Impact of foot arch status on the outcome of infra-popliteal bypasses in critical limb ischemia patients with tissue loss

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Objective

This study evaluates the effect of arterial pedal arch quality on patency rates, freedom from major amputation, and wound healing in patients with critical limb ischemia (CLI) with tissue loss undergoing distal bypasses.

Materials and methods

A retrospective analysis of prospectively collected data of all patients with CLI with tissue loss who underwent distal bypass between 2017 and 2021 at a single institution was done. Post-bypass pedal angiography was performed to classify patients according to the foot arch status into three groups: complete pedal arch (CPA), incomplete pedal arch (IPA), and no pedal arch (NPA). Patency, amputation-free survival, patient survival, and wound healing rates are assessed at 1-year follow-up and compared among the three groups.

Results

A total of 88 patients had infrapopliteal bypasses (62 male; mean age, 74±9; hypertension, 85%; diabetes mellitus, 76%; smoking, 78%; and dyslipidemia, 71%). Overall, 49% of the distal bypasses originated from the popliteal artery, 31% from the superficial femoral artery, and 20% from the common femoral artery. The most common outflow artery was the anterior tibial artery (39%) followed by the posterior tibial artery (36%).

At 1-year follow-up, primary patency rates in the CPA, IPA, and NPA groups were 62, 53, and 45%, respectively (P=0.41). Assisted primary patency rates were 91, 76, and 83%, respectively (P=0.424). Secondary patency rates are 100, 88, and 83%, respectively (P=0.193). Overall patient survival at the end of the follow-up period was 81%. There was a statistically significant difference in terms of 12-month amputation-free survival among the three groups (CPA 100% vs. IPA 98% vs. NPA 83%, P=0.015). Moreover, a statistically significant difference existed in wound healing rates between the study groups (CPA 81% vs. IPA 90% vs. NPA 61%, P=0.039).

Conclusion

Pedal arch status has a positive effect on major amputation-free survival and wound healing in patients with CLI with foot wounds undergoing infrapopliteal bypass grafting.

Keywords:
critical limb ischemia, distal bypasses, pedal arch, wound healing

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Introduction

Revascularization of critical limb ischemia (CLI) is crucial for limb salvage and healing of tissue loss. This can be established by surgical or endovascular approaches. Re-establishing direct blood flow to the foot is essential for healing of foot tissue loss [1]. A lot of studies have explored the outcomes of endovascular techniques to revascularize the pedal arch [2–5].

Pedal runoff status has a prognostic significance in femoro-popliteal and femoro-distal bypasses; thus, complete visualization of the crural and pedal arteries before a surgical bypass is important [6]. Although infrapopliteal (IP) arterial bypasses are firmly established techniques in the treatment of patients with CLI, only few studies have addressed the effect of the pedal arch quality on the outcome of distal bypass grafts in such patients. The study by Rashid *et al.* [7] concluded that the pedal arch status influenced healing rates and times, with no influence on patency rates or amputation-free survival in IP bypasses.

The aim of this study was to assess the effect of foot arch status on the amputation-free survival, patient survival, wound healing, and patency rates of IP bypasses in patients with CLI with tissue loss.

Materials and methods

Study design

A retrospective review of our prospectively collected IP bypass database was done to identify patients with CLI with tissue loss (Rutherford 5 or 6) who underwent distal bypasses in the Vascular Surgery Department, Zagazig University Hospitals, Egypt, between January 2017 and January 2021. IP bypass is defined as the one on which its distal anastomosis is done onto the tibioperoneal trunk, anterior tibial artery, posterior tibial artery, or peroneal artery. Preoperative duplex assessment was performed in all patients. Computed tomography angiography was done to delineate the arterial tree in patients with good kidney function, which is replaced by MRA if kidney function is impaired.

After the bypass, pedal angiogram was done to delineate the arterial foot arch status. According to pedal arch quality, patients were divided into three groups: complete pedal arch (CPA), incomplete pedal arch (IPA), and no pedal arch (NPA). A pedal arch is considered complete when the dorsalis pedis artery is continuous with at least one of the plantar arteries without interruption. IPA is defined when the dorsalis pedis component or one of the plantar arteries are present without direct communication. NPA is when neither the dorsalis pedis component nor the plantar arteries are patent but the foot is supplied by collateral circulation [1].

