European Journal of Vascular and Endovascular Surgery 43 (2012) 322–328

Contents lists available at SciVerse ScienceDirect

European Journal of Vascular and Endovascular Surgery

journal homepage: www.ejves.com

Factors Influencing Wound Healing of Critical Ischaemic Foot after Bypass Surgery: Is the Angiosome Important in Selecting Bypass Target Artery?☆

N. Azuma*, H. Uchida, T. Kokubo, A. Koya, N. Akasaka, T. Sasajima

Division of Cardiovascular Surgery, Department of Surgery, Asahikawa Medical University, 2-1, Midorigaoka-higashi, Asahikawa 078-8510, Japan

WHAT THIS PAPER ADDS

- The study discusses ischaemic ulcer healing after bypass surgery, especially in end-stage renal disease (ESRD) patients, and the role of the angiosome.

ARTICLE INFO

Article history:
Received 3 October 2011
Accepted 5 December 2011
Available online 9 January 2012

Keywords:
Critical limb ischaemia
Infrainguinal bypass
Vein graft
Wound healing
Angiosome

ABSTRACT

Objectives: The aim of the study is to determine factors affecting ischaemic wound healing and role of the angiosome concept in bypass surgery.
Design: Single-centre, retrospective clinical study.
Materials and methods: A total of 249 consecutive critical ischaemic limbs with tissue loss in 228 patients who underwent distal bypasses from 2003 to 2009 were reviewed. A total of 81% of patients were diabetic, and 49% of patients had dialysis-dependent renal disease (end-stage renal disease, ESRD). Distal targets of bypasses were the crural artery (57%) and the pedal artery (43%).
Results: The complete healing of ischaemic wounds was achieved in 211 limbs (84.7%). ESRD (odds ratio (OR) 0.127, $p < 0.001$), diabetes (OR 0.216, $p = 0.030$), Rutherford category 6 (R6) with heel ulcer/gangrene (OR 0.134, $p < 0.001$), R6 except heel (OR 0.336, $p = 0.025$) and low albuminaemia (OR 0.387, $p = 0.049$) were negative predictors of wound healing. Regarding the angiosome, the healing rate in the indirect revascularisation (IR) group was slower than in the direct revascularisation (DR) group, especially in patients with ESRD ($p < 0.001$). However, the healing rates of the DR and IR groups were similar after minimising background differences with propensity score methods ($p = 0.185$).
Conclusions: In the field of bypass surgery, the angiosome concept seems unimportant, at least in non-ESRD cases. The location and extent of ischaemic wounds as well as co-morbidities may be more relevant than the angiosome in terms of wound healing.

Bypass surgery and endovascular treatment (EVT) are reliable strategies for revascularisation of critical ischaemic limbs. The final results of the bypass versus angioplasty in severe ischaemia of leg (BASIL) trial demonstrated that the outcome of bypass surgery after failed EVT was worse than that of bypass surgery performed as the first line of treatment, which suggested that EVT should not always be the first line of treatment. Thus, additional evidence is needed to decide how to select the appropriate revascularisation procedure in daily practice.[1] The TransAtlantic Inter-Society Consensus has recommended that the profile and extent of arterial lesions be used to select EVT or bypass surgery, while the BASIL trial group favoured life expectancy.[1,2] However, the status of ischaemic wounds and the healing ability of patients are not regarded as important factors in selecting revascularisation procedures. The angiosome concept, introduced by Taylor and Palmer, is also considered an important factor in wound healing, at least by plastic surgeons and interventionalists.[3–5] Good healing has been achieved by direct endovascular intervention at the artery feeding the angiosome where

☆ This article was accepted for oral presentation at the XXVth congress of ESVS, and presented on September 23 in the scientific session 4 of the meeting at Greece.

* Corresponding author. Tel.: +81 166 68 2494; fax: +81 166 68 2499.
E-mail addresses: az919@asahikawa-med.ac.jp (N. Azuma), huchida@asahikawa-med.ac.jp (H. Uchida), kokubo@asahikawa-med.ac.jp (T. Kokubo), akoya@asahikawa-med.ac.jp (A. Koya), aksk@asahikawa-med.ac.jp (N. Akasaka), sasajima@asahikawa-med.ac.jp (T. Sasajima).

1078-5884/$ – see front matter © 2011 European Society for Vascular Surgery. Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.ejvs.2011.12.001

ischaemic ulcers or gangrenes exist.[6,7] However, most vascular surgeons believe that the blood supplied by a bypass graft is sufficient to fill the entire foot, regardless of the angiosome. The purpose of this study is to determine the factors affecting ischaemic wound healing, including the angiosome concept, in the use of a relatively large patient population.

Materials and Methods

A total of 249 consecutive critical ischaemic limbs with tissue loss in 228 patients who underwent distal bypass surgery for crural artery occlusive disease were analysed retrospectively. A total of 81% of patients were diabetic, and 49% of patients had end-stage renal disease (ESRD), including five cases of peritoneal dialysis. The diagnosis of critical limb ischaemia (CLI) was made based on a non-healing ulcer or gangrene with haemodynamic evidence of ischaemia by the ankle–brachial pressure index or skin perfusion pressure (SPP). Clinical characteristics, the status of ischaemic wounds, operative data and immediate postoperative outcome data of these patients were registered in the database of our institution. The patients were entered into a graft surveillance program (Tables 1 and 2).

