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LEVEL SELECTION IN LEG AMPUTATION FOR ARTERIAL OCCLUSIVE DISEASE

A Comparison of Clinical Evaluation and Skin Perfusion Pressure

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In 102 leg amputations for arterial occlusion including 84 below-knee (BK), 16 above-knee (AK) and 2 through-knee (TK) amputations, the amputation level was determined by means of clinical criteria. The healing results and the selection of levels were then compared with sealed preoperative measurements of the skin perfusion pressure (SPP). Out of 62 BK amputations with an SPP above 30 mmHg wound healing failed in only 2 cases (3 per cent). Out of 13 BK amputations with an SPP between 20 and 30 mmHg 7 cases (54 per cent) failed and out of 9 BK amputations with an SPP below 20 mmHg no less than 8 cases (89 per cent) failed to heal. The difference in failure rate is significant ($P < 0.0001$). Out of the 15 failed BK amputations at low pressures (below 30 mmHg) only one case had local signs of ischaemia, which might have warned the surgeons. On the other hand, in 13 out of the 18 cases of primary AK (or TK) amputations there were clinical signs of ischaemia of the calf, comprising temperature demarcation, cyanosis and/or necrotic skin lesion. The SPP below the knee appeared in all these cases to lie below 30 mmHg. In the 5 other cases of primary AK (or TK) amputation the knee was sacrificed for reasons other than signs of local ischaemia, e.g. poor physical or mental condition. It was moreover found that the presence of pulsations in the popliteal artery indicated an 89 per cent chance of healing of BK amputations. Infection was present in 24 BK amputations (28 per cent) and equally frequent among diabetic and non-diabetic cases. The postoperative SPP measured on the stumps averaged only 5 mmHg ($P < 0.05$) higher than the preoperative SPP explaining why the preoperative SPP related closely to the postoperative course. It is concluded that ischaemia at the BK election site cannot be ruled out by clinical assessment alone and that preoperative determination of the SPP can be used in determining the chance of healing in BK amputations.

Key words: amputation; diabetes; ^{131}I-antipyrine; ischaemia; level selection in amputation; occlusive arterial disease; skin blood pressure; skin perfusion pressure.

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In recent literature it has been demonstrated that ischaemic wound complications can be expected when major amputation for severe occlusive arterial disease of the legs is performed with local skin perfusion pressures (SPP) below 20 to 30 mmHg (Holstein 1973, Lund & Sager 1977, Holstein et al. 1979 a, b, Kolind-Sørensen & Marqversen 1979). The present study was undertaken to compare conventional clinical level selection with measurements of the local skin perfusion pressure (SPP).

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Table 1. Number of amputations in the two orthopaedic departments divided according to age, the selected level and the presence of diabetes mellitus (DM)

	Years of age	≤50		51–60		61–70		71–80		81–90		91–100		Total	Arithmetic mean age
	Diabetes mellitus (DM)	–DM	+DM	–DM	+DM	–DM	+DM	–DM	+DM	–DM	+DM	–DM	+DM		
Department O	Primary BK amp.			2	2	7	6	11	12	6		1		47	72.7
	(Failed BK amp.)			(1)	(2)	(3)		(1)	(2)	(1)				(10)	(60.7)
	Primary AK amp.				1	1		1	1	1	1	1		7	75.9
														54	73.1
Department T-2	Primary BK amp.	1	1	3	3	7	3	10	7	3	2			40	68.5
	(Failed BK amp.)			(2)		(3)				(2)				(7)	(64)
	Primary AK or TK amp.					3		5	1	2				11	76
														51	69.6
	Whole series													105	

PATIENTS AND METHODS

Patients. A prospective study over a 2½-year period (1.9.1972–1.3.1975) was made by the Department of Orthopaedic Surgery O, County Hospital, Hillerød, the Department of Orthopaedic Surgery T-2, County Hospital, Gentofte and the Department of Clinical Physiology, Bispebjerg Hospital, Copenhagen. The series comprises all patients referred for measurement of the skin perfusion pressure (SPP) before major amputation and consists of 99 patients undergoing 105 major amputations: 87 amputations at the below-knee (BK) level (81 patients), 16 amputations at the above-knee (AK) level (15 patients) and 2 amputations at the through-knee (TK) level (2 patients).

