
2 Baker G, Walied E, Hussein E, Ahmed T. Endovascular management of flush common iliac artery occlusive disease: challenges and solutions. *Int J Angiol* 2017;**26**:20–6.
3 Aboyans V, Ricco J-B, Bartelink M-LEL, Björck M, Brodmann M, Cohnert T, 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.
4 Kakkos SK, Haurani MJ, Shepard AD, Nypaver TJ, Reddy DJ, Weaver MR, et al. Patterns and outcomes of aortofemoral bypass grafting in the era of endovascular interventions. *Eur J Vasc Endovasc Surg* 2011;**42**:658–66.
5 Adam DJ, Beard JD, Cleveland T, Bell J, Bradbury AW, Forbes JF, et al. Bypass versus angioplasty in severe ischaemia of the leg (BASIL): multicentre, randomised controlled trial. *Lancet* 2005;**366**:1925–34.
6 Piazza M, Ricotta JJ, Bower TC, Kalra M, Duncan AA, Cha S, et al. Iliac artery stenting combined with open femoral endarterectomy is as effective as open surgical reconstruction for severe iliac and common femoral occlusive disease. *J Vasc Surg* 2011;**54**:402–11.
7 Chang RW, Goodney PP, Baek JH, Nolan BW, Rzucidlo EM, Powell RJ. Long-term results of combined common femoral endarterectomy and iliac stenting/stent grafting for occlusive disease. *J Vasc Surg* 2008;**48**:362–7.
8 Altieri MS, Yang J, Jones T, Voronina A, Zhang M, Kokkosis A, et al. Incidence of ventral hernia repair after open abdominal aortic aneurysm and open aortofemoral or aortoiliac bypass surgery: an analysis of 17,594 patients in the state of New York. *Am Surg* 2018;**84**:1388–93.
9 Ebaugh JL, Gupta N, Raffetto JD. Single-incision external iliac artery endarterectomy and patch angioplasty. *Ann Vasc Surg* 2011;**25**:1165–9.
10 Dosluoglu HH, Lall P, Harris LM, Dryjski ML. Long-term limb salvage and survival after endovascular and open revascularization for critical limb ischemia after adoption of endovascular-first approach by vascular surgeons. *J Vasc Surg* 2012;**56**:361–71.
11 Leville CD, Kaskyap VS, Clair DG, Bena JF, Lyden SP, Greenberg RK, et al. Endovascular management of iliac artery occlusions: extending treatment to TransAtlantic Inter-Society Consensus class C and D patients. *J Vasc Surg* 2006;**43**:32–9.
12 Nishibe T, Kondo Y, Darkik A, Muto A, Koizumi J, Nishibe M. Hybrid surgical and endovascular therapy in multifocal peripheral TASC D lesions: up to three year follow-up. *J Cardiovasc Surg* 2009;**50**:493–9.
13 Nevelsteen A, Wouters L, Suy R. Aortofemoral Dacron reconstruction for aorto-iliac occlusive disease: a 25 year study. *Eur J Vasc Surg* 1991;**5**:179–86.
14 Soga Y, Iida O, Kawasaki D, Yamauchi Y, Suzuki K, Hirano K, et al. Contemporary outcomes after endovascular treatment for aorto-iliac artery disease. *Circ J* 2012;**76**:2697–704.
15 Starodubtsev V, Karpenko A, Ignatenko P. Hybrid and open surgery of Trans-Atlantic Inter-Society II type C and D iliac occlusive disease and concomitant lesion of common femoral artery. *Int Angiol* 2016;**35**:484–91.
16 Layden J, Michaels J, Bermingham S, Higgins B, Guideline Development Group. Diagnosis and management of lower limb peripheral arterial disease: summary of NICE guidance. *BMJ* 2012;**345**:e4947.
17 Rocha-Singh KJ, Zeller T, Jaff MR. Peripheral arterial calcification: prevalence, mechanism, detection, and clinical implications. *Catheter Cardiovasc Interv* 2014;**83**:E212–20.
18 Chakfé N, Diener H, Lejay A, Assadian O, Berard X, Caillon J, et al. Editor's Choice – European Society for Vascular Surgery (ESVS) 2020 clinical practice guidelines on the management of vascular graft and endograft infections. *Eur J Vasc Endovasc Surg* 2020;**59**:339–84.