We analysed whether the angiosome concept can contribute to the improvement of outcomes in bypass surgery and evaluated the efficacy of angiosome-oriented revascularisation itself; 31 limbs of 22 patients who died before healing and nine limbs whose bypass grafts occluded before healing were excluded.

Ischaemic tissue lesion

All ischaemic wounds were evaluated by the Rutherford classification[8] immediately before the operation (Table 1). The locations of the wounds were recorded and their photographs were taken preoperatively. Bacterial culture was performed in every case, and magnetic resonance imaging (MRI) was performed if osteomyelitis was suspected.

Revascularisation procedure

All distal bypasses were conducted using vein grafts. A total of 20% of limbs underwent inflow reconstruction by EVT or bypass surgery simultaneously. The anastomotic sites of the distal bypasses are listed in Table 2. The most common distal anastomosis was dorsalis pedis. Because the angiosome concept was not yet recognised at the time of the present study, a disease-free artery with better runoff was our primary standard for selecting the distal target artery. The conduits of grafts are also listed in Table 2. The *in situ* saphenous veins were used most frequently. For the patients who did not have a good saphenous vein, the short saphenous vein, arm vein, or in some cases, femoral vein was used, but the artificial grafts were never used in the infrapopliteal area.

Table 1
Baseline characteristics of patients subjected to healing time analysis.

	249 limbs/228 patients
Age	67 (36–91)
Female gender	63 (28%)
Diabetes	184 (81%)
Hypertension	148 (65%)
Coronary artery disease	122 (54%)
ESRD	111 (49%)
Cerebral vascular disease	62 (27%)
Congestive Heart Failure	19 (8%)
Ischaemic tissue loss	
Rutherford Classification	
Category 5	155 (62%)
Category 6	94 (38%)
Single/multiple	
Single lesion	72 (29%)
Multiple lesions	177 (71%)

ESRD: end-stage renal disease.

Table 2
Characteristics of distal bypass procedures.

Conduit type	
Single vein grafts	163 (66%)
Spliced vein grafts	86 (35%)
Proximal anastomosis	
Common femoral	101 (41%)
Superficial femoral	72 (29%)
Popliteal	62 (25%)
Others	14 (6%)
Most distal anastomosis	
Anterior tibial	38 (15%)
Posterior tibial	86 (35%)
Peroneal	18 (7%)
Dorsalis pedis	87 (35%)
Plantar	15 (6%)
Other pedal branch	5 (2%)
Adjunctive inflow reconstruction	
EVT[a] for iliac artery	24 (10%)
EVT for superficial femoral	4 (2%)
Anatomical bypass	16 (6%)
Extra-anatomical bypass	7 (3%)

[a] EVT: endovascular treatment.

Postoperative wound care and additional procedure for wound healing

Necrotic tissues were debrided immediately after the bypass procedure. A total of 49% of limbs underwent minor amputation. After minor amputation, most wounds were left open, and then we waited for the disappearance of infection signs and the growth of granulation tissues. Negative pressure treatments using vacuum-assisted devices were applied to most of the deep wounds that reached tendons or bones, and recombinant basic fibroblast growth factor (Fiblast Spray®, Kaken Pharmaceutical Co., Ltd., Tokyo, Japan) was used to facilitate epithelialisation in most wounds. A total of 17% of limbs underwent skin grafting. Free flap transfers, such as with scapular, latissimus dorsi, or rectus musculocutaneous flaps, were performed in 6% of patients to cover extensive tissue defects.

Definition of wound healing

Complete wound healing was defined by the achievement of complete epithelialisation of all wounds in their affected limbs. The duration from the initial bypass surgery to complete epithelialisation was defined as the healing time. If the ulcer recurred within 2 months after epithelialisation, the diagnosis of complete healing was rescinded; otherwise, the observation of wounds was terminated for the calculation of the wound healing time. The 'end' point of this study was clinical success defined by complete wound healing; therefore healing that took more than 1 year, death before complete healing or major amputation was defined as clinical failure. In patients who underwent major amputations, the healing time was considered to be infinite (which was treated as >25 months in the statistical analysis).

Definitions of direct (DR) and indirect revascularisation (IR)

The judgement of direct (DR) or indirect revascularisation (IR) was made by collating the location of ischaemic tissue loss with the

angiosome model described previously.[3–5] DR was assigned if the feeding artery of the affected angiosome was revascularised, while IR was assigned if the revascularised artery fed unrelated angiosomes. As an exception, in accordance with a previous report, revascularisation of digit ulcers by the dorsalis pedis or plantar artery was considered as DR, regardless of whether the ulcer was located on the dorsal side or plantar side.[9]

Statistical analysis

Statistical analysis was performed using PASW statistics version 18, formerly called SPSS statistics (SPSS Inc., Chicago, IL, USA). Continuous variables are reported as the median values with ranges. The Mann–Whitney test and chi-squared test were used for univariate analysis. The graft patency, limb salvage, survival and ulcer healing rate were calculated using Kaplan–Meier methods, and the curves were compared by the log-rank test. Because the healing time of the patients who underwent major amputation was considered to be infinite, a multivariate logistic regression model was used to determine the predictors of 'end' points.

