

Factors associated with long-term graft patency after lower extremity arterial bypasses

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Purpose: This study was conducted to determine factors associated with long-term graft patency after lower extremity arterial bypass (LEAB).

Methods: Database of LEABs for patients with chronic arterial occlusive disease (CAOD) at a single institution was retrospectively reviewed. To determine the factors we compared demographic, clinical, and procedural variables between 2 patient groups; group I (graft patency < 2 years) and group II (graft patency ≥ 5 years after LEAB) using univariable and multivariable analyses.

Results: Among 957 LEABs, 259 limbs (group I, 125 limbs and group II, 134 limbs) in 213 patients were included for the analysis. On a univariable analysis, younger age (69 years vs. 66 years, $P = 0.024$), hypertension (60.8% vs. 74.6%, $P = 0.017$), claudication (51.2% vs. 70.9%, $P = 0.001$), absence of prior intervention (50.4% vs. 73.9%, $P < 0.001$), common femoral artery based bypass (57.6% vs. 70.1%, $P = 0.035$), above-the knee bypass (36.8% vs. 64.2%, $P < 0.001$), postoperative graft salvage procedure (3.2% vs. 14.8%, $P = 0.001$), and statin use (75.2% vs. 88.8, $P = 0.004$) were associated with long-term patency. On a multivariate analysis hypertension (odds ratio [OR], 1.91; $P = 0.038$), claudication (OR, 2.08; $P = 0.032$), no prior intervention (OR, 2.48; $P = 0.001$), vein graft (OR, 4.36; $P = 0.001$), above-the knee bypass (OR, 4.68; $P < 0.001$), and graft salvage procedures (OR, 7.70; $P < 0.001$) were identified as independent factors.

Conclusion: These factors can be considered in decision making before treatment of patients with CAOD. [Ann Surg Treat Res 2021;100(3):175-185]

Key Words: Arterial bypass, Graft patency, Lower extremity, Peripheral arterial disease

INTRODUCTION

Lower extremity arterial bypass (LEAB) has been performed less frequently than in the past since endovascular treatment (EVT) has become more popular in treatment of chronic arterial occlusive disease (CAOD) of the lower extremity (LE) [1]. Though it is known that LEAB carries relatively higher mortality and morbidity rates compared to EVT, a successful LE vein bypass is the most durable treatment option for patients with CAOD [2,3].

In current practice, LEAB is recommended for patients with severe ischemic symptoms, and acceptable surgical risk and who are not suitable for EVT [4,5].

For patients with critical limb ischemia (CLI), it is still elusive which treatment is the best optimal initial therapy between EVT and open surgical treatment. Prospective multicenter trials such as Best endovascular versus best surgical therapy for patients with critical limb ischemia (BEST-CLI) [6] and Bypass versus angioplasty in severe ischaemia of the leg-2 (BASIL-2)

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[7] are now underway to determine the best initial treatment option for those specific groups of patients.

Many clinical studies have been conducted to determine risk factors of graft occlusion, which tested conduit materials, bypass procedures, indications for LEAB, coexisting disease, extent of the arterial lesion, presence of prior surgical or endovascular intervention, etc. [8-11]. Furthermore, we have known that the risk factors for limb loss are not only ischemic condition but also sites of the ischemic wound and presence of foot infection [12].

Though a patent graft cannot guarantee the limb salvage, graft patency still remains as the most important parameter of the successful treatment of the ischemic limb. In this study, we attempted to determine factors associated with long-term patency after LEAB.

METHODS

After being approved by an Institutional Review Board of Samsung Medical Center (No. 2019-11-054-001), a retrospective study was conducted with waiving informed consents from the individual patients.

From the database of all consecutive patients who underwent LEAB at a tertiary referral center from September 2003 to May 2018, LEABs due to CAOD with proven graft patency shorter than 2 years (group I) and longer than 5 years (group II) were included for our comparative study. Fig. 1 shows the scheme of this comparative study.

Graft patency was determined by periodic examinations of duplex ultrasonography (DUS, Philips iU22, Philips Healthcare Solutions, Bothell, WA, USA; GE Logiq E9, GE Medical Systems, Milwaukee, WI, USA) every 3 months during the first postoperative year, and every 6–12 months after then. In cases with unobvious findings of graft patency on DUS, CT angiography or femoral arteriography was performed to determine whether the graft is failing or occluded.

LEAB was performed for patients with CLI or disabling

short distance (usually <3 block distance) claudication which did not respond to conservative treatment. Regarding bypass conduit, autologous vein graft or polytetrafluoroethylene graft was liberally used in the above-the-knee (AK) popliteal bypass in discretion of surgeons. In cases of below-the-knee (BK) arterial bypass, we used vein graft as the first choice. When an ipsilateral great saphenous vein (GSV) was not available, alternative vein grafts, such as opposite GSV, arm veins, short saphenous veins, or spliced vein grafts, were used. In cases with autologous vein graft unavailable, we used a PTFE graft with distal vein cuff in BK arterial bypass.