Inclusion criteria

All patients with CLI presenting with tissue loss (Rutherford 5 or 6) secondary to IP arterial occlusion or long occlusive femoro-popliteal disease or after failed endovascular therapy (EVT) were included.

Exclusion criteria

Revascularization procedures other than IP bypasses, ultradistal bypasses as well as unsalvageable limbs were the exclusion criteria.

Technical procedure

Reversed great saphenous vein (GSV) is the conduit of choice used. Polytetrafluoroethylene grafts are used if GSV is deemed unsuitable. Intravenous heparin is administered before vascular clamping. After anatomical tunneling of the conduit, proximal anastomosis is performed taking inflow from the common femoral artery (CFA), superficial femoral artery, or popliteal artery (PA). If inflow angiographic lesions are present, they are dealt with by preoperative angioplasty. Distal anastomosis is performed considering the concept of foot angiosomes.

At the end of the bypass, intraoperative Doppler assessment was done to confirm graft patency. Ulcer debridement and minor amputations were then performed on the same setting after revascularization. Postoperative anticoagulation with low-molecular-weight-heparin was given to all patients during hospital admission. Statin and dual antiplatelets were initiated before the bypass and continued thereafter for the first 3 months and then a single antiplatelet agent was continued for life.

Follow-up

Duplex surveillance program was initiated in all patients in addition to wound care until complete healing. Follow-up scans were performed postoperatively and every 3 months for the first 12 months. Duplex evaluation of inflow artery, proximal anastomosis, in-graft, distal anastomosis, and outflow artery was done. At-risk graft was identified if a focal peak systolic velocity (PSV) was more than 200 cm/s, PSV ratio was more than 2.0 (>50% stenosis), or overall graft PSV less than 35 cm/s. Grafts at risk for occlusion were offered urgent angiography, and immediate salvage angioplasty was performed if significant stenosis was confirmed. Surgical revision was done if angioplasty was deemed unsuccessful. Patients were discharged from the surveillance program after completing an intervention-free follow-up year.

Study end points and outcome measures

Primary end points were graft primary, assisted-primary, and secondary patency rates. Secondary end points included complete wound healing, amputation-free survival, and patient survival rates. Study end points and outcome measures were compared between the three study groups at 1-year follow-up period after the bypass.

Statistical analysis

IBM SPSS software, version 28 (SPSS Inc., Chicago, Illinois, USA) was used for data collection and statistical analysis. Pearson χ^2 test was used to test categorical data, whereas numerical variables were compared using independent t test. P value less than 0.05 was considered statistically significant. Kaplan–Meier life-table analysis was used to compare study end points among the three groups.

Results

Patient population

A total of 88 consecutive patients with CLI with tissue loss underwent IP bypasses at our department. They were predominantly males (62 men, 70%; 26 women, 30%), with a mean age of 74 years (range, 50–88 years). Cardiovascular risk factors included hypertension (85%), diabetes mellitus (76%), smoking (78%), and hypercholesterolemia (71%). The 88 IP bypasses were classified into three groups according to the pedal arch status, as CPA in 21 (24%), IPA in 49 (56%), and NPA in 18 (20%). Demographic criteria and cardiovascular risk factors are compared among the three groups in Table 1.

Table 1 Patients demographics and risk factors in pedal arch groups

Variables	CPA (*N*=21) [*n* (%)]	IPA (*N*=49) [*n* (%)]	NPA (*N*=18) [*n* (%)]	*P* value
Males	14 (67)	31 (63)	17 (94)	0.042**
Diabetes mellitus	17 (81)	37 (76)	13 (72)	0.806
Hypertension	19 (90)	37 (76)	17 (94)	0.204
Dyslipidemia	14 (67)	34 (69)	14 (78)	0.728
IHD	11 (52)	19 (39)	10 (56)	0.363
Renal impairment	11 (52)	10 (20)	4 (22)	0.089
Smoking/ex-smoking	17 (81)	41 (84)	11 (61)	0.158

CPA, complete pedal arch; IHD, Ischemic heart disease; IPA, incomplete pedal arch; NPA, no pedal arch. **Statistically significant.

Intervention

A total of 55 (62.5%) patients presented with Rutherford stage 5 and 33 (37.5%) with stage 6. Autogenous GSV was used in 86 (98%) cases and polytetrafluoroethylene in only two cases. Proximal anastomotic site was CFA in 18 (20%), superficial femoral artery in 27 (31%), and PA in 43 (49%). Distal anastomosis was tailored onto tibioperoneal trunk in six (7%), anterior tibial artery in 34 (39%), posterior tibial artery in 32 (36%), and peroneal artery in 16 (18%). Bypasses characteristics are summarized in Table 2.

