Selection of amputation level in ischemia

Skin blood flow and perfusion pressure equally predictive

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In 33 patients who had major amputation for ischemia of the lower extremity, skin blood flow and perfusion pressure were compared in terms of prediction of amputation level. Skin blood pressure was measured photoelectrically. Only the blood flow was known to the surgeon. The primary amputation was performed below the level of the knee in 15 patients, through-knee in 14, and above the knee in only 4 patients. Primary healing was achieved in 27 patients, 5 patients had delayed healing at the same level, and 1 patient was reamputated.

The same amputation level was predicted in 24 patients (primary healing/secondary healing/failure = 20/3/1) and a different one in 9 patients. In 4 patients the perfusion pressure suggested a more proximal amputation (2/2/0) and in 5 patients a more distal amputation (all primary healing). There was no difference between the two methods in predicting wound healing.

The benefit of peroperative determination of skin blood flow by the Xenon-133 technique (Moore 1973, Malone et al. 1981, Harris et al. 1986), as well as skin perfusion by the same method (Lassen et al. 1974, Holstein et al. 1979, Støckel et al. 1982), or by the photoelectric method (Holstein 1985, Støckel et al. 1982) is well established.

These two methods measure different physiologic properties: viz., perfusion and pressure. We have applied both methods in patients who had a major amputation and compared the prediction with the outcome.

Patients and methods

Thirty-six consecutive patients undergoing major amputations for ischemic gangrene were investigated. Three patients died before wound healing and were excluded. Thus, the series included 33 patients, 16 females and 17 males. The median age was 72 (38–91) years. Seven patients had previously undergone vascular surgery. Three patients had an aorticofemoral prosthesis implanted; 1 of these later had a femoro-femoro bypass. Another 4 had bypass operations: either a femoropopliteal (3) or a femorofemoro bypass. The artificial grafts were not extracted during the amputations. Thirteen patients had diabetes mellitus (Table 1).

According to the department's established routine, the selection of the amputation level was based on measurement of the skin blood flow supported by a clinical examination.

The skin blood flow was measured by the Xenon washout technique (Sejrsen 1971). Xenon 133 in saline with 200μg histamine was injected intracutaneously. The washout curve was recorded at four standardized measuring points: medially and laterally on the calf and thigh. A blood flow less than 1 mL blood/100 g tissue/min on the lateral, as well as on the medial side, was interpreted as incompatible with primary healing.

The skin blood pressure was measured at the same four points by a photoelectric method (Støckel et al. 1982). The external counterpressure was applied by a blood-pressure cuff under which the photodetector (Medimatic) was placed. The skin perfusion pressure was taken as the lowest external pressure sufficient to arrest blood flow in the skin. A skin perfusion pressure at 31 mmHg on the lateral as well as on the medial side was regarded as the lower limit at the amputation level (Holstein et al. 1979).

Skin blood flow and skin perfusion pressure were measured on the same occasion. The result of the skin perfusion pressure measurement was unknown

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Table 1. Skin blood flow (SBF) and skin perfusion pressure (SPP) in the calf and thigh of 33 patients with major amputation for ischemia of the lower extremity

A	B	C	D	E	F	G	H	I
1	M	63	2	1	2.2/110	2.5/90	2.2/85	3.0/80
2	M	75	3	1	7.0/120	1.6/60	7.0/70	3.2/65
3	M	52	1	1	2.8/60	8.0/110	5.3/60	9.4/100
4	M	66	1	2	3.2/50	3.4/45	2.0/75	1.6/60
5	F	65	1	1	2.8/50	1.7/35	4.5/50	4.2/50
6	M	71	1	1	5.8/70	6.1/70	5.8/120	1.9/120
7	M	79	1	2	0.4/5	3.5/5	2.9/70	2.2/70
8	M	79	1	2	4.0/35	2.7/30	4.4/65	4.1/60
9	F	68	2	1	1.7/45	1.3/60	4.5/60	4.5/60
10	F	72	1	1	6.0/40	3.9/50	3.2/60	6.1/90
11	M	31	1	1	2.9/90	5.3/80	1.8/ -	3.0/ -
12	M	76	2	1	5.3/35	5.7/10	9.9/55	8.6/40
13	F	76	1	1	3.1/80	1.8/75	- / -	- / -
14	F	91	1	1	1.5/80	1.0/80	2.1/90	0.6/90
15	M	79	1	1	5.9/50	5.4/85	8.1/55	8.2760
16	F	74	1	1	- / -	- / -	1.4/40	0.7/65
17	F	75	3	1	3.8/60	2.4/25	2.1/110	9.9/110
18	F	42	1	1	9.9/105	7.9/90	6.7/110	5.9/110
19	F	88	1	1	0.7/35	1.2/30	1.6/65	1.9/60
20	F	65	3	1	5.8/45	4.3/45	1.0/41	1.6/38
21	M	77	1	2	1.8/55	2.4/45	1.9/60	2.4/65
22	F	85	2	1	2.7/80	0.7/70	1.1/95	0.8/100
23	M	82	2	1	3.5/45	1.0/45	4.5/115	1.7/90
24	M	84	2	1	0.4/28	0.3/20	3.3/95	2.5/65
25	F	38	2	1	1.7/55	3.6/100	3.6/100	2.8/140
26	M	72	2	1	0.6/0	0.3/0	3.2/60	4.4/45
27	F	69	2	3	0.4/25	0.2/35	2.0/65	4.1/85
28	M	66	2	2	1.2/15	1.8/30	1.2/50	2.1/50
29	M	80	2	1	1.04/40	1.4/40	8.4/55	5.4/45
30	M	71	2	1	0.3/20	1.8/20	1.9/45	2.0/50
31	F	62	1	1	1.1/38	1.0/50	3.9/72	5.3/80
32	F	85	3	1	3.6/48	- / -	1.2/55	2.9/70
33	F	81	2	1	1.0/110	0.3/90	4.4/130	6.3/110