Postoperatively, we routinely prescribed antiplatelet agents such as aspirin or clopidogrel. Postoperative statin was routinely used since 2014. For a certain period of time during the study, one surgeon in our group routinely used warfarin (134 limbs) after LEAB for the purpose of clinical research.

We compared patient demographics, coexisting medical conditions, risk factors of atherosclerosis, indication for LEAB, past history of arterial intervention in the index limb, procedural details of LEAB, reintervention (either endovascular or open surgical) rate after LEAB (not for an occluded graft but for failing graft), and postoperative medications between the 2 groups with univariable and multivariable analyses. Hypertension was defined as systolic blood pressure > 140 mmHg or diastolic blood pressure > 90 mmHg on at least 2 occasions or current use of antihypertensive agents. Diabetes mellitus was defined as presence of history of diabetes regardless of duration of disease, use of antidiabetic agents, or a fasting blood glucose > 126 mg/dL. Hyperlipidemia was defined as history of dyslipidemia and/or treated by a physician or total serum cholesterol > 200 mg/dL or LDL cholesterol \geq 130 mg/dL or current use of lipid-lowering agent. Coronary artery disease was defined as history of myocardial infarction, angina pectoris or history of percutaneous coronary intervention or coronary artery bypass grafting, and chronic renal insufficiency was defined as serum creatinine > 2.0 mg/dL or on dialysis.

To find any association between postoperative antihy-

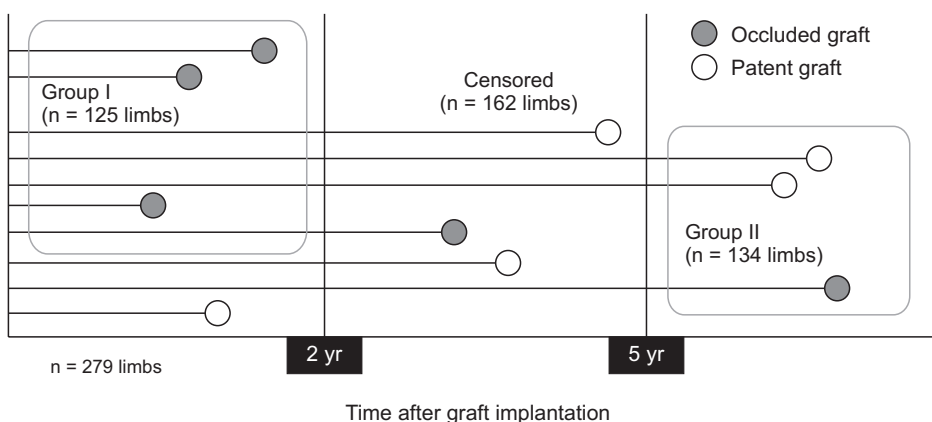


Fig. 1. Scheme of comparative study to determine factors associated with long-term graft patency after lower extremity arterial bypasses.