A total of 42 EVT attempts were performed to rescue 32 (36%) threatened grafts. In fact, 10 (48%), 21 (43%), and 11 (61%) salvage EVT attempts were performed in CPA, IPA, and NPA groups, respectively (Table 2). Nine (10%) cases necessitated redosurgery as follows: revision of the whole bypass in three acutely occluded grafts, jump graft to a distal vein graft/tibial vessel in four cases, CFA endarterectomy and patch plasty of proximal anastomosis in one, and CFA pseudoaneurysm repair in a case.

Table 2 Bypasses characteristics

Variables	CPA (*N*=21) [*n* (%)]	IPA (*N*=49) [*n* (%)]	NPA (*N*=18) [*n* (%)]	*P* value
Limb affected				
Right	11 (52)	24 (49)	10 (56)	0.885
Left	10 (48)	25 (51)	8 (44)	
Rutherford stage				
5	13 (62)	33 (67)	9 (50)	0.429
6	8 (38)	16 (33)	9 (50)	
Proximal anastomosis				
CFA	4 (19)	10 (20)	4 (22)	0.357
SFA	8 (38)	11 (23)	8 (45)	
PA	9 (43)	28 (57)	6 (33)	
Distal anastomosis				
TPT	3 (14)	3 (6)	0	0.125
ATA	8 (38)	19 (39)	7 (39)	
PTA	7 (33)	21 (43)	4 (22)	
PerA	3 (14)	6 (12)	7 (39)	
Conduit used				
GSV	21 (100)	48 (98)	17 (94)	0.448
PTFE	0	1 (2)	1 (6)	
Salvage angioplasty attempts	10 (48)	21 (43)	11 (61)	0.550
Inflow	8	12	5	
In-graft	1	3	2	
Outflow	1	6	4	
Redosurgery	2 (10)	6 (12)	1 (6)	0.697

ATA, anterior tibial artery; CFA, common femoral artery; CPA, complete pedal arch; GSV, great saphenous vein; IPA, incomplete pedal arch; NPA, no pedal arch; PA, popliteal artery; PerA, peroneal artery; PTA, posterior tibial artery; PTFE, polytetrafloroethylene; SFA, superficial femoral artery; TPT, tibioperoneal trunk.

In the CPA group, seven (33%) grafts become threatened and one (5%) occluded but the ulcer healed by the time the graft got occluded, so no further intervention was necessitated, and no patient required major amputation. In the IPA group, 18 (37%) grafts become threatened and one (2%) got occluded, which underwent major amputation. In the NPA group, seven (39%) threatened grafts were encountered in addition to three (17%) occluded grafts. The three occluded grafts required major amputation.

Outcome

By Kaplan–Meier analysis, overall primary patency, assisted-primary patency, and secondary patency rates were 53, 81, and 90%, respectively, at 1-year follow-up. Overall amputation-free survival was 96%. Four above-knee amputations were encountered during the study period, of which three for Rutherford stage 5 and one for stage 6 at a median of 124.5 days (range, 8–176 days) after the IP bypass. Complete foot wound healing rate was 82%. Overall patient survival rates at 30 days and 1 year were 97 and 81%, respectively.

Table 3 Comparative analyses of outcomes of the three study groups

Outcomes	CPA (%)	IPA (%)	NPA (%)	*P* value
Primary patency	62	53	44	0.410
Assisted-primary patency	91	76	83	0.424
Secondary patency	100	88	83	0.193
Amputation-free survival	100	98	83	0.015**
Wound healing	81	90	61	0.039**
Patient survival	76	88	67	0.128

CPA, complete pedal arch; IPA, incomplete pedal arch; NPA, no pedal arch. **Statistically significant.