In analysing the angiosome, there were significant differences between the DR and IR groups in terms of patient background, severity of ischaemic tissue loss and infection. To minimise these background differences between the DR and IR groups and better assess the role of the angiosome concept, we employed propensity score methods. A logistic regression analysis model to estimate the likelihood of undergoing DR or IR revascularisation was created. The covariates entered into the model included diabetes, ESRD, heel ulcer, Rutherford classification and serum albumin and CRP levels. The propensity score calculated according to the logistic regression model was employed for one-to-one matching according to a less than 0.03 difference in the propensity score between the DR and IR groups. In all analyses, $p < 0.05$ was considered statistically significant.

Results

The operative death rate was 0.9% due to cardiac events. The overall cumulative primary and secondary patency rates of bypass grafts were 61.4%, and 86.5% at 2 years, respectively.

Limb salvage

The cumulative limb salvage rate at 2 years was 93.1%. A total of 70% of limb losses were due to uncontrollable infection or infection-related graft problems.

Ulcer healing time

The complete healing of ischaemic wounds was achieved in 211 limbs (84.7%). The cumulative wound healing rate was 72.2% at 6 months and 86.9% at 1 year. The median ulcer healing time was 47 days in non-ESRD patients with Rutherford category (R) 5, 73 days in ESRD patients with R5, 115 days in non-ESRD patients with R6 and 237 days in ESRD patients with R6.

The location of the ulcer (heel), extensive tissue loss defined by R6, diabetes, ESRD, CRP and severely low albuminaemia (defined as <3.0 g dL^{-1}) were the factors inhibiting clinical success according to the univariate analysis, while ESRD (odds ratio (OR) 0.127), diabetes (OR 0.216), low albuminaemia (OR 0.387), R6 with heel ulcer/gangrene (OR 0.134) and R6 except in the heel (OR 0.336) were the factors predicting clinical failure according to multivariate analysis (Table 3).

According to the results of the multivariate analysis, limbs with ischaemic tissue loss were divided into three groups: non-ESRD, ESRD without severely low albuminaemia (ESRDnorAlb) and ESRD with severely low albuminaemia (ESRDlowAlb). The wound healing rate of the ESRDlowAlb group was significantly worse compared to the other groups ($p < 0.001$), while that of the ESRDnorAlb group was acceptable (Fig. 1).

Table 3
Univariate and multivariate analysis of freedom from clinical failure.[a]

Factors	Univariate analysis	Multivariate analysis		
	p-value	Odds ratio	(95% CI)	*p*-value
ESRD	<0.001	0.13	(0.048–0.338)	<0.001
Diabetes	<0.05	0.22	(0.054–0.859)	0.030
Albumin < 3[b] g/dL	<0.001	0.39	(0.150–0.996)	0.049
CRP > 5[b] mg/dL	<0.001	0.9	(0.355–2.277)	0.822
Heel ulcer/gangrene	<0.001	0.13	(0.051–0.350)	<0.001
R6 except heel[c]	<0.05	0.34	(0.130–0.871)	0.025

CI: confidence interval.
[a] Delay healing more than one year, death before complete healing, or major amputation was defined as clinical failure.
[b] Lowest quaterile value approximation.
[c] Tissue loss categorised Rutherford 6 except in the heel.

Amputation-free survival

The amputation-free survival (AFS) of the ESRDlowAlb group was significantly worse compared to the other groups ($p < 0.001$) (Fig. 2).

Role of angiosome

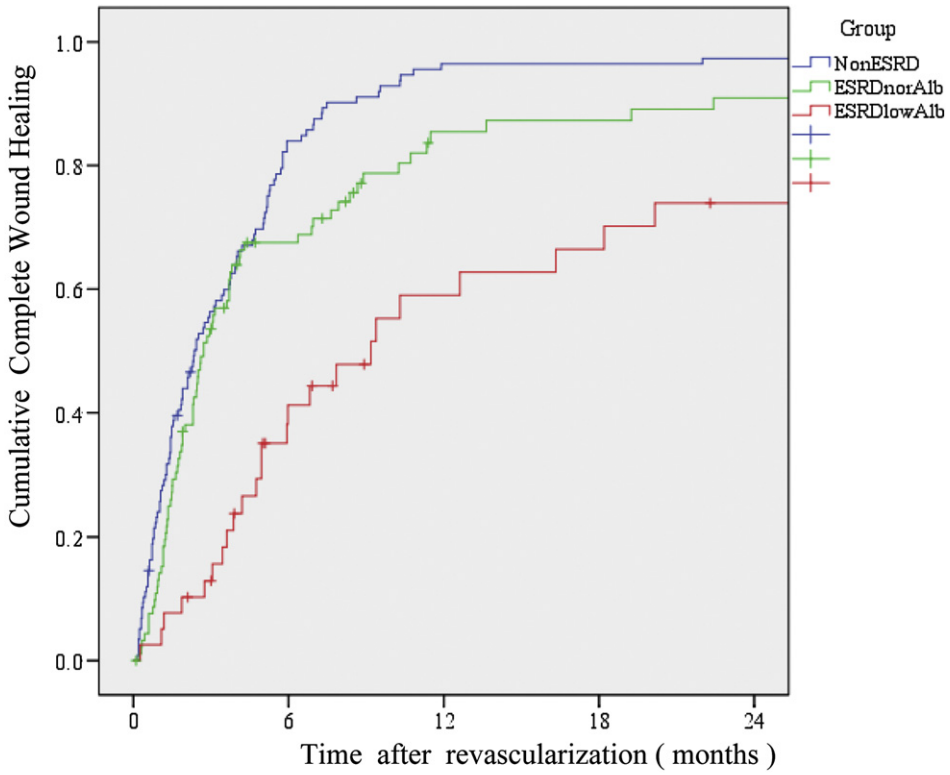
A total of 218 limbs were used for further analysis (Table 4). The healing rate of the DR group was significantly faster compared to the IR group among non-ESRD patients ($p = 0.01$), while the limb salvage rate of both the DR and IR groups among non-ESRD patients was 100% at 12 months (N.S., Fig. 3(A)). In ESRD patients, on the other hand, the IR group was markedly worse compared with the DR group in terms of the healing rate ($p < 0.001$) and the limb salvage rate ($p = 0.0032$, Fig. 3(B)).