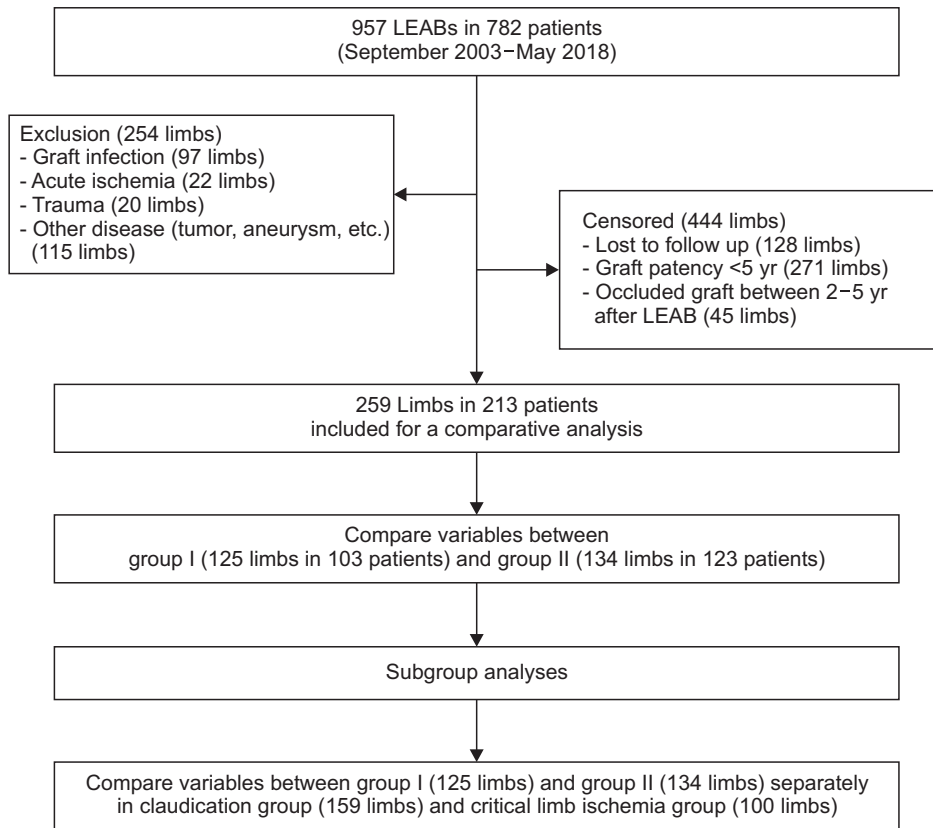


Fig. 2. Patient inclusion for a comparative study. Group I, limbs showed graft occlusion within 2 years after lower extremity arterial bypass (LEAB); group II, limbs showed patent graft for longer than 5 years after LEAB.

Table 1. Comparison of demographic and clinical characteristics between groups

| Characteristic | Group I (125 limbs) | Group II (134 limbs) | P-value |
|------------------------------|---------------------|----------------------|---------------------|
| Age (yr) | 69 (62–73) | 66 (61–72) | 0.024 ^{a)} |
| Male sex | 114 (91.2) | 125 (93.3) | 0.530 ^{b)} |
| Coexisting medical condition | | | |
| Hypertension | 76 (60.8) | 100 (74.6) | 0.017 ^{b)} |
| Diabetes mellitus | 54 (43.2) | 65 (48.5) | 0.392 ^{b)} |
| Hyperlipidemia | 56 (44.8) | 51 (38.1) | 0.272 ^{b)} |
| Coronary artery disease | 37 (29.6) | 37 (27.6) | 0.723 ^{b)} |
| Chronic renal insufficiency | 5 (4.0) | 3 (2.2) | 0.413 ^{b)} |
| Current or ex-smoker | 69 (55.2) | 84 (62.7) | 0.271 ^{b)} |
| Blood test | | | |
| Hyperlipidemia | 23 (18.4) | 36 (26.9) | 0.105 ^{b)} |
| Total cholesterol (mg/dL) | 151.5 (123.0–186.0) | 157 (133.5–186.0) | 0.774 ^{c)} |
| LDL cholesterol (mg/dL) | 94 (69–121) | 102 (80.5–125.5) | 0.767 ^{c)} |
| hs-CRP (mg/dL) | 0.32 (0.12–1.93) | 0.27 (0.07–1.08) | 0.797 ^{c)} |
| Serum creatinine (mg/dL) | 0.94 (0.84–1.20) | 0.96 (0.85–1.12) | 0.980 ^{c)} |
| Indications for LEAB | | | |
| Claudication | 64 (51.2) | 95 (70.9) | 0.001 ^{b)} |
| CLI | 61 (48.8) | 39 (29.1) | |
| Rest pain | 22 | 8 | |
| Ischemic tissue loss | 39 | 31 | |
| Foot infection | 13 (10.4) | 14 (10.4) | 0.993 ^{b)} |

Values are presented as median (interquartile range), number (%), or number only.

Group I, limbs showed graft occlusion within 2 years after graft implantation; group II, limbs showed patent graft for 5 years or longer after graft implantation.

hs-CRP, high-sensitivity CRP; LEAB, lower extremity arterial bypass; CLI, critical limb ischemia.

^{a)}Independent t-test, ^{b)}chi-square test, ^{c)}Bonferroni test.

pertensive medication and long-term graft patency, we investigated postoperative prescribed antihypertensive agents and compared graft patency according to their acting mechanisms of the antihypertensive agents.

After the multivariable analyses to determine factors associated with long-term graft patency, additional subgroup analysis was performed in claudication and CLI group, separately.

For univariable analysis, numeric data were compared with the independent t-test and categorical data were compared with the chi-square test. Multiple hypothesis was corrected with Bonferroni method. Multivariable analysis was conducted

with a logistic regression model using variables showed $P < 0.2$ on the univariable analysis and previously reported variables related to graft patency. Additionally, Kaplan-Meier survival curve and log-rank test were used to confirm the multivariable analysis. IBM SPSS Statistics ver. 22 (IBM Corp., Armonk, NY, USA) was used for statistic support.