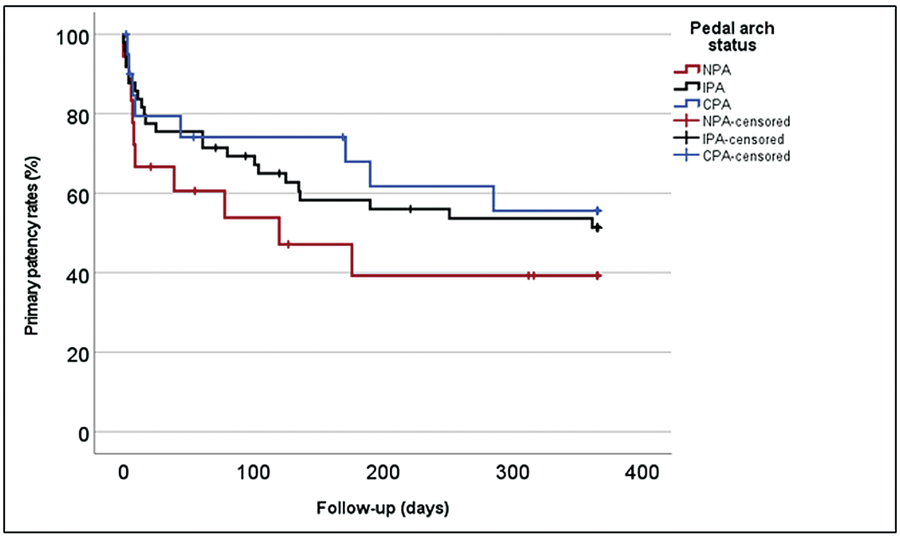
When comparing the three study groups, there was no statistically significant difference among them regarding primary patency, assisted-primary patency, secondary patency, and patient survival rates at 1-year follow-up (Table 3, Figs 1–4). A statistically significant difference existed among the three groups in terms of 12-month amputation-free survival (CPA 100% vs. IPA 98% vs. NPA 83%, P=0.015) (Fig. 5). Moreover, there was a statistically significant difference in wound healing rates among the study groups (CPA 81% vs. IPA 90% vs. NPA 61%, P=0.039) (Table 3). At the end of the study period, overall mortality was 17 (19%) cases, of which five (5%) in CPA and six (7%) in each of IPA and NPA groups (P=0.128).

Absent foot arch (P=0.015) was the only statistically significant independent factor associated with worse amputation-free survival, whereas absent pedal arch (P=0.038) and smoking (P=0.019) were independent factors associated with poor wound healing.

Discussion

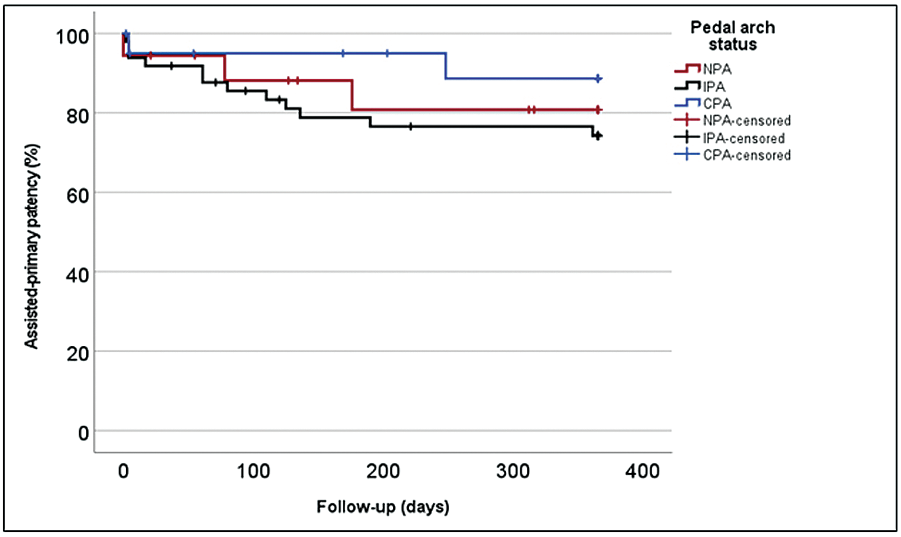
In 1988, Lea Thomas and colleagues analyzed 100 foot angiograms in patients with leg ischemia to assess the frequency of plantar arch visualization. Plantar arch was present in 75% of feet, occluded in 12%, and not demonstrated for technical reasons in 13%. They emphasized the importance of pedal arch evaluation before distal bypass surgery in patients with CLI [8].