Details of the series including age, sex, selected level of amputation and the presence of diabetes mellitus, according to blood sugar determinations, are shown in Tables 1 and 2. Since only one out of the six patients undergoing bilateral amputation in the period studied had both operations performed at the same time, we consider each amputation as one case and unless otherwise indicated the numbers in Tables, Figures and calculations refer to the numbers of amputations.

Measurements of the SPP. The SPP was measured as that external counter pressure which was just sufficient to stop the washout of an intra-dermal depot of radioactive isotopes ($^{131}I^-$- or $^{125}I^-$-antipyrine mixed with histamine). The technique has been described previously (Holstein et al. 1977, Holstein et al. 1979a). The site of measurement was approximately 10 cm distal to the knee joint on the anterolateral side of the calf just superficial to the anterior tibial muscle. The SPP below the knee on the contralateral leg was also measured and served as a control. In patients in whom a contralateral AK amputation had previously been performed the control point was chosen to be 15 cm proximal to the end of the stump on the anterolateral side. The preoperative measurements were made within a week before the surgery. About 8 weeks after surgery the SPP was again measured at the same sites. During

Table 2. The number of amputations in the two orthopaedic departments divided according to sex, the presence of diabetes mellitus (DM) and treatment with insulin

	Male/Female ratio	+DM/–DM ratio	Arithmetic mean age		Duration of DM (years)			Taking insulin
			–DM	+DM	<5,	5–10,	>10	
Department O	31/23=1.35	23/31=0.74	74.9	70.7	7	3	13	16
Department T-2	25/26=0.96	17/34=0.50	69.8	69.2	3	6	8	8

all measurements the patients were examined in the supine position with horizontal legs. Repeated i.v. doses of analgetics (demerole, 35 mg) sufficient to prevent involuntary movements from pain were given and, in addition, the legs were supported by sandbags. The arm blood pressure was measured repeatedly using a 12 by 26 cm blood pressure cuff placed around the left arm. Before the examinations the thyroid gland was blocked with 0.5 g potassium iodide given perorally in solution.

Selection of level. The level of amputation was selected by senior members of the surgical staff according to conventional clinical criteria including the condition of the patient, the presence and extent of skin lesions, the level of temperature demarcation, the presence of pulsations and the bleeding at the operation. The preoperatively measured SPP values were not disclosed to the surgeons until postoperative measurements had been made about 8 weeks after surgery. In the case of re-amputation as an emergency, however, postoperative measurements were expedited if at all possible.

SURGERY

BK amputations. In Department O all 47 BK amputations were performed with the *sagittal* technique (Robb et al. 1965, Persson & Sundén 1971). The stumps were padded and dressed in closed circular bandages using elastic plaster of Paris bandage. Sutures were removed 11 to 21 days after operation. Immediate fitting systems were not used, but the patients were mobilized as soon as possible on crutches possibly with a splint. In Department T-2 the *long posterior flap* technique (Bichel 1943, Burgess et al. 1971) was used in all but four cases, in which the sagittal technique was used. Postoperatively the stumps were padded and dressed in closed circular bandages using ordinary plaster of Paris. A few patients were allowed to walk immediately with a pylon, but only when the operation had demonstrated bleeding with vigorous pulsations. Sutures were removed 14 to 21 days after surgery.

Levels higher than BK. In 16 cases undergoing AK amputation the level was mid-thigh or low mid-thigh with anterior and posterior flaps of about equal length. In two cases through-knee (TK) amputations using sagittal flaps were used.