RESULTS

Over the past 13 years, 957 LEABs were performed in 782 patients (mean age, 63.7 years; male, 85.8%) at a single institution. After excluding LEABs due to non-atherosclerotic

Table 2. Comparison of bypass procedures between groups

| Procedure | Group I (125 limbs) | Group II (134 limbs) | P-value |
|--|---------------------|----------------------|----------------------|
| Prior intervention at the index limb | 62 (49.6) | 35 (26.1) | <0.001 ^{a)} |
| Bypass surgery | 42 (67.7) | 17 (48.6) | |
| Endovascular treatment | 15 (24.2) | 17 (48.6) | |
| PTA | 6 | 4 | |
| Stenting | 9 | 13 | |
| Both | 5 (8.1) | 1 (2.9) | |
| Inflow artery procedure | 44 (35.2) | 39 (29.1) | 0.294 ^{a)} |
| Bypass | 29 | 24 | |
| PTA/stenting | 15 | 15 | |
| Bypass conduit | | | 0.165 ^{a)} |
| Autologous vein | 62 (49.6) | 78 (58.2) | |
| Reversed vein graft | 51 | 77 | |
| Ipsilateral GSV | 40 | 69 | |
| Contralateral GSV | 4 | 5 | |
| Arm vein conduit | 3 | 0 | |
| Spliced vein graft | 4 | 3 | |
| <i>In situ</i> bypass | 11 | 2 | |
| PTFE graft | 63 (50.4) | 56 (41.8) | |
| PTFE graft with distal vein cuff | 7 | 0 | |
| Level of proximal anastomosis | | | 0.035 ^{a)} |
| CFA | 72 (57.6) | 94 (70.1) | |
| Other than CFA | 53 (42.4) | 40 (29.9) | |
| DFA | 13 | 10 | |
| SFA | 17 | 12 | |
| AK popliteal | 4 | 4 | |
| BK popliteal | 3 | 7 | |
| Level of distal anastomosis | | | <0.001 ^{a)} |
| AK popliteal | 46 (36.8) | 86 (64.2) | |
| BK popliteal | 26 (20.8) | 21 (15.7) | |
| Infrapopliteal artery | 53 (42.4) | 27 (20.1) | |
| Graft salvage procedure to treat failing graft | 4 (3.2) | 20 (14.9) | 0.001 ^{a)} |
| Endovascular treatment | 1 | 10 | |
| Surgical treatment | 3 | 10 | |

Values are presented as number (%) or number only.

Group I, limbs showed graft occlusion within 2 years after graft implantation; group II, limbs showed patent graft for 5 years or longer after graft implantation.

PTA, percutaneous transluminal angioplasty; PTFE, polytetrafluoroethylene; GSV, great saphenous vein; CFA, common femoral artery; DFA, deep femoral artery; SFA, superficial femoral artery; AK, above-the-knee; BK, below-the-knee.

^{a)}Chi-square test.

Table 3. Comparison of postoperative medication between groups

| Postoperative medication | Group I (125 limbs) | Group II (134 limbs) | P-value |
|-------------------------------------|---------------------|----------------------|---------------------|
| Single antiplatelet therapy | 24 (19.2) | 21 (15.7) | 0.454 ^{a)} |
| Dual antiplatelet therapy | 97 (77.6) | 110 (82.1) | 0.367 ^{a)} |
| Warfarin | 70 (56.0) | 64 (47.8) | 0.185 ^{a)} |
| Statin medication | 94 (75.2) | 119 (88.8) | 0.004 ^{a)} |
| Antihypertensive drug ^{c)} | 76 (60.8) | 100 (74.6) | 0.017 ^{a)} |
| ACE inhibitor | 5 (6.6) | 9 (9.0) | 0.557 ^{b)} |
| ARB | 35 (46.1) | 49 (49.0) | 0.698 ^{b)} |
| CCB | 37 (48.7) | 59 (59.0) | 0.173 ^{b)} |
| BB | 27 (35.5) | 29 (29.0) | 0.357 ^{b)} |
| Diuretics | 18 (23.7) | 36 (36.0) | 0.079 ^{b)} |

Values are presented as number (%).

Group I, limbs showed graft occlusion within 2 years after graft implantation; group II, limbs showed patent graft for 5 years or longer after graft implantation.

ACE, angiotensin converting enzyme; ARB, angiotensin II receptor blocker; CCB, calcium channel blocker; BB, beta-blocker.

^{a)}Chi-square test, ^{b)}Bonferroni test; ^{c)}76 limbs for group I and 100 limbs for group II were investigated.

causes (254 limbs), and censoring limbs lost to follow up (127 limbs), grafts maintaining patency for less than 2 years (154 limbs), and patent grafts for 2–5 years after LEAB (167 limbs), 259 limbs in 213 patients (mean age, 67 years; male, 91.2%, CLI, 38.6%; diabetes mellitus, 46.0%; redo bypass, 8.1%) were included for the analysis (Fig. 2). Group I and II was 125 limbs and 134 limbs and mean duration of follow-up was 55.35 ± 7.92 months and 106.06 ± 5.77 months, respectively.