A Case
B Sex
C Age
D Amputation level
  1 below knee amputation
  2 through knee amputation
  3 above knee amputation
E Result
  1 primary healing
  2 secondary healing
  3 failure
F SBF/SPP calf, medial
G SBF/SPP calf, lateral
H SBF/SPP thigh, medial
I SBF/SPP thigh, lateral

to the surgeon. The median interval between the measurement and the operation was 6 (1–45) days.

All the below-the-knee amputations were sagittal (Persson 1974), whereas the through-the-knee amputations, as described by Kjølbye (1970), and all the above-the-knee amputations were performed with myoplastic technique. Methicillin and streptomycin were given for 3 days. Two suction drains were used, and the sutures were removed on Day 14.

Primary healing was defined as complete healing on Day 21, secondary healing as spontaneous healing after Day 21 or healing at the same level after further surgery. Reamputation was recorded as a failure.

Results

Primary healing was achieved in 27 patients; secondary healing in 5, and there was 1 failure (Table 1). In 4 patients the blood flow was below 1 mL/100 g tissue/min at the amputation level. One patient would only accept a below-the-knee amputation (Case 7); in 3 cases clinical examination suggested that primary wound healing was possible in spite of a reduced skin blood flow (Cases 16, 19, 22). In 7 cases the amputation was performed at a higher level than suggested by skin blood flow because of ulceration at the planned amputation level or contracture of the knee (Cases 1, 12, 17, 20, 23, 28, 29). In

Table 2. The clinical results and predicted level of amputation by skin blood flow (SBF) measured by 133-Xenon wash-out technique and skin perfusion pressure (SPP) measured by photoelectric method

	Predicted level		
	Same	SBF lower SPP higher	SBF higher SPP lower
Primary healing	20	2	5
Secondary healing	3	2	0
Failure	1	0	0
Total	24	4 [a]	5 [b]

[a] Cases 8 12 17 28
[b] Cases 22 23 25 29 33

2 cases, above-the-knee amputation was performed because the patients were in poor general condition and mobilization could not be expected (Cases 2, 32).

The same amputation level was predicted by the two methods in 24 cases (Table 2). In 4 cases, skin perfusion suggested a higher amputation level than skin blood flow. One below-the-knee amputation healed secondarily, and the remaining 3 patients had, for various reasons, an amputation performed at a higher level (2 healed primarily, 1 secondarily). In 5 patients, skin perfusion pressure suggested a lower amputation level than actually was carried out; all healed primarily.

The ability of skin blood flow and skin perfusion pressure to predict wound healing in cases where the amputation level was selected according to skin blood flow was evaluated. Through-the-knee amputations were excluded because the measurements were not performed at the amputation level. In the 15 patients, healing was predicted correctly by skin blood flow in 12 and by skin perfusion pressure in 13; both methods predicted incorrectly in the same 2 cases.

Discussion

In several studies, skin blood flow has proved to be of value in selecting the level for amputation (Moore 1973, Harris et al. 1986, Malone et al. 1981), but there is disagreement concerning the lower limit of skin blood flow. Malone et al. (1981) found healing in all the cases with skin blood flow over 2.6 mL/100 g tissue/min and healing in half the cases when the flow was between 2 and 2.6 mL. Harris et al. (1986) reported healing when skin blood flow was more than 1 mL/100 g tissue/min. However, Holloway and Burgess (1978) were not able to document a clear-cut end point for skin blood flow above which all the amputations healed, and in a more recent investigation Malone et al. (1987) found skin blood flow unreliable for selecting the amputation level.

Skin perfusion pressure measured by the photoelectric technique seems to give results similar to those obtained by the isotope washout technique (Holstein et al. 1980, Støckel et al. 1982). The reproducibility was high, and healing was achieved in 24 of 29 cases in which the amputation level was guided by skin perfusion pressure measured by the photoelectric method (Støckel et al. 1982).

However, the two techniques have not previously been compared in the same patients. We found agreement between the two methods in 24 of 33 cases. Falsely high skin perfusion pressure has been detected in some patients suffering from severe arteriosclerosis that was probably due to calcified non-compressible vessels—a phenomenon especially found among diabetic patients (Gibbons et al. 1979). Out of the 5 cases in our series in whom skin perfusion pressure suggested a lower amputation level than skin blood flow, 3 were diabetics.

Only 15 cases were suitable for a comparative study of the clinical applicability of the methods. With reservation for the small size of our material, no difference could be found. Wound healing is dependent on other factors than blood flow, e.g., infection (Squires et al. 1982) and nutrition (Dickhout et al. 1984). Such factors might have been present in the 2 cases where wound complications occurred despite a sufficient blood flow according to both methods.

We had no difficulties in reading the photoelectric curves. The photoelectric method is more rapid than the isotope washout, and it is also better tolerated by the patients. Therefore, we recommend this method for routine preoperative selection of the amputation level in patients with severe arterial disease.

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