However, the differences between the DR and IR groups in terms of patient background and the characteristics of the ischaemic wounds, such as their extent and infection, were problematic (Table 4). To resolve this problem regarding background bias, the propensity score method was employed. Then 48 matched pairs were taken for further statistical analysis. After matching according to the propensity score, the differences between the DR and IR groups were minimised (Table 4). The wound healing rate in the IR group after matching was slightly slower than that of the DR group, but this observation did not reach statistical significance ($p = 0.185$) (Fig. 4). The limb salvage rates of the DR and IR groups in matched pairs were 97.8% and 92.3% at 2 years, respectively ($p = 0.855$).

Discussion

The present study represents one of the largest investigations of ischaemic ulcer healing after bypass surgery. To our knowledge, this is the first detailed description of ulcer healing in a relatively large population of patients with dialysis-dependent ESRD. Furthermore, this study attempts to address the role of the angiosome in the field of bypass surgery, and our findings suggest that the angiosome concept is not highly important in the field of bypass surgery in most non-ESRD patients, contrary to previous reports.

Wound healing after revascularisation has been not fully studied even though it is one of the most important outcomes of CLI treatment. Although there are only few studies describing in detail



No. at risk					
NonESRD	117	17	3	3	2
ESRDnorAlb	93	24	7	6	4
ESRDlowAlb	39	18	10	8	5

Figure 1. Cumulative healing rate of ischaemic tissue defects after distal bypass surgery in different groups categorised according to patient background. Non-ESRD: limbs in patients without ESRD; ESRDnorAlb: limbs in ESRD patients without severely low albuminaemia; ESRDlowAlb: limbs in ESRD patients with severely low albuminaemia (<3.0 g/dL). There was a significant difference among groups ($p < 0.001$ by the log-rank test).

ischaemic ulcer healing after revascularisation, the following five factors have been reported to inhibit wound healing after revascularisation: (1) the location and extent of ischaemic tissue defects,[10–13] (2) systemic factors relating to wound healing ability and the defence system,[10,14] (3) infection,[15] (4) inadequate topical treatment[15,16] and (5) insufficient blood supply due to inappropriate revascularisation.[15,17]

One of the co-morbidities that affect wound healing is diabetes, which also impairs the host defence system against infection. Moreover, microcirculation disorders are common in diabetic patients. Apelqvist et al. criticised that studies with regard to vascular intervention have focussed on limb salvage, indicating a need to recognise and introduce decreased perfusion and impaired circulation.[10] In our series, diabetes was one of the risk factors for prolonged tissue healing time, which is supported by previous findings.[14]

ESRD was the strongest factor in predicting clinical failure in our series. Many authors already reported the high amputation rate in ESRD patients regardless of patent grafts, and concluded that the failure of foot salvage in this patient population was due to wound healing problems rather than graft thrombosis, although no studies have offered a precise description of wound healing after bypass surgery.[15,18,19] The present study is the first to report the cumulative ulcer healing rate of patients with ESRD. The median ulcer healing time was 73 days in ESRD patients with R5 tissue loss, whereas it was 237 days in ESRD patients with R6 tissue loss, suggesting that early referral to a vascular specialist is crucial to achieve clinical success in CLI patients with ESRD.

Previous studies recommended that bypass surgery for ESRD patients should be performed only in carefully selected patients, because of their poor outcomes.[15,20] However, guidelines describing how to select optimal ESRD patients for bypass surgery are rarely reported.[21] Our data clearly show that serum albumin level was a strong predictor of whether an ESRD patient would be a good or bad responder to bypass surgery. The correlation between serum albumin level and life prognosis in ESRD patients is well established,[19] and the hypoalbuminaemia is most likely caused by inflammation, not by malnutrition.[22,23] ESRD with low albuminaemia fits the model proposed by the authors of the BASIL trial as a patient group with a life expectancy less than 2 years.[1] On the other hand, ESRD patients without low albuminaemina tolerated bypass surgery well, and their wound healing rate and AFS were acceptable. In this context, ESRD patients with CLI seem non-homogeneous; therefore, proper patient selection may be important before planning revascularisation.

