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Original Article

Long-Term Results of Crossover Bypass for Iliac Atherosclerotic Lesions in the Era of Endovascular Treatment: The Re-ACTION Study (*Re*trospective *A*ssessment of Crossover Bypass as a *T*reatment for *I*liac Lesi*ON*s)

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Objective: The aim of this study was to elucidate the long-term results of crossover bypass (CB) for iliac atherosclerotic lesions in the era of endovascular treatment (EVT).

Methods: A retrospective multicenter cohort study was performed. CB was performed in 242 patients between 2003 and 2014 by vascular surgeons at multiple medical centers in Japan.

Results: Perioperative mortality was 1.7%. Primary patency rates were 86% at 5 years and 82% at 8 years. Univariate analysis showed that critical limb ischemia (Rutherford class 4–6), vein graft, and superficial femoral artery occlusion were significantly associated with low primary patency. In multivariate analysis, only critical limb ischemia influenced primary patency. The secondary patency rate was 87% at both 5 and 8 years. The limb salvage rate was 98% at both 5 and 8 years. The overall survival rates were 71% at 5 years and 49% at 8 years.

Conclusion: The long-term results of CB were good in our study, compared with previous reports. Our results suggest that CB remains an option for the arterial reconstruction in unilateral iliac occlusive disease after EVT failed.

Keywords: peripheral arterial disease, unilateral iliac occlusive disease, crossover bypass, long-term results

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Introduction

Femorofemoral crossover bypass (FFB) is an extra-anatomical bypass procedure recognized as a lower-limb revascularization method for high-risk patients with unilateral iliac artery occlusive disease. The operative survival rate of FFB is acceptable; however, the patency rate of FFB is thought to be lower than that of anatomical aorto-femoral bypass.[1] Therefore, the Trans-Atlantic Inter-Society Consensus II (TASC II) does not recommend FFB as a first-line surgical bypass technique.[1] In recent years, endovascular therapy (EVT) has been the first-line treatment for patients with peripheral arterial disease with iliac lesions. Although surgical revascularization is usually recommended for treatment of TASC II type D iliac lesions, EVT is often performed and its durability is promising.[2,3] With recent progress in surgical skills and instruments, we have performed FFB not only in high-risk patients but also in medium-risk and high-activity claudicant patients. The purpose of this study was to elucidate the long-term results of crossover bypass (CB) for iliac atherosclerotic lesions in the era of EVT. This study (Re-ACTION study: *Re*trospective *A*ssessment of *C*B as a *T*reatment for *I*liac lesi*ON*s) was conducted by peripheral vascular surgeons at multiple institutions in Japan.

Methods

Study population

This is a retrospective cohort study. CB was performed in 242 patients between 2003 and 2014 by vascular surgeons at 16 medical centers. This study was performed in accordance with the Declaration of Helsinki. The indication for CB were critical limb ischemia (CLI; Rutherford class 4–6), severe claudication (Rutherford class 3), and graft infection of previous bypass. Bypass surgery was performed with Dacron, polytetrafluoroethylene (PTFE), or vein grafts. The study included all femorofemoral and iliofemoral CBs and bypasses to the deep femoral artery. Bypass procedures for patients without peripheral arterial disease were excluded.

Measurement methods

The clinical characteristics investigated included age, sex, TASC II classification, Rutherford classification, runoff (patency of superficial femoral artery [SFA]), and co-morbidity (hypertension, diabetes mellitus, dyslipidemia, chronic kidney disease, dialysis dependence, coronary artery disease, and cerebrovascular disease). Operative data were collected retrospectively, including year when CB was performed, graft material, graft size, location of inflow and outflow, graft routing, and adjunctive arterial reconstruction.