When patient characteristics were compared between the 2 groups, group II patients were younger (median, 69 years vs. 66 years; $P = 0.024$), more frequently hypertensive (60.8% vs. 74.6%, $P = 0.017$) compared to group I patients (short-term graft patency). Group II had more limbs with claudication as an indication for LEAB (51.2% vs. 70.9%, $P = 0.001$); however, no significant differences were found in frequencies of other comorbidities or blood test results (Table 1).

When we compared procedural details of the LEABs between the groups, group II patients had less frequent history of prior arterial intervention (49.6% vs. 26.1%, $P < 0.001$), had more frequent common femoral artery (CFA) origin bypass (57.6% vs. 70.1%, $P = 0.035$), AK bypass (36.8% vs. 64.2%, $P < 0.001$) and more common graft salvage procedures (3.2% vs. 14.9%, $P = 0.001$) after LEABs (Table 2).

When we compared postoperative medications between the groups, use of statins was more common in group II than group I (75.2% vs. 88.8%, $P = 0.004$) (Table 3).

After seeing that hypertension was more frequently associated with group II, we conducted a subgroup analysis with antihypertensive agents according to their action mechanisms to find which antihypertensive agent(s) is (are) associated with long-term graft patency. However, no significant difference between antihypertensive agents was found (Table 3).

After conducting a subgroup univariable analysis in claudi-

cation and CLI groups (Table 4), we performed multivariable analysis with whole patients and a subgroup analysis in claudication and CLI groups, separately.

On a multivariable analysis, hypertension (odds ratio [OR], 1.91; 95% confidence interval [CI], 1.02–3.60; $P = 0.038$), claudication (OR, 2.08; 95% CI, 1.09–3.98; $P = 0.032$), no prior intervention (OR, 2.48; 95% CI, 1.33–4.63; $P = 0.001$), vein graft (OR, 4.36; 95% CI, 1.75–10.87; $P = 0.001$), AK bypass (OR, 4.68; 95% CI, 2.07–10.60; $P < 0.001$), and postoperative graft salvage procedures (OR, 7.70; 95% CI, 2.24–26.49; $P < 0.001$) were identified as independent factors associated with long-term graft patency (Table 5). Kaplan-Meier survival curve and log-rank test were shown in Fig. 3

When we conducted a multivariable analysis separately in claudication and CLI patient groups, no prior intervention, vein graft, AK bypass, and graft salvage procedure were associated with long-term graft patency in the claudication group, while hypertension, vein graft, graft salvage procedure, and low high-sensitivity (hs)-CRP was associated with long-term graft patency in the CLI group (Table 6). The common factors in both claudication and CLI groups were vein graft and postoperative graft salvage procedure. When blood hs-CRP level was analyzed as a continuous variable, increased level of hs-CRP was associated with decrease in frequency of long-term patency patients (18.5% decrease per 0.01 mg/dL increase of hs-CRP) only in the CLI limbs, not in claudication limbs.

DISCUSSION

For the treatment of CAOD of the LE, use of EVT has increased due to its merit of less invasiveness, lower morbidity and mortality compared to LEAB [13,14]. However, many patients require LEAB as a primary treatment due to unfavorable

Table 4. Univariable analysis for the factors associated with long-term graft patency in claudication and CLI patient groups