Figure 1



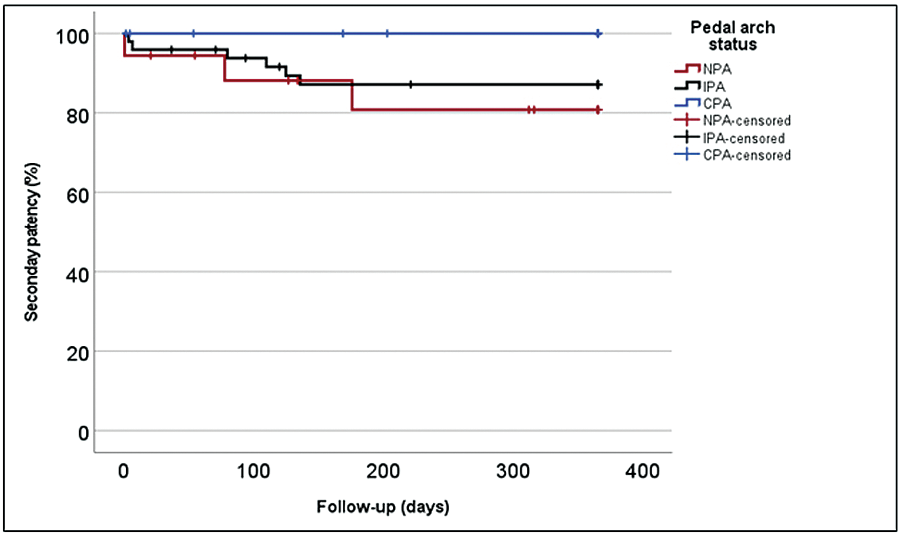
Primary patency rates among the three groups by Kaplan–Meier analysis.

Figure 2



Assisted-primary patency rates among the study groups by Kaplan–Meier analysis.

Figure 3



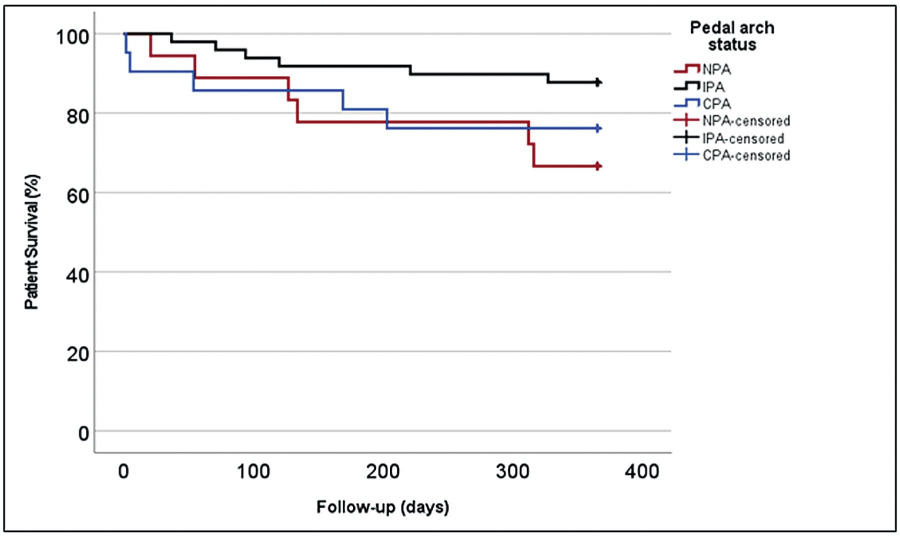
Secondary patency rates among the three groups by Kaplan–Meier analysis.

In 1994, Gloviczki *et al.* [9] concluded that pedal bypasses are safe, effective, and durable methods especially in high-risk patients with CLI. In the 2009, Manzi and colleagues reviewed the outcomes of 135 patients with CLI treated by balloon angioplasty of the pedal vessels using the pedal-plantar loop technique. Immediate success with a significant improvement in the transcutaneous oxygen tension was maintained at 1-year follow-up in most cases [2].

In 2013, Rashid and colleagues reviewed the data of 154 patients with CLI who underwent 167 IP bypasses. Tissue loss was present in 54%, toe gangrene in 30%, and rest pain in 16%. According to the foot arch status, 31 (19%) had CPA, 104 (62%) had IPA, and 32 (19%) had NPA. A total of 55 (33%) threatened grafts were picked up on duplex surveillance, which necessitated 85 salvage EVT. Primary patency rates in the CPA, IPA, and NPA groups were 58.4, 54.6, and 63.8%, respectively at 1-year follow-up. Secondary patency rates were 86, 84.7, and 88.8%, respectively. Amputation-free survival was 67.2, 69.7, and 45.9%, respectively, at 48 months. Overall mortality was 1 and 11% at 30-day and 1-year follow-up, respectively [7].