19 Khwaja A. KDIGO clinical practice guidelines for acute kidney injury. *Nephron Clin Pract* 2012;**120**:179–84.
20 Azéma L, Davaine JM, Guyomarch B, Chaillou P, Costargent A, Patra P, et al. Endovascular repair of common femoral artery and concomitant arterial lesions. *Eur J Vasc Endovasc Surg* 2011;**41**:787–93.
21 Sinci V, Kalaycioglu S, Halit V, Gökgöz L, Soncul H, Ilgit E, et al. Long-term effects of combined iliac dilatation and distal arterial surgery. *Int Surg* 2000;**85**(l):13–7.
22 Aburahma AF, Robinson PA, Cook CC, Hopkins ES. Selecting patients for combined femorofemoral bypass grafting and iliac balloon angioplasty and tenting for bilateral iliac disease. *J Vasc Surg* 2001;**33**(2). S93–9.
23 Kim Min Su, Joo Yoon Sung, Park Ki Hyuk. Results of simultaneous hybrid operation in multi-level arterial occlusive disease. *J Korean Surg So* 2010;**79**:386–92.

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COUP D'OEIL

Prosthetic Superior Mesenteric Artery Bypass Patent After 32 Years

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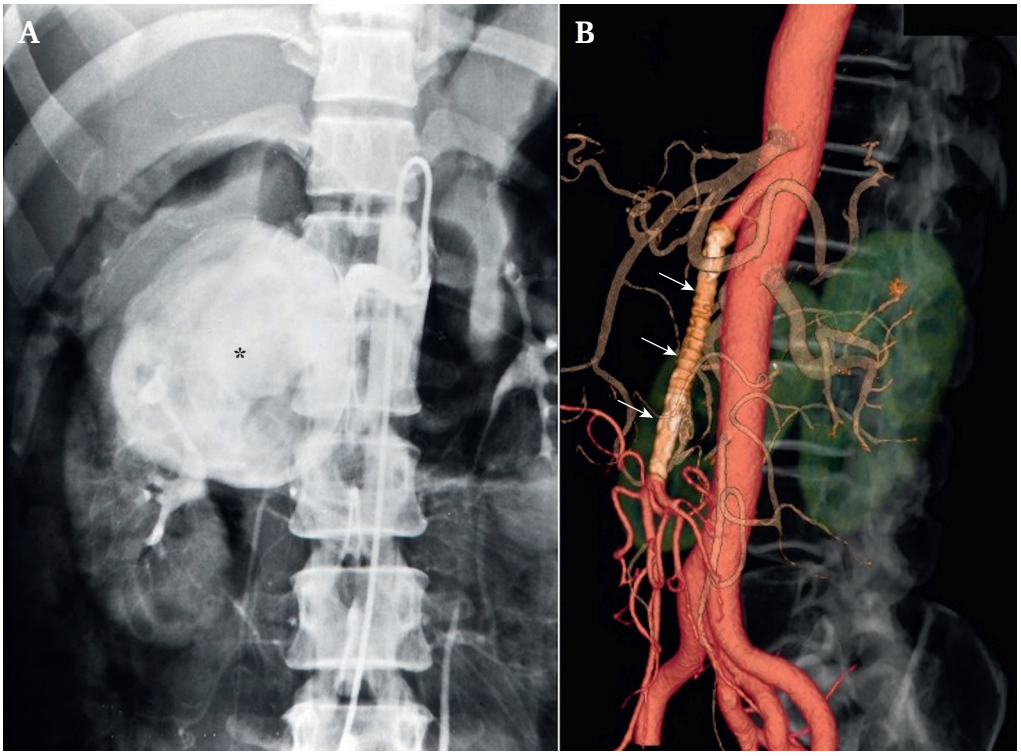

A 37 year old woman with a history of blunt abdominal trauma during childhood complained of epigastric pain. At that time, computed tomography (CT) and selective angiography (A) revealed a 10 cm unruptured aneurysm of the superior mesenteric artery (asterisk; A). The aneurysm was resected and replaced by a great saphenous vein bypass. The colour of the bowel did not improve, so a reinforced 6 mm polytetrafluoroethylene graft was used. Aspirin was discontinued after one year and the patient was lost to follow up. After 32 years, when the patient was 69 years old, the CT scan showed a patent prosthetic bypass (white arrows; B).

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