| Variable | Group I | Group II | P-value |
|--|-----------------|---------------|----------------------|
| Claudication group (159 limbs) | | | |
| No. of limbs | 64 | 95 | |
| Hypertension | 39 (60.9) | 68 (71.6) | 0.161 ^{a)} |
| Blood test | | | |
| Total cholesterol (mg/dL) | 147.5 (116–187) | 161 (138–196) | 0.033 ^{b)} |
| LDL cholesterol (mg/dL) | 91 (61–111) | 108 (80–138) | 0.012 ^{b)} |
| Prior intervention on the index artery | 35 (54.7) | 29 (30.5) | <0.001 ^{a)} |
| Bypass | 28 | 15 | |
| Endovascular treatment | 10 | 15 | |
| Conduit | | | |
| Autologous vein graft | 27 (42.2) | 57 (60.0) | 0.030 ^{a)} |
| PTFE graft | 37 (57.8) | 56 (40.0) | |
| Level of proximal anastomosis | | | |
| CFA | 40 (62.5) | 72 (75.8) | 0.068 ^{a)} |
| Other than CFA | 24 (37.5) | 23 (24.2) | |
| Level of distal anastomosis | | | |
| AK popliteal | 33 (51.6) | 69 (72.6) | 0.031 ^{a)} |
| BK popliteal | 15 (23.4) | 13 (13.7) | |
| Distal artery | 16 (25.0) | 13 (13.7) | |
| Graft salvage procedure | 2 (3.1) | 13 (13.7) | 0.032 ^{a)} |
| Postoperative warfarin | 40 (62.5) | 42 (44.2) | 0.019 ^{a)} |
| Postoperative statin | 54 (84.4) | 86 (90.5) | 0.242 ^{a)} |
| CLI group (100 limbs) | | | |
| No. of limbs | 61 | 39 | |
| Hypertension | 37 (60.7) | 32 (82.1) | 0.023 ^{a)} |
| Prior intervention of the index artery | 27 (44.3) | 6 (15.4) | <0.001 ^{a)} |
| Bypass surgery | 19 | 3 | |
| Endovascular treatment | 10 | 3 | |
| Graft type | | | |
| Autologous vein | 35 (57.4) | 21 (53.8) | 0.732 ^{a)} |
| PTFE graft | 26 (42.6) | 18 (46.2) | |
| Level of proximal anastomosis | | | |
| CFA | 32 (52.5) | 22 (56.4) | 0.701 ^{a)} |
| Other than CFA | 29 (47.5) | 17 (43.6) | |
| Level of distal anastomosis | | | |
| AK popliteal | 13 (21.3) | 17 (43.6) | 0.026 ^{a)} |
| BK popliteal | 11 (18.0) | 8 (20.5) | |
| Distal artery | 37 (60.7) | 14 (35.9) | |
| Graft salvage procedure | 2 (3.3) | 7 (17.9) | 0.034 ^{a)} |
| Postoperative statin | 40 (65.6) | 33 (84.6) | 0.041 ^{a)} |

Values are presented as number only, number (%), median (interquartile range).

Group I, limbs showed graft occlusion within 2 years after graft implantation; group II, limbs showed patent graft for 5 years or longer after graft implantation.

CLI, critical limb ischemia; PTFE, polytetrafluoroethylene; CFA, common femoral artery; AK, above-the-knee; BK, below-the-knee.

^{a)}Chi-square test, ^{b)}Bonferroni test.

anatomy for an EVT or the secondary treatment options after failures of EVT [15].

According to the practice guidelines [16] for the treatment of CAOD of the LE, EVT is recommended as an initial treatment hoping that it does not adversely affect the results of open surgery that will be performed later. There are increasing reports showing adverse effects of prior EVT on the results of

later LEAB [5,17].

For assessment of treatment results after LE arterial revascularization, various objective and subjective endpoints have been used, including patency of the treated artery or bypass graft, healing rates of the ischemic wound, limb salvage, walking ability, ankle brachial index, absence of target limb revascularization, reintervention rate, cost, treatment-related

Table 5. Multivariable analysis^{a)} for the factors associated with long-term graft patency

| Variable | Reference | OR (95% CI) | P-value |
|-------------------------|--------------------------------|-------------------|---------|
| Age < 80 yr | Age ≥ 80 yr | 2.83 (0.67–11.90) | 0.163 |
| Hypertension | Normotension | 1.91 (1.02–3.60) | 0.038 |
| Claudication | Critical limb ischemia | 2.08 (1.09–3.98) | 0.032 |
| No prior intervention | Prior target limb intervention | 2.48 (1.33–4.63) | 0.001 |
| Vein graft | Prosthetic graft | 4.36 (1.75–10.87) | 0.001 |
| AK arterial bypass | BK or distal arterial bypass | 4.68 (2.06–10.60) | <0.001 |
| Graft salvage procedure | No graft salvage procedure | 7.70 (2.24–26.49) | <0.001 |
| Postoperative warfarin | No warfarin | 1.00 (0.49–2.03) | 0.976 |
| Postoperative statin | No statin | 2.28 (0.99–5.22) | 0.053 |

OR, odds ratio; CI, confidence interval; AK, above-the-knee; BK, below-the-knee.

^{a)}Logistic regression model.

morbidity and mortality, etc. [12,18-22].

In the past, outcomes of EVT were often assessed with procedural success and a relatively short-term efficacy of the treatment [2,18,19,23]. Though there have been improvements in the results of EVT [24] it is still incomparable to that of successful LEAB, particularly in the long-term results.

According to systematic reviews and meta-analyses regarding bypass surgery vs. endovascular interventions in severe or CLI, bypass surgery and endovascular approach may have similar effect on mortality and major amputations. However, better primary and primary assisted patency can be expected with open surgery though quality of evidence was low due to imprecision and heterogeneity [10,25].

A prospective study, the BASIL trial, recommended LEAB rather than EVT as an initial treatment for patients with severe leg ischemia and life expectancy longer than 2 years [26]. Some other studies also suggested LEAB as the first-line treatment option when long-term efficacy is required [27,28]. Additionally, Global Vascular Guidelines on the Management of Chronic Limb-Threatening Ischemia warned that nonselective endovascular-first approach carries some risk of both clinically ineffective and cost-ineffective treatment and potential for harm [16].