Endpoint

The primary outcomes of this study were patency rate, limb salvage rate, and survival rate. Patency, limb salvage, and survival rate were reported in accordance with the Society for Vascular Surgery/International Society for Cardiovascular Surgery Ad Hoc Committee recommended standards for reports dealing with lower extremity ischemia.[4]

Statistical analysis

Data are presented as mean ± standard deviation. Univariate analysis was performed to determine the factors affecting the long-term patency of CB grafts including age, sex, Rutherford classification, graft material, graft size, location of inflow, runoff (patency of SFA), graft routing, and comorbidity. After univariate analysis with the log-rank test, variables with a P-value <0.2 were entered into a Cox's proportional hazard model for multivariate analysis. Statistical significance was defined as P-value <0.05. All statistical analyses were performed with JMP11 Pro software (SAS Institute Japan Ltd.).

Results

Patient characteristics and operative data

Patient characteristics are shown in **Table 1**. The mean follow-up period was 38 ± 32 months (range 1–137, median 32 months). Mean age was 73.2 ± 9.2 years (range 43–95 years, median 74 years). The patients included 186 men (77%) and 56 women (23%). The indications for CB were CLI (Rutherford class 4–6) in 99 patients (41%) and severe claudication (Rutherford class 3) in 143 patients (59%). Among all patients, 11% (27 patients) underwent redo bypass because of an occlusion of the aortobifemoral bypass or CB, or because of graft infection of previous CB. One hundred fifty-four patients (64%) were classified as TASC II type D.

Operative data are shown in **Table 2**. The graft material was PTFE in 183 cases (75%), Dacron in 45 cases (19%), and vein in 14 cases (6%). Graft diameter was 8 mm in

Table 1 Patient characteristics

Age	73.2±9.2 (Median 74)
Male gender	186 (77%)
IC/CLI	143 (59%)/99 (41%)
Hypertension	172 (71%)
Diabetes mellitus	84 (35%)
Dyslipidemia	78 (32%)
Dialysis dependence	28 (12%)
CAD	86 (36%)
CVD	53 (22%)

IC: intermitted claudication; CLI: critical limb ischemia; CAD: coronary arterial disease; CVD: cerebral vascular disease

Table 2 Baseline information about iliac lesion and bypass surgery

Year when bypass was performed	
2003/4/5/6/7/8/9/10/11/12/13/14	7/14/20/24/21/39/23/20/28/24/13/9
TASC II	
A/B/C/D/unknown	4 (2%)/32 (13%)/46 (19%)/154 (64%)/6 (2%)
Graft material	
ePTFE/Dacron/vein	183 (75%)/45 (19%)/14 (6%)
Graft size (ePTFE or Dacron)	
6 mm/7 mm/8 mm	26 (11%)/33 (14%)/170 (70%)
Inflow	
CIA/EIA/CFA/SFA	1 (1%)/100 (41%)/138 (57%)/3 (1%)
Outflow	
EIA/CFA/SFA/DFA	7 (3%)/173 (71%)/29 (12%)/33 (14%)
Route	
Subcutaneous/preperitoneal	119 (49%)/123 (51%)
Adjunctive arterial reconstruction	158 (65%)
Femoral endarterectomy	33 (Ipsilateral 18, Contralateral 12, Bilateral 3)
Fem-Pop bypass	58 (Ipsilateral 35, Contralateral 15, Bilateral 8)
Distal bypass	13 (Ipsilateral 12, Contralateral 1)
EVT for contralateral iliac	44
EVT for ipsilateral femoropopliteal	7
EVT for ipsilateral crural	3

CIA: common iliac artery; EIA: external iliac artery; CFA: common femoral artery; SFA: superficial femoral artery; DFA: deep femoral artery; Fem-Pop bypass: femoropopliteal bypass; EVT: endovascular treatment

