



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

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### 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.

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### 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.

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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

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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.<sup>1</sup> 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.<sup>1,2</sup> 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.<sup>3–5</sup> Good healing has been achieved by direct endovascular intervention at the artery feeding the angiosome where

ischaemic ulcers or gangrenes exist.<sup>6,7</sup> 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<sup>8</sup> 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

**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 <sup>a</sup> for iliac artery	24 (10%)
EVT for superficial femoral	4 (2%)
Anatomical bypass	16 (6%)
Extra-anatomical bypass	7 (3%)

<sup>a</sup> EVT: endovascular treatment.

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.

### 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<sup>®</sup>, 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

**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.

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