If we can select an optimal patient group considering risk and benefits of the EVT and LEAB, we can avoid unnecessary intervention or extra-cost and reduce the treatment-related complications. Under the assumption that there is suitable patients group for LEAB, we attempted to determine factors associated with long-term graft patency after LEAB.

For a comparative analysis, we arbitrarily defined a long-term patency as limbs with graft patency of ≥5 years after LEAB regardless of current patency and a short-term patency group as limb with graft patency of <2 years after LEAB. When we defined short-term patency group as <2 years of graft patency, we tried to keep an influence of technical failure to be minimal in our comparative study. Patient characteristics, procedural details, and postoperative management were compared

between the 2 patient groups.

On univariable analysis, younger age, hypertension, claudication as indication for surgery, no prior history of arterial intervention in the index limb, CFA origin bypass, postoperative graft salvage procedure, and statin use were more common in the long-term patency group. On multivariable analysis, presence of hypertension, claudication as an indication for LEAB, no prior arterial intervention, vein graft, AK bypass, and postoperative graft salvage procedure were identified as independent factors associated with long-term graft patency.

Among those factors, use of autologous vein graft, claudication as an indication for LEAB, short graft (AK bypass), and graft salvage procedure are well-known factors for long-term graft patency. Multivariable analysis showed that hypertension (vs. normotension) was independent factor associated with long-term graft patency after LEAB.

Regarding hypertension as a protective factor on graft patency after LEAB, the mechanism is not well known. In our previous study with crossover femoro-femoral bypass with prosthetic graft, we found that hypertension acted as a protective factor on graft occlusion [29]. To determine any class effect of antihypertensive agent on the graft patency, we conducted a subgroup analysis with patients who prescribed antihypertensive agent after LEAB according to the action mechanisms of the antihypertensive agents. Among 176 limbs of them, we found no significant relationship between specific antihypertensive agent and graft patency. Further investigations are recommended to reveal the mechanism of the beneficial effects of hypertension or antihypertensive agent on the graft patency.

In comparison of postoperative medications between 2 groups, statin prescription was more common in long patency group whereas there was no differences in antithrombotic medications.

Regarding the effect of prior intervention on the late LEAB, a recent systemic review warned the adverse effect of EVT on the results of the late LEAB [30]. Similarly, prior intervention was