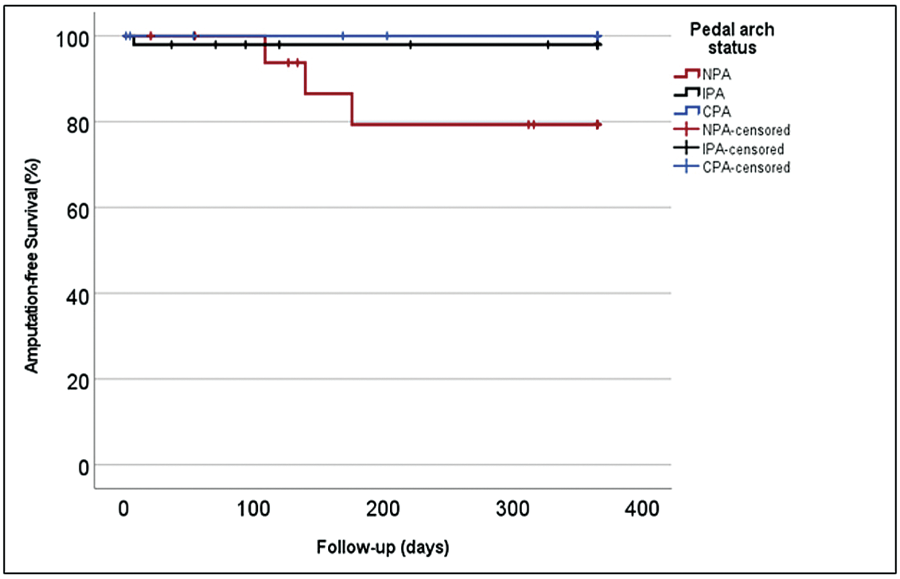
Rashid *et al.* [7] concluded that the pedal arch quality did not influence patency rates or amputation-free

Figure 4



Patient survival rates among the three groups by Kaplan–Meier analysis.

Figure 5



Amputation-free survival rates among the study groups by Kaplan–Meier analysis.

survival. However, the healing rates and time were directly influenced by the quality of the pedal arch. On the contrary, many studies have shown the importance of patent pedal vessels for successful bypasses and that graft patency rates are better in patients with CPA [10–12].

In 2018, Troisi and colleagues analyzed 137 diabetic patients with foot wounds who underwent infrainguinal endovascular revascularization. CPA was found in 42 (31%), IPA in 60 (44%), and NPA in 35 (25%). Wound healing rate at 3 months was 50% with CPA, 28% with IPA, and 20% with NPA. A statistically significant difference in terms of 1-year freedom from minor amputation was found among the study groups (CPA 84.1% vs. IPA 82.4% vs. NPA 48.9%). Limb salvage rate at 1-year was significantly better in patients with CPA (CPA 100% vs. IPA 93.8% vs. NPA 70.1%). Patient survival at 1 year was significantly better in CPA patients (CPA 90% vs. IPA 80.8% vs. NPA 62.7%). They concluded that pedal arch status has a positive effect on wound healing, limb salvage, and patient survival in diabetic patients with foot wounds undergoing infrainguinal EVT [5].

In the study by Rashid *et al.* [7], patency rates were numerically higher in NPA group, which is not the case with our study. In the current series, we found that bypasses with CPA or IPA have numerically higher primary patency, secondary patency, and patient survival rates than NPA bypasses, but this was not statistically significant. On the contrary, amputation-free survival and wound healing rates were statistically significantly better with CFA or IPA cases when compared with absent foot arch cases.

Absent foot arch (P=0.015) was the only statistically significant independent factor associated with worse amputation-free survival, whereas absent pedal arch (P=0.038) and smoking (P=0.019) were independent factors associated with poor wound healing necessitating close follow-up.

Conclusion

Pedal arch quality has a positive influence on patency rates, amputation-free survival, and wound healing in patients with CLI with tissue loss undergoing IP bypass grafting.

Limitation

This study is limited by the small sample size being a single-center study, in addition to long duration of patient recruitment, which makes long-term follow-up quite difficult.

Recommendation

Further multiple-center studies with long-term follow up are needed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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