Systemic antibiotics guided by cultures were given in cases of deep infection after surgery. Preoperative antibiotics were not used prophylactically.

Primary healing was defined as complete healing of the wound at the end of the fourth postoperative week. Healing by second intention was defined as healing at a later time, possibly after surgical revision provided that the BK level was maintained. Re-amputation from BK to AK level was considered as a failure (no BK amputations were revised to TK level).

RESULTS

Mortality. Within 1 month from the operation 8 patients died (3 patients from Dept. O and 5 from Dept. T-2), 4 after BK amputation (4.9 per cent) and 4 after AK amputation (25 per cent). In 3 cases of death after BK amputation the sutures had not yet been removed and since wound healing was not assessed these cases were excluded from the analysis below. In the fourth case of death after BK amputation the stump had broken down due to deep necrosis and a re-amputation at AK level had been planned. This case is included as a failure in the analysis below which thus comprises 102 cases.

The preoperative SPP. Table 3 shows the results of diabetics and non-diabetics, the results from the two different orthopaedic departments and of the two surgical techniques in relation to the SPP.

Figure 1 shows the level selection and the healing results below the knee in all the 102 cases.

BK amputations. According to previous investigations (Holstein et al. 1979 a, b) and in agreement with the appearance of the histogram (Figure 1) the amputations were classified into three groups: with SPP below 20 mmHg, with SPP within the range 20 to 30 mmHg and with SPP above 30 mmHg.

In 9 cases of BK amputation the SPP was below 20 mmHg. In 8 of these cases (89 per cent) wound healing failed. Deep necrosis developed in 7 cases – in 4 cases combined with deep infection. Re-amputation at AK level had to be performed in 7 cases and in one case the patient died before the planned re-amputation. The re-amputations were prompted by severe pain and a deteriorating general condition – except in one case where the re-amputation was postponed for a year while waiting for healing.

Only one BK amputation with an SPP below 20 mmHg healed, and healing was only completed after 6 months. The stump had then a flexion contracture of 45 degrees. The patient

Table 3. The selected level and the healing of BK amputations in 102 evaluated cases of major amputation in relation to the preoperative skin perfusion pressure (SPP)

SPP	<20 mmHg				21–30 mmHg				>30 mmHg			
	Prim. BK			(Prim. AK	Prim. BK			(Prim. AK	Prim. BK			(Prim. AK)
	Prim. healing	Sec. healing	Failure	or TK)	Prim. healing	Sec. healing	Failure	or TK)	Prim. healing	Sec. healing	Failure	
Without Dept. O	0	0	3	(1)	0	2	2	(1)	16	4	0	(2)
DM Dept. T2	0	0	3	(6)	1	1	3	(4)	7	7	1	(0)
$n = 64$												
	0	0	6	(7)	1	3	5	(5)	23	11	1	(2)
	(a)		(b)		(a)		(b)		(a)		(b)	
With Dept. O	0	0	2	(1)	0	2	2	(1)	4	8	1	(1)
DM Dept. T2	0	1	0	(0)	0	0	0	(1)	9	5	0	(0)
$n = 38$												
	0	1	2	(1)	0	2	2	(2)	13	13	1	(1)
	(c)		(d)		(c)		(d)		(c)		(d)	
Whole series	0	1	8 (89%)*	(8)	1	5	7 (54%)**	(7)	36	24	2 (3%)***	(3)
	(e)		(f)		(e)		(f)		(e)		(f)	
Sagittal technique	0	0	5 (100%)		0	4	5 (55%)		22	12	2 (5.5%)	
$n = 50$	(g)		(h)		(g)		(h)		(g)		(h)	
Long posterior flap technique	0	1	3 (75%)		1	1	2 (50%)		14	12	0 (0%)	
$n = 34$			(i)				(i)				(i)	