170 cases (70%), 7 mm in 33 cases (14%), and 6 mm in 26 cases (11%). The major inflow vessel was the common femoral artery in 138 patients (57%) and the external iliac artery in 100 patients (41%). The outflow vessel was the common femoral artery in 173 patients (71%), the deep femoral artery in 33 patients (14%), and SFA in 29 patients (12%). Forty-two patients (17%) had SFA occlusion in the recipient limb. The graft was routed subcutaneously in 119 cases (49%) and through the preperitoneal space in 123 cases (51%). Adjunctive arterial reconstruction was simultaneously performed in 158 patients (65%), including 58 femoropopliteal bypass procedures (35 in recipient limb, 15 in donor limb, and 8 in bilateral limbs), 44 iliac EVT on the donor side to recover inflow, 33 endarterectomy of the common femoral artery (18 on recepient side, 12 on donor side, and 3 bilaterally), 13 distal bypass procedures (11 on recipient side and 2 on donor side), and 7 femoropopliteal EVT in the recipient limb.

Thirty-day mortality and morbidity

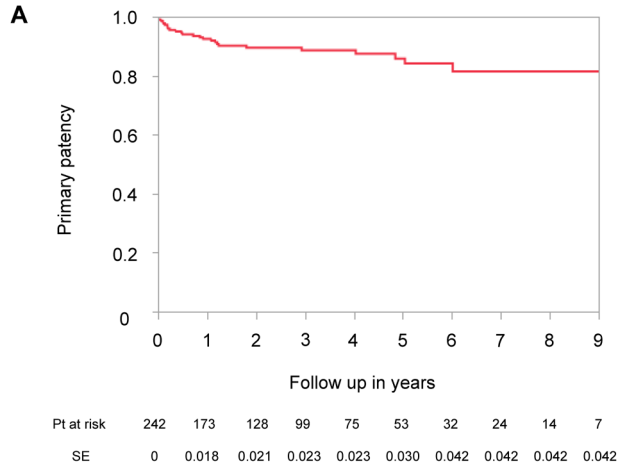
Four patients died within 30 days after surgery because of myocardial infarction (n = 1), sepsis (n = 1), hyperkalemia (n = 1), or aspiration pneumonia (n = 1). The perioperative mortality was 1.7% (4/242). Major complications occurred in six patients: two cases of graft infection, one of unstable angina, one of stroke, one of subarachnoid hemorrhage, and two of gastrointestinal bleeding.

Graft patency, limb salvage, and survival rates

Primary patency rates were 86% at 5 years and 82% at 8 years (**Fig. 1A**). Univariate analysis showed that CLI, vein graft, and SFA occlusion were significantly associated with low primary patency (**Table 3**). Cox's proportional hazard model demonstrated that only CLI influenced primary patency (odds ratio, 3.11; 95% confidence interval, 1.36–7.52; P = 0.007; **Table 3**). The primary patency rates of claudicant patients and CLI patients at 5 years were 93% and 68%, respectively (P = 0.0014). The secondary patency rate was 87% at both 5 and 8 years (**Fig. 1B**). The limb salvage rate was 98% at both 5 and 8 years (**Fig. 2A**). The overall survival rates were 71% at 5 years and 49% at 8 years (**Fig. 2B**).

Discussion

This study revealed better surgical outcomes after CB than previously reported outcomes. Primary patency of CB in our study was better than that in most previous studies, which have reported patency rates of 49% to 82% at 5 years.[5–9] However, those series were reported over 10 years ago; there are few recent data regarding outcomes after CB. Possible reasons for better results in the current study include improvements in surgical skills, graft materials, and antiplatelet therapy. The perioperative mortality was also lower in our study than in previous reports,[5–9] perhaps because of perioperative care including cardiac