The angiosome concept is widely accepted by interventionalists to improve outcomes, and several retrospective studies have reported that the outcomes of angiosome-oriented EVT were better than those of indirect treatmnt.[6,7] This advantage seems reasonable because the blood supply through one diseased tibial artery that undergoes EVT may be limited. In the field of bypass surgery, Neville et al. also reported a large difference between DR and IR in terms of limb salvage.[17] However, many vascular surgeons may criticise their results, because vascular surgeons believe that the blood supplied by bypass graft anastomosed to one foot artery is sufficient to fill the entire foot regardless of the angiosome. Neville

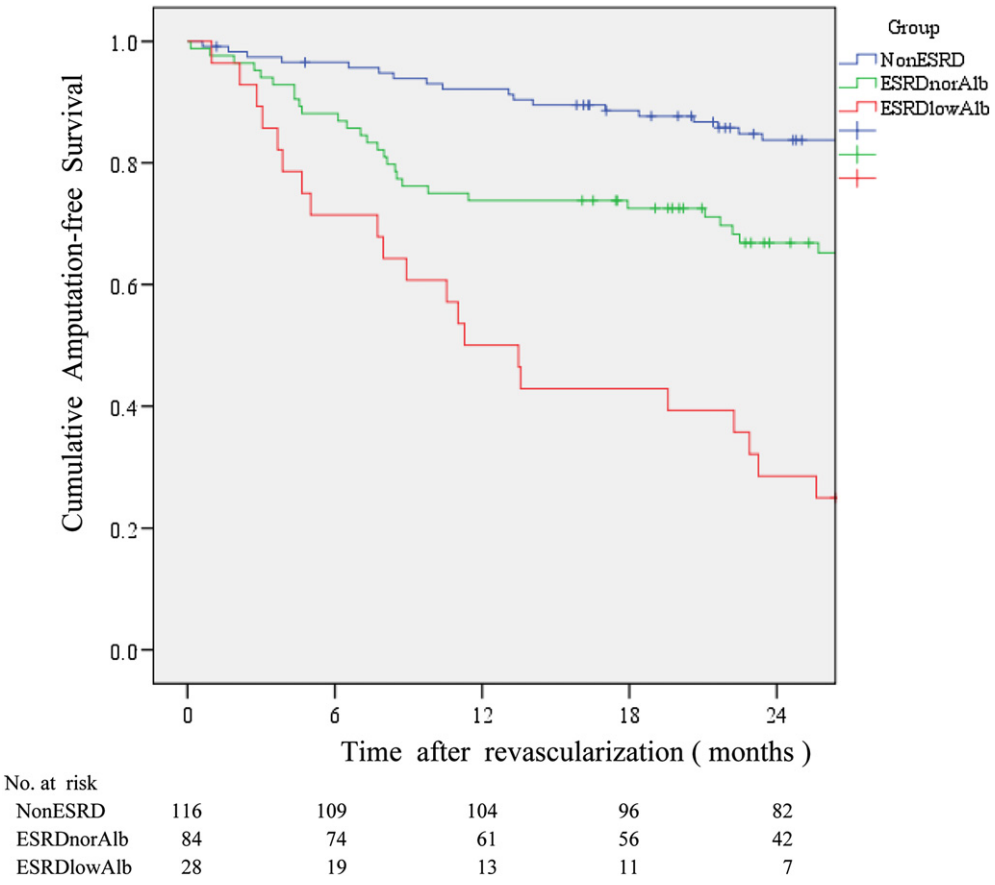


Figure 2. Cumulative amputation-free survival rate according to patient background. Non-ESRD: patients without ESRD; ESRDnorAlb: ESRD patients without severely low albuminaemia; ESRDlowAlb: ESRD patients with severely low albuminaemia (<3.0 g/dL). There was a significant difference among groups ($p < 0.001$ by log-rank test).

et al. mentioned that there was no difference in patient background between their DR and IR groups, but they did not mention the difference in ischaemic wound status between groups. Angiosome-guided bypass surgery is not always possible because infection, extensive tissue loss and severe arterial disease sometimes preclude DR. The present study found significant differences between the DR and IR groups in terms of CRP and albumin levels, the location and extent of tissue defects and the bypass target artery, reflecting the disadvantageous condition of the IR group. Our data demonstrate the shortcoming of direct comparisons between IR and DR. Thus, we employed propensity score methods. After minimising background differences between propensity score-matched groups, no difference between the DR and IR groups in terms of limb salvage rate or wound healing rate was found, suggesting that the angiosome concept seems unimportant in the field of bypass surgery, unlike the EVT field. In other words, surgeons do not have to approach a neighbouring infectious area or a severely diseased artery and risk graft failure. The results of our

Table 4
Baseline characteristics and operative data of patients subjected to angiosome analysis.

