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A rationale for skew flaps in below-knee amputation surgery

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Abstract
The use of thermography in the assessment of amputation levels has demonstrated a medial to lateral thermal gradient in many cases. In order to see whether this reflected a true medial to lateral skin blood flow gradient, a prospective study was set up to measure blood flow medially and laterally below the knee. Twenty-one patients, presenting for amputation assessment with end-stage peripheral vascular disease, were studied. Skin blood flows were measured using an intradermal radioisotope clearance technique. Results showed a highly significant difference between medial and lateral skin blood flows ($t = 4.79$; $p < 0.001$). In view of the significantly higher blood flow in the medial skin of the lower leg, it is suggested that a more medially based posterior below-knee amputation skin flap may be of more value in some patients.

Introduction
Over the past 15 years, the long posterior flap has become accepted as the technique of choice for below-knee amputation (Robinson, 1972; Murdoch, 1975). The method was first suggested by Bickel and Ghormley (1943), but although Kendrick (1956) also recommended a longer posterior flap, it was not until relatively recently that extensive clinical results demonstrated its superiority over equally dissected flaps (Burgess and Romano, 1968; Hunter-Craig et al, 1970; Condon and Jordan, 1970).

Despite the current general acceptance of the benefits of the long posterior flap, there is little objective evidence to explain why skin blood flow is optimal posteriorly. It may be that, as is widely believed, the skin blood flow is enhanced by collateral supply from the underlying posterior calf muscles. However, in the severely ischaemic limb, femoral, popliteal and tibial vessel occlusion may well lead to the development of alternative collaterals upon which the skin blood flow will depend. If this is true, then it is likely that the long posterior flap may not always be the most favourable option, and that an alternative arrangement of skin flaps may offer an improved healing potential.

The potential of the thermographic method for outlining flaps is well recognised (Spence et al, 1981, 1984), and the technological improvement in modern cameras has made the isothermal definition of the level of viability a more realistic proposition. The authors have recently shown that the isothermal gradients, used in the definition of the level of viability in the ischaemic limb, are directly related to blood flow (Spence and Walker, 1984). Futhermore, it has been noticed for some time that the longitudinal thermal gradient which exists in the ischaemic limb tends also to run in a medial to lateral direction, especially so at the all important below-knee amputation level (Fig. 1.). It was therefore decided to test the hypothesis that the skin blood flow is better on the medial aspect of the ischaemic limb compared to the lateral in order to provide some objective evidence for a more medially based below-knee amputation flap.

Methods
Twenty-one patients with ages ranging from 56 to 90 years and a mean age of 75 years were included in the study. There were 13 males and eight females, including eight diabetics with associated large vessel disease. The patients presented to the vascular laboratory for limb viability assessment — 17 had distal gangrene ± rest pain and four had intractable rest pain only.

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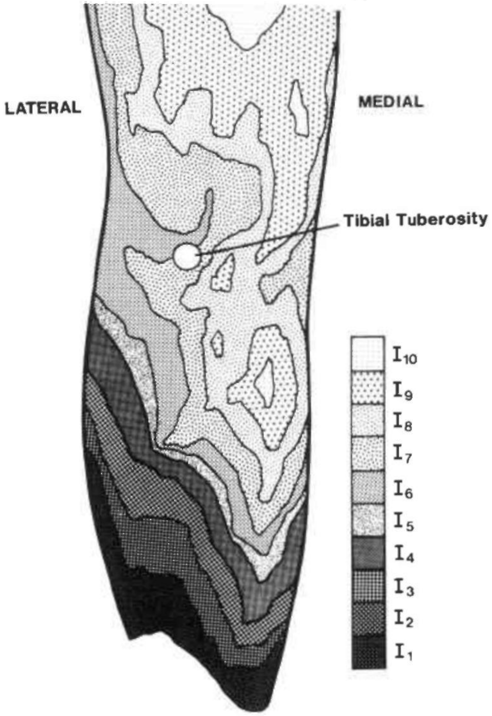

Fig. 1. Black and white reproduction of a colour thermogram. A density graded black and white scale (Ii to Iio) has replaced the colour coded thermal gradient. The thermal gradient which exists at the all important below-knee amputation level runs in a medial to lateral as well as a longitudinal direction.