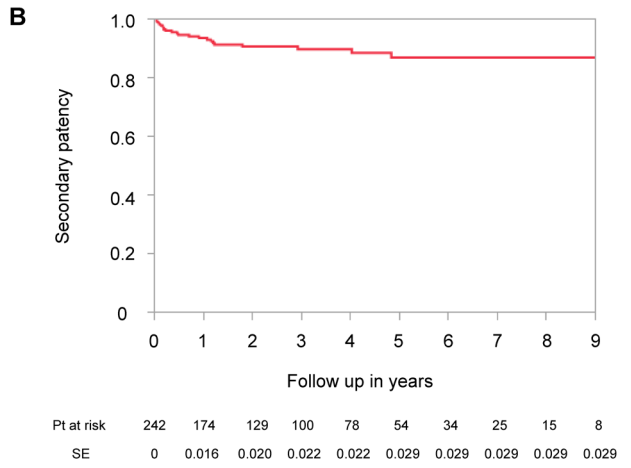
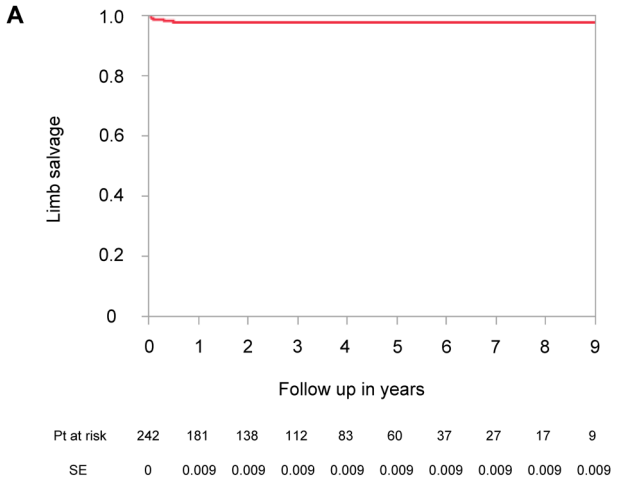


Fig. 1 Patency rate of crossover bypass analyzed according to the Kaplan–Meier method. (**A**) Primary patency. (**B**) Secondary patency.



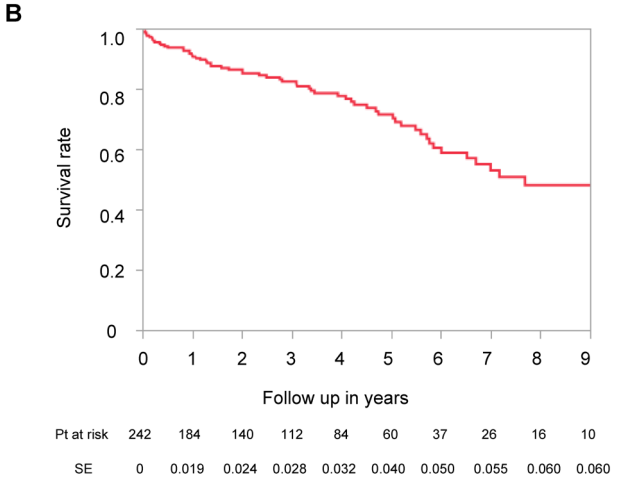


Fig. 2 Limb salvage and survival rate of crossover bypass analyzed according to the Kaplan–Meier method. (**A**) Limb salvage. (**B**) Survival.

risk management and pharmacotherapy (beta-blocker, statin, and antiplatelet usage).[10]

The primary patency rates after CB in our study are comparable with those after EVT for iliac lesions. Reported primary patency rates after EVT for iliac lesions are 64% to 85% at 5 years.[2,11,12] Several authors have reported no difference in long-term patency after iliac EVT for TASC A/B versus TASC C/D lesions[2,11]; however, not all authors agree.[12] Today, EVT is acceptable as a first-line treatment for long iliac occlusive lesions because the procedures is less invasive and has acceptable patency rates compared with bypass surgery. Bypass surgery should be considered to be a next option after failed EVT, and aortofemoral bypass has been a gold standard as bypass surgery for iliac lesions for decades as TASC II mentioned. However, aortofemoral bypass is still much an invasive surgery, and sometimes there is some hesitancy to perform it. Our data revealed satisfactory patency not only at 5 years but also at 8 years after CB. Furthermore, the patency in claudicant patients was over 90% at 5 years, and those results are comparable with those after aortofemoral bypass. CB is much less invasive than aortofemoral bypass. Therefore, our data suggest that CB is an option for not only high-risk patients but also medium-risk patients including older patients and claudicant patients with unilateral TASC C/D lesions after failed EVT, instead of aortofemoral bypass.