	Overall series			Propensity score-matched pairs		
	DR group	IR group	*p*-value	DR group	IR group	*p*-value
	126 limbs	92 limbs		48 limbs	48 limbs	
Age	66.5 (39–91)	67.5 (46–86)	0.434	67.5 (54–91)	67.5 (53–86)	0.849
Female gender	32 (26%)	24 (26%)	0.908	18 (38%)	12 (25%)	0.186
Diabetes	101 (80%)	74 (80%)	0.960	38 (79%)	36 (75%)	0.627
ESRD	67 (53%)	41 (44%)	0.209	22 (46%)	18 (38%)	0.408
Serum albumin[a]	3.4 (2.2–4.9)	3.3 (1.6–4.2)	0.001	3.3 (2.2–4.2)	3.35 (2.2–4.2)	0.942
CRP[b]	0.9 (27.8)	3.2 (30.1)	0.004	1.96 (27.8)	2.14 (18.1)	0.852
Rutherford 6	20 (16%)	59 (64%)	<0.001	20 (42%)	18 (38%)	0.676
Heel ulcer/gangrene	6 (5%)	30 (32%)	<0.001	6 (13%)	8 (17%)	0.772
Bypass target						
Crural	60 (48%)	69 (75%)	<0.001	30 (63%)	33 (69%)	0.519
Pedal	66 (52%)	23 (25%)		18 (38%)	15 (31%)	
Propensity score				0.6239	0.6295	0.982

DR: direct revascularisation, IR: indirect revascularisation in terms of angiosome, ESRD: end-stage renal disease.
[a] g/dL.
[b] Only maximum values are listed. Minimum value of CRP was <0.1 mg/dL.

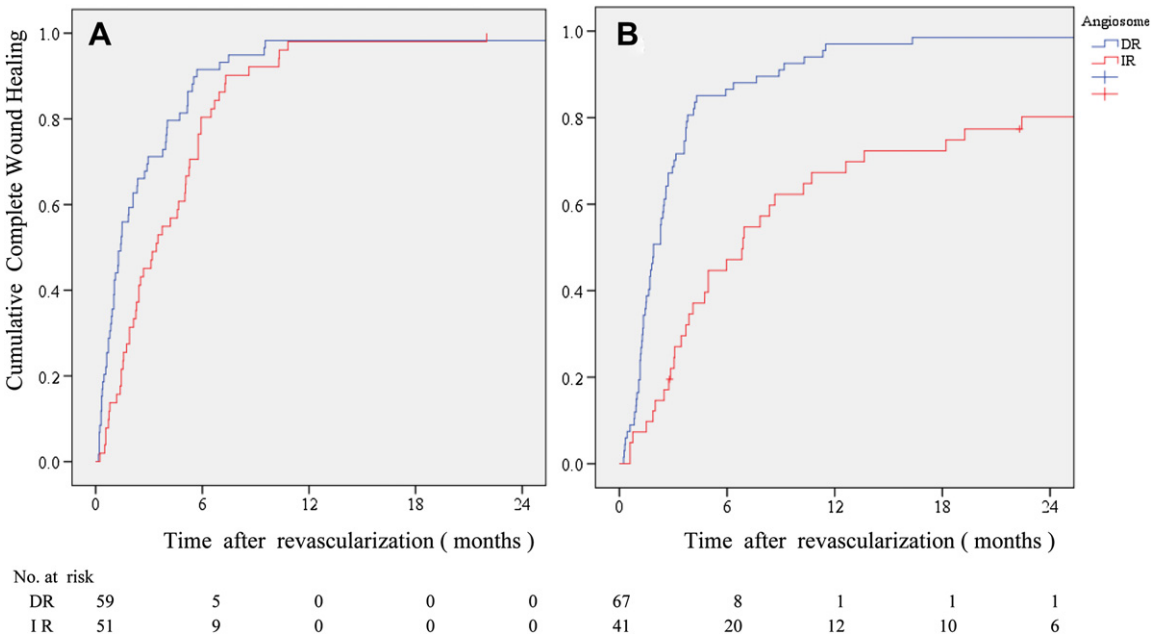


Figure 3. Cumulative healing rate in different bypass strategies based on the angiosome concept. 3A: DR versus IR in non-ESRD patients ($p = 0.01$). 3B: DR versus IR in ESRD patients ($p < 0.001$). DR: direct revascularisation. IR: indirect revascularisation.