Distribution a: $P < 0.01$; b: $P < 0.0001$; c: $P > 0.1$; d: $P < 0.05$; e: $P < 0.001$; f: $P < 0.0001$; g: $P < 0.01$; h: $P < 0.001$; i: $P < 0.01$ (Rank sum tests)
Confidence limits (95%): * 51.8–99.7%; ** 25.1–80.8%; *** 0.4–11.2%
BK = BK amputation; AK = AK amputation; TK = TK amputation; Prim. = primary; Sec. = secondary

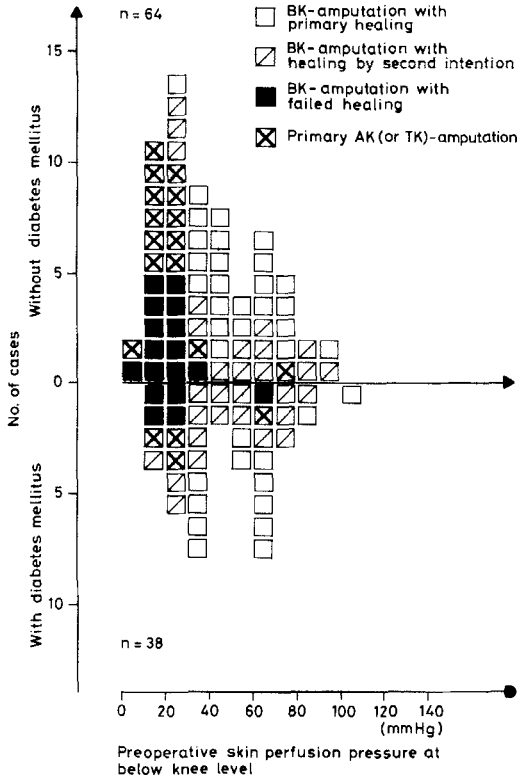

Figure 1. Level selection and healing results in 102 cases of major amputation.

died 2 months later. Thus the results of BK amputations at this low SPP were very poor.

With an SPP of 20 to 30 mmHg 7 out of 13 BK amputations had to be revised to AK level (54 per cent) due to deep necrosis and infection. In 5 cases minor defects delayed the healing and only in one case was primary wound healing obtained. Obviously SPP values of 20 to 30 mmHg constitute the "grey zone" with regard to healing.

With an SPP of above 30 mmHg wound healing below the knee failed in only 2 out of 62 cases (3 per cent). In one of these cases with an SPP of 68 mmHg, i.e. an approximately normal value, re-amputation at AK level had to be carried out after repeated revisions because of deep infection. In the other case, with an SPP of 33 mmHg, re-amputation was performed because of deep necrosis in combination with infection. The preservation of the knee in the other 60 cases was obtained with primary healing in 36 cases and with secondary healing in 24 cases, including 5 cases where surgical revision consisting of excision of necrosis, possibly with reclosure of the wound, was carried out. Thus wound complications were frequent also with adequate circulation but in most cases there were only minor defects, which healed uneventfully.

AK amputations. Table 4 lists the 18 cases selected for primary AK (or TK) amputation. In 9 cases the SPP as measured below the knee was less than 20 mmHg. In none of these cases was the skin intact at the usual site suitable for BK amputation. In one of these cases a TK amputation was performed, but because of necrosis revision to AK amputation was later carried out.

In 7 cases the SPP below the knee was within the range 20 to 30 mmHg. In only 2 of these cases was the skin on the calf intact; AK amputation was chosen in one of these cases because the patient insisted and in the other case because a re-

Table 4. Clinical findings in patients selected for primary AK (or TK) amputation

No. of AK (or TK) amputations	Skin perfusion pressure at BK level (mmHg)	Skin at BK level			Other factors* contributing to AK level	Poor physical and mental condition
		Temperature demarcation	Cyanosis	Ulceration or necrosis		
9	<20	3	4	6	3	5
6	20–30	1	1	2	2	2
3	>30	0	0	2	1	2

* Other factors:
Severe oedema, 2 cases; steroid skin changes, 2 cases; paralysed leg (poliomyelitis), 1 case; uraemia, 1 case.

cent contralateral BK amputation had not yet healed. In one of the other cases with ulceration on the posterior surface of the calf a TK amputation healed primarily.