Many adjunctive reconstructions were performed in our study, including not only iliac inflow but also common femoral artery or SFA outflow. One reason for the high adjunctive reconstruction rate is that over half of the subjects were CLI patients, who usually have multi-segmental lesions. Simultaneous bypass allows faster arterial reconstructions for multi-segmental lesions. Those adjunctive arterial reconstructions to restore inflow or outflow might have led to better patency of CB in our study. Recently, hybrid surgery combined with EVT is more common for TASC D lesion with the common femoral artery. The number of CB has been decreasing with the development of EVT or hybrid surgery. However, CB would continue

Table 3 Univariate and multivariate analysis of the factors affecting primary patency

	Univariate analysis P-value	Multivariate analysis ORs (95%CI) P-value
Age ≥73	0.334	
Male	0.882	
CLI	**0.001**	**3.11 (1.36–7.52) 0.007**
TASC II D	0.472	
Graft material Vein	**0.015**	2.52 (0.58–7.71) 0.187
Graft size 6 mm	0.187	
Inflow EIA	0.863	
Preperitoneum route	0.202	
SFA occlusion (exclude additional Fem-Pop bypass case)	**0.029**	2.04 (0.57–5.72) 0.244
Hypertension	0.565	
Diabetes mellitus	0.365	
Dyslipidemia	0.317	
Dialysis	0.514	
CAD	0.924	
CVD	0.717	

CLI: critical limb ischemia; EIA: external iliac artery; SFA: superficial femoral artery; Fem-Pop bypass: femoropopliteal bypass; CAD: coronary artery disease; CVD: cerebrovascular disease; OR: odds ratio; CI: confidence interval

remaining as a rescue after EVT or previous bypass failed.

Multivariate analysis revealed that CLI was associated with low graft patency. Several reports also have identified poor patency in patients with CLI or SFA occlusion.[7,8] CLI patients usually have multi-segmental lesions and poor runoff, which might be associated with low patency. Lower patency in CLI patients is a common problem in both surgical bypass and EVT,[7] as in our results. All PTFE grafts used in this study were uncoated grafts. Lindholt et al. reported that patients undergoing femorofemoral or femoropopliteal bypass with heparin-bonded PTFE grafts for CLI were more likely to have a patent graft at 5 years than those with uncoated grafts.[13] SFA occlusion and vein grafts were associated with low patency in univariate analysis. SFA occlusion might be another factor associated with patency. Additional reconstruction for the femoropopliteal region might improve FFB patency. Other papers have reported that 6 mm grafts were associated with patency.[14] However, no significant difference was noted in patency between 6 mm grafts and others in our study. Vein grafts were associated with poor patency in univariate analysis. Over half of patients were undergoing the procedure for previous graft infection or bypass to the deep femoral artery, which may be associated with poor patency.

This study has several limitations. First, it was a retrospective study. A randomized prospective study might be necessary to compare outcomes of FFB with those of EVT or aortofemoral bypass. Second, decisions about operative indication, anastomosis methods, follow-up methods, and antiplatelet medication after surgery depended on the surgeons. Differences in these factors might have influenced FFB patency.

Conclusion

The long-term results of FFB were satisfactory. Our results indicate that FFB remains a valuable option for arterial reconstruction for unilateral iliac occlusive disease after EVT failed.

Disclosure Statement

All authors have no conflict of interest to disclose.

Author Contributions

Study conception: NM, HK
Data collection: all authors
Analysis: NM
Investigation: all authors
Writing: NM
Critical review and revision: all authors
Final approval of the article: all authors
Accountability for all aspects of the work: all authors

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