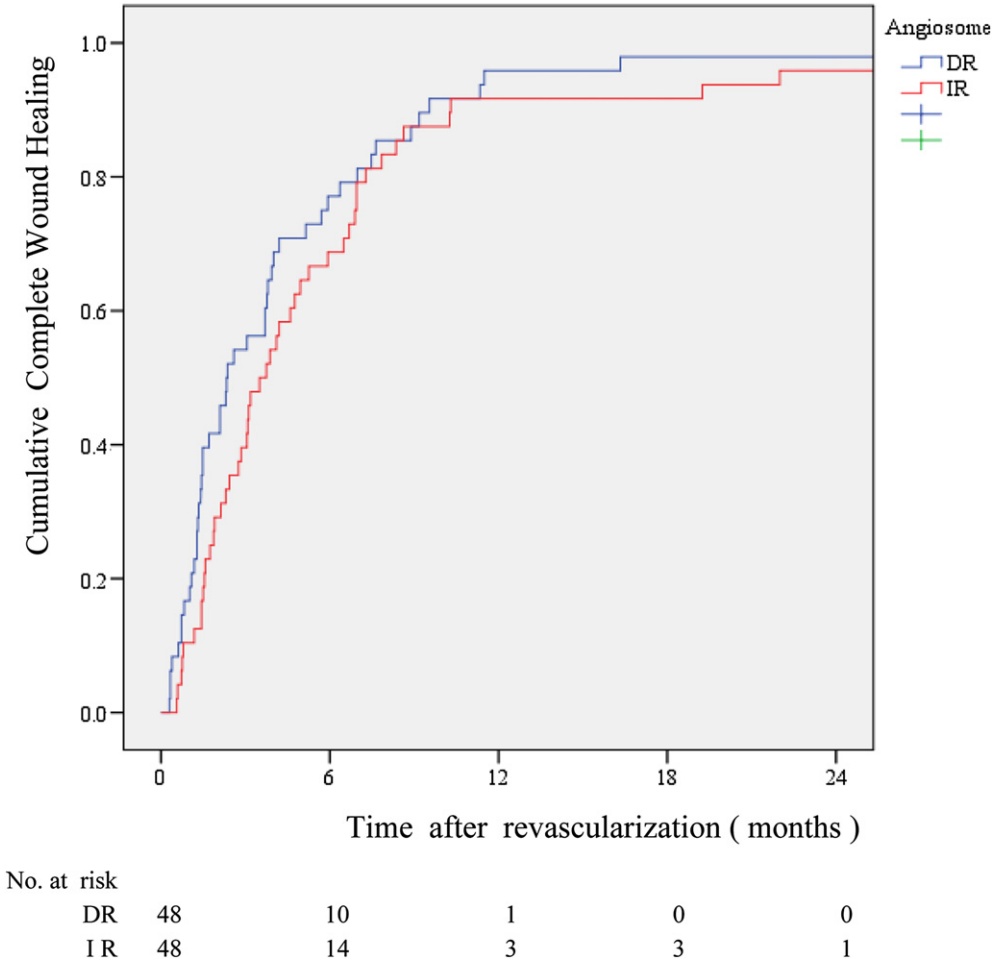


Figure 4. Cumulative healing rate in propensity score-matched pairs. There was no significant difference between the DR group and IR group ($p = 0.185$). DR: direct revascularisation. IR: indirect revascularisation.

angiosome analysis may influence the selection of the distal target artery of bypass surgery in patients with ischaemic tissue loss. Based on our data, we believe that a good artery with good runoff to the foot, regardless of the angiosome, should be selected in non-ESRD patients, which may allow bypass surgery to be more beneficial in the long term. On the other hand, angiosome-oriented target selection might improve the poorer outcomes in ESRD patients. We did not investigate whether the collateral development was sufficient, or whether the arterial disease involved the connecting arteries between angiosomes. The poorer outcomes in the IR group among these ESRD patients might suggest that the severe arterial disease involved the connecting arterial network in some ESRD patients. Further studies investigating the haemodynamic changes in angiosomes after bypass surgery by SPP measurement, as well as the morphological connections between angiosomes by precise completion angiography or indocyanine green staining, are needed to clarify the role of the angiosome in patients with ESRD.

Our study has some limitations. First, this was a single-centre, retrospective study. Second, the population for the angiosome analysis had been reduced after propensity score matching. Although the propensity score method was useful to minimise background differences, hidden bias may remain. Therefore, larger-scale, prospective studies are needed to confirm our results.

Conclusions

In the field of bypass surgery, the angiosome concept seems unimportant in non-ESRD cases, while it is still not clear whether angiosome-guided bypass grafting improves the wound healing of ESRD patients. The location and extent of ischaemic wounds, as well as co-morbidities such as diabetes, ESRD and low albuminaemia, might be more relevant in terms of wound healing after bypass surgery. Patients with ESRD with low albuminaemia are not good candidates for bypass surgery because of poor wound healing and AFS, while ESRD patients without low albuminaemia can be treated by bypass surgery because of their acceptable AFS and wound healing.

Conflict of Interest

None.

Funding

None.

References

1 Bradbury AW, Adam DJ, Bell J, Forbes JF, Fowkes FG, Gillespie I, et al. Bypass versus angioplasty in severe ischaemia of leg (BASIL) trial: analysis of amputation free and overall survival by treatment received. *J Vasc Surg* 2010;**51**:18S–31S.

2 TASC II Working Group. Inter-society consensus for the management of peripheral arterial disease. *J Vasc Surg* 2007;**45**:S1–68.

3 Taylor GI, Palmer JH. The vascular territories (angiosomes) of the body: experimental study and clinical applications. *Br J Plast Surg* 1987;**40**:113–41.

4 Taylor GI, Pan WR. Angiosomes of the leg: anatomic study and clinical implication. *Plast Reconstr Surg* 1998;**102**:599–616.