All patients underwent routine laboratory investigations including segmental limb blood pressures, skin blood flow measurements and a thermographic evaluation of the affected leg.

Skin blood flows were determined by the radioisotope clearance technique using a stable compound of I-125 4-Iodoantipyrine (125 I-4-IAP), specially prepared in the Medical Physics Department (Forrester et al, 1980). Twenty microlitres of (125 I-4-IAP) were injected intradermally with a 28 gauge needle such that a small papule was raised on the skin surface. Two injections were made 10 cm distal to the tibial tuberosity: one 3 cm medial to the anterior tibial border and the other 3 cm lateral to this border. Skin blood flow (F) was calculated from the formula:

$$F = \frac{\ln 2 * \lambda * 100}{T\ 1/2}$$

when λ is the tissue blood partition coefficient which is unity for (125 I-4-IAP) (Carlin and Chien, 1977), and T 1/2 is the half time of the indicator clearance which can be calculated from the (125 I-4-IAP) washout curve.

Results

Medial and lateral skin blood flow measurements along with the corresponding limb pressure data are listed in the table. In 19 out of 21 patients the medial skin blood flow exceeds the lateral measurement, and, using a paired t test, the difference between them is highly significant ($t = 4.79$; $p < 0.001$).

Discussion

There is no doubt that in an ageing population the ability to perform successfully an amputation for end-stage peripheral vascular disease at the below-knee level greatly improves the chances of mobility and reduces patient morbidity (Lim et al, 1967; Romano and Burgess, 1971; Browse, 1973; Murdoch, 1977). However, there is still a disappointingly high rate of above-knee amputation in most centres. This is not altogether surprising, as the chances of a successful outcome to a below-knee amputation can vary from as low as 50% to as high as 97% (Warren and Kihn, 1968; Malone et al, 1981). There are several reasons for this considerable variation, but amongst the most important are the selection of the precise level of viability, surgical expertise and post-operative management (Thompson, 1974; Robinson, 1976; Burgess and Matsen, 1981). The selection of amputation level is particularly difficult in certain patients, and a method which not only assists in determining the level of amputation but also provides objective information on the viability of a specific skin flap is especially useful.

The use of the radioisotope clearance technique to measure skin blood flow has been extensively investigated (Bohr, 1967; Holstein and Lassen, 1973; Kostuik et al, 1976; Carr et al, 1977; Moore et al, 1981; Stockel et al, 1981), and its use as an objective means of assessment of the level of viability has been vindicated by Malone et al, (1981). However, the technique provides information from a point source only. This is why methods such as infrared thermography and fluorescein angiography have so much advantage, because whole areas of skin may be visualized simultaneously. In this study, skin blood flow measurements were made at standard reference points in every subject and the significant difference between the medial and lateral blood flow values supports the authors' previously unqualified observation that a medial to lateral isotherm gradient exists at the knee level in most ischaemic limbs. If one accepts that skin blood flow measurements provide a reasonable index of tissue viability, then it is likely that the differences seen between medial and lateral flows may provide a justification for alternative skin flaps.