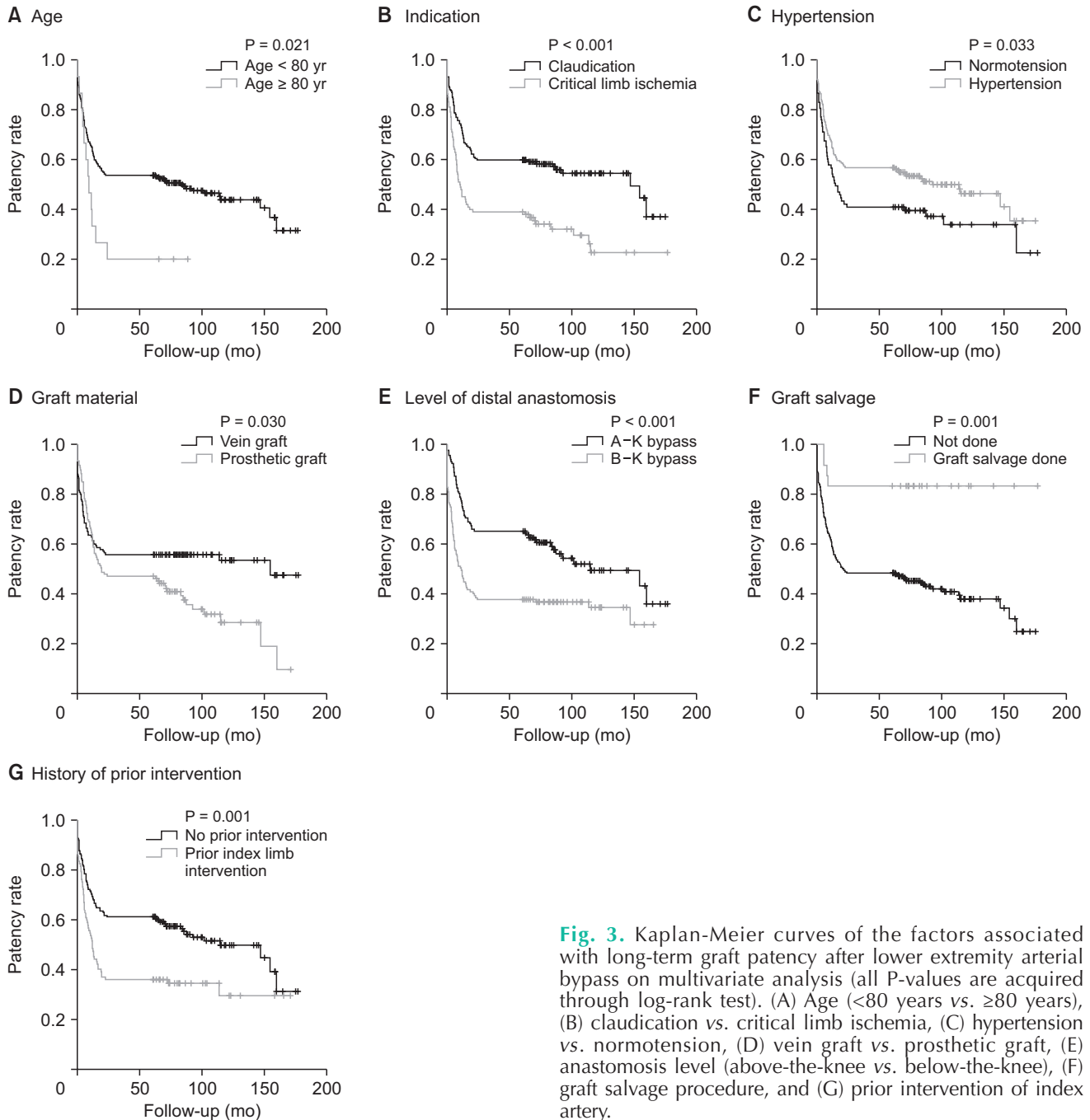


Fig. 3. Kaplan-Meier curves of the factors associated with long-term graft patency after lower extremity arterial bypass on multivariate analysis (all P-values are acquired through log-rank test). (A) Age (<80 years vs. ≥80 years), (B) claudication vs. critical limb ischemia, (C) hypertension vs. normotension, (D) vein graft vs. prosthetic graft, (E) anastomosis level (above-the-knee vs. below-the-knee), (F) graft salvage procedure, and (G) prior intervention of index artery.

an independent factor associated with early graft occlusion in our study.

Postoperative graft salvage procedure to treat failing grafts was associated with long-term graft patency whether it was endovascular or surgical intervention. We assumed that there may be some bias regarding postoperative graft salvage procedure because most failing grafts were vein grafts. And it is easy to anticipate that a successful graft salvage procedure can improve graft patency.

From the results of current study, we found that long-term

graft patency can be expected for patients with claudication, use of autologous vein conduit, AK bypass, presence of hypertension, and no prior history of arterial intervention in the index limb.

Our study has some limitations due to its retrospective design and arbitrary grouping of patients for the comparison. We thought further investigation is required to confirm the association between hypertension and graft patency.

In conclusion, we have experienced that LEAB is still a recommendable treatment option for a selected group of

Table 6. Subgroup analysis^{a)} for the factors associated with long-term graft patency in claudication and critical limb ischemia patients

| Variable | Reference | OR (95% CI) | P-value |
|--|-------------------------------|---------------------|---------|
| Claudication group (159 limbs) | | | |
| Age < 80 yr | Age ≥ 80 years | 2.91 (0.41–20.62) | 0.292 |
| No prior intervention | Prior index limb intervention | 2.21 (1.05–4.67) | 0.043 |
| Vein graft | Prosthetic graft | 6.12 (2.33–16.13) | 0.007 |
| AK arterial bypass | BK or distal arterial bypass | 6.60 (2.38–18.27) | <0.001 |
| Graft salvage procedure | No graft salvage procedure | 8.13 (1.55–42.59) | 0.012 |
| Postoperative statin | No statin use | 2.24 (0.41–20.62) | 0.294 |
| Critical limb ischemia group (100 limbs) | | | |
| Hypertension | Normotension | 5.13 (1.17–22.51) | 0.027 |
| No diabetes | Diabetes mellitus | 0.47 (0.15–1.48) | 0.192 |
| No prior intervention | Prior index limb intervention | 2.39 (0.62–9.23) | 0.173 |
| Vein graft | Prosthetic graft | 2.04 (0.35–11.96) | 0.001 |
| AK popliteal bypass | BK popliteal or distal bypass | 2.63 (0.43–16.21) | 0.482 |
| Graft salvage procedure | No graft salvage procedure | 21.12 (1.95–229.15) | 0.014 |
| Postoperative statin | No statin use | 1.19 (0.26–5.45) | 0.945 |
| Low hs-CRP | High hs-CRP | 0.82 (0.68–0.97) | 0.032 |

OR, odds ratio; CI, confidence interval; AK, above-the-knee; BK, below-the-knee; hs-CRP, high-sensitivity CRP.

^{a)}Logistic regression model.

patients. In decision making for the treatment of CAOD patients requiring long-term graft patency, above-described factors can be considered.

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Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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