5 Attinger CE, Evans KK, Bulan E, Blume P, Cooper P. Angiosomes of the foot and ankle and clinical implications for limbs salvage: reconstruction, incision, and revascularization. *Plast Reconstr Surg* 2006;**117**:261S–93S.

6 Alexandrescu VA, Hubermont G, Phillips Y, Guillaumie B, Ngongang C, Vandenbossche P, et al. Selective primary angioplasty following an angiosome model of reperfusion in the treatment of Wagner 1–4 diabetic foot lesions: practice in a multidisciplinary diabetic limb salvage. *J Endovasc Ther* 2009;**15**:580–93.

7 Iida O, Nanto S, Uematsu M, Ikeoka K, Okamoto S, Dohi T, et al. Importance of the angiosome concept for endovascular therapy in patients with critical limb ischemia. *Catheter Cardiovasc Interv* 2010;**75**:830–6.

8 Rutherford RB, Baker JD, Ernst C, Johnston KW, Porter JM, Ahn S, et al. Recommended standard for reports dealing with lower extremity ischemia: revised version. *J Vasc Surg* 1997;**26**:517–38.

9 Verela C, Acin F, Haro JD, Bleda S, Esparza L, March JR. The role of foot collateral vessels on ulcer healing and limb salvage after successful endovascular and surgical distal procedures according to an angiosome model. *Vasc Endovascular Surg* 2010;**44**:654–60.

10 Apelqvist J, Elgzyri T, Larsson J, Löndahl M, Nyberg P, Thörne J. Factors related to outcome of neuroischemic/ischemic foot ulcer in diabetic patients. *J Vasc Surg* 2011;**53**:1582–8.

11 Treiman GS, Oderich GSC, Ashrafi A, Schneider PA. Management of ischemic heel ulceration and gangrene: an evaluation of factors associated with successful healing. *J Vasc Surg* 2000;**31**:1110–8.

12 Söderström M, Aho PS, Lapäntalo M, Albäck A. The influence of the characteristics of ischemic tissue lesions on ulcer healing time after infrainguinal bypass for critical leg ischemia. *J Vasc Surg* 2009;**49**:932–7.

13 Chung J, Bartelson BB, Hiatt WR, Peyton BD, McLafferty RB, Hopley CW, et al. Wound healing and function outcomes after infrainguinal bypass with reversed saphenous vein for critical limb ischemia. *J Vasc Surg* 2006;**43**:1183–90.

14 Söderström M, Arvela E, Albäck A, Aho PS, Lapäntalo M. Healing of ischemic tissue lesions after infrainguinal bypass surgery for critical leg ischemia. *Eur J Vasc Endovasc Surg* 2008;**36**:90–5.

15 Johnson BL, Glickman MH, Bandyk DF, Esses GE. Failure of foot salvage in patients with end-stage renal disease after surgical revascularization. *J Vasc Surg* 1995;**22**:280–6.

16 Vuerstaek JDD, Vainas T, Wuite J, Nelemans P, Neumann MHA, Veraart JCJM. State-of-the-art treatment of chronic leg ulcers: a randomized controlled trial comparing vacuum-assisted closure (V.A.C.) with modern wound dressings. *J Vasc Surg* 2006;**44**:1029–38.

17 Neville RF, Attinger CE, Bulan EJ, Bulan EJ, Ducic I, Thomassen M, et al. Revascularization of a specific angiosome for limb salvage: does the target artery matter? *Ann Vasc Surg* 2009;**23**:367–73.

18 Ramdev P, Rayan SS, Sheahan M, Hamdan AD, LoGerfo FW, Akbari AM, et al. A decade experience with infrainguinal revascularization in a dialysis-dependent patient population. *J Vasc Surg* 2002;**36**:969–74.

19 Biancari F, Kantonen I, Mäizle S, Albäck A, Roth WD, Edgen J, et al. Infrainguinal endovascular and bypass surgery for critical leg ischemia in patients on long-term dialysis. *Ann Vasc Surg* 2002;**16**:210–4.

20 Albers M, Romiti M, Bragança Pereira CA, Fonseca RLA, da Silva Júnior M. A meta-analysis of infrainguinal arterial reconstruction in patients with end-staged renal disease. *Eur J Vasc Endovasc Surg* 2001;**22**:249–300.

21 Schanzer A, Goodney PP, Li Y, Eslami M, Cronenwett J, Messina L, et al. Validation of the PIII CLI risk score for the prediction of amputation-free survival in patients undergoing infrainguinal autogenous vein bypass for critical limb ischemia. *J Vasc Surg* 2009;**50**:769–75.

22 de Mutsert R, Grootendorst DC, Indemans F, Boeschoten EW, Krediet RT, Dekker FW. Association between serum albumin and mortality in dialysis patients is partly explained by inflammation, and not by malnutrition. *J Renal Nutr* 2009;**19**:127–35.

23 Owen Jr WF, Lew NL, Liu Y, Lowrie EG, Lazarus JM. The urea reduction ratio and serum albumin concentration as predictors of mortality in patients undergoing hemodialysis. *N Eng J Med* 1993;**329**:1001–6.