A rationale for such a significant difference between medial and lateral skin blood flows must lie with the local vascular anatomy. Indeed there is recent experimental evidence in support of these findings. In a series of post-mortem angiographic studies, Haertsch (1981a) demonstrated that there were no perforating arteries penetrating the muscles of the anterior compartment, and thus none supplying the lateral skin of the lower leg, although he did find a few perforating arteries posteriorly. Moreover, he noted an axial supply to the skin on the medial and posterior aspects of the lower leg from the vessels accompanying the saphenous and sural nerves. These vessels are likely to be of particular importance where the popliteal and tibial vessels are occluded, as they may act as the main source of blood flow to the medial and posterior skin. Furthermore, Haertsch (1981b) demonstrated a network of arteries just superficial to the deep fascia of the lower leg from which this blood supply is primarily derived. This suggests that there is little need to include the gastrocnemius muscle belly on the grounds of augmenting collateral blood supply, as is done in myocutaneous flaps although the inclusion of a well bevelled muscle may simplify the formation of a neat stump. However, it is obviously important to include the deep fascia in any below-knee flap, as is routinely done at present. Indeed, Robinson et al, (1982) have described a technique for a laterally skewed below-knee amputation in which the muscle and skin flaps are essentially separated, and in which the muscle flap is used purely to effect a neat and functional stump end. However, Robinson et al used equal antero-lateral and posterior skin flaps which, on the

Table — Medial and lateral skin blood flow measurements.

No.	Sex	Age (yrs)	Diabetes	Ankle Pressure (mmHg)	A/B Ratio	Skin Blood Flow (ml/100g/min) Medial	Lateral	Outcome
1	M	77	No	82	0.52	5.6	2.0	BKA
2	M	73	Yes	120	0.86	14.4	4.0	BKA
3	F	90	No	50	0.31	4.0	3.4	died
4	M	72	No	30	0.20	2.9	2.1	AKA
5	M	57	Yes	40	0.26	10.7	8.6	BKA
6	M	75	No	>300	—	6.5	8.2	PFA
7	M	76	No	36	0.27	9.1	2.9	BKA
8	F	70	No	120	0.80	4.3	3.5	BKA
9	F	82	Yes	34	0.20	4.2	3.2	BKA
10	F	82	No	66	0.38	8.7	4.4	BKA
11	F	82	No	74	0.43	7.3	4.3	BKA
12	M	76	No	28	0.24	2.5	4.0	AKA
13	M	76	No	34	0.29	10.0	7.4	deferred
14	F	77	Yes	>300	—	6.9	1.0	BKA
15	F	83	Yes	32	0.16	4.2	3.9	BKA
16	M	76	No	64	0.40	13.9	7.3	AKA
17	F	83	Yes	150	0.71	12.6	7.8	PFA
18	F	56	Yes	160	0.87	16.9	10.6	Symp
19	M	79	Yes	>300	—	8.3	7.0	BKA
20	M	59	Yes	78	0.51	4.1	0.9	Symp
21	M	74	No	50	0.31	13.9	7.8	BKA

Mean Lateral Skin Blood Flow = 5.0 + 2.8 ml/100g/min
Mean Medial Skin Blood Flow = 8.1 + 4.3 ml/100g/min
AKA = above knee amputation
BKA = below knee amputation
PFA = part foot amputation
Symp = sympathectomy

basis of the present data, may not be the optimal choice. Their hypothesis was that the skin blood flow over the tibia was reduced, but this is not substantiated by the present data.

It seems possible that an attempt to preserve the end branches of the saphenous artery might be worthwhile, and therefore a medially (rather than laterally) skewed posterior flap is proposed as a reasonable alternative to the standard below-knee amputation. It is only necessary to skew this flap by about 45 degrees in order to incorporate the relevant vessels, as the new medial line of incision lies just anterior to the posterior tibial border and encompasses the long saphenous vein. There are therefore no insurmountable technical problems.

Accurate assessment of the skin circulation in the lower legs can lead to the planning of individual amputation flaps, and this can readily be achieved by thermographic delineation of the level of viability in conjunction with specific skin blood flow measurements. The results from this study highlight the importance of making these measurements in tissue viability assessment and suggest that a more medially based posterior flap be considered as an alternative in cases where the skin viability is marginal. A clinical trial is required to determine the efficacy of such a postero-medially based flap.

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