In three cases AK amputation was performed in spite of an SPP below the knee that was more than 30 mmHg. In these cases there were ulcerations on the calf and/or poor physical condition. Healing was accomplished in all the 14 patients surviving AK amputation.

Clinical signs of poor circulation

Skin temperature demarcation line. This was found at the standard site for BK amputation in 5 cases. Distal to the demarcation line the SPP was below 20 mmHg and 5 cm proximal to the demarcation it was of the order of 20 to 30 mmHg. Thus the skin area just above the demarcation constitutes a borderline zone as regards wound healing. Only in one of these cases was a BK amputation tried. The stump, however, broke down because of infection and necrosis. The four other cases were selected for primary AK (or TK) amputation.

Cyanosis. In 5 cases cyanosis of the skin extended to the knee or even more proximally. The SPP at BK level was below 20 mmHg in 4 cases and 23 mmHg in one case. Thus local cyanosis points to severe ischaemia, that is, of course, if venous engorgement or shock can be excluded.

Ulceration. In 18 cases one or more ulcerations on the calf close to the election site of BK amputation were present (Table 5). The SPP was above 30 mmHg in as many as 9 of these cases and the BK amputations as performed in 7 cases resulted in healing. Ulcerations therefore do not necessarily indicate ischaemia. On the contrary their appearance as regards granulation tissue, necrosis, localization, size and depth obviously demonstrate the viability of the tissues.

Pulsation. Table 6 shows that the level of the most distal palpable pulsations is correlated with level selection, the healing of BK amputation and with the SPP. The presence of pulsations in the popliteal artery signifies an almost 90 per cent chance of healing of BK amputations, whereas the presence or absence of pulsations in the groin are of little value in level selection.

Bleeding at the operation. A quantitation has not been attempted. It is likely that vigorous bleeding at the operation has been of help in maintaining many BK levels. Only in one case did the lack of bleeding lead to a switch from a planned BK amputation to an AK amputation – and obviously judgement of the bleeding did not prevent ischaemic failures.

Diabetes mellitus. Five out of 34 diabetic BK amputations failed (15 per cent) as against 12 out of 50 non-diabetic cases (24 per cent). Fifteen non-diabetic cases, however, had an SPP below 30 mmHg as against only 7 diabetic cases with this low SPP. On average the SPP was lower in the non-diabetic group than in the diabetic group: 47 mmHg (range 8–98) compared to 51 mmHg (range 18–108) $P > 0.1$. The healing of BK amputations was significantly correlated with the SPP in diabetics as well as in non-diabetics.

Table 5. Skin lesions on the calf in 18 cases in relation to skin perfusion pressure (SPP) and to selected level of amputation

SPP below the knee (mmHg)	Cases with ulcerations and/or necrosis on the calf (n = 18)	Primary BK amputation		Primary AK (or TK) amputation
		Healed	Failed	
<20	6		1	5
20–30	3			3
>30	9	7		2

Table 6. Selection of amputation level, healing of BK amputation and preoperative skin perfusion pressure (SPP) in relation to the level of the most distally palpable pulsations

	Pulsation in the popliteal artery $n = 18$		Pulsation in the femoral artery $n = 66$		No pulsation in the femoral artery $n = 18$
Primary BK amputations	17		54		13
(failed BK amputations)*	(1)		(9)		(7)
Primary AK amputations	1		12		5
Healed BK amputations in per cent*	16/18 = 88.9%		45/66 = 68.2%		6/18 = 33.3%
SPP mean (mmHg)	69.7		40.6		28
		$P < 0.0001$		$P < 0.01$	
SPP range (mmHg)	(43–112)	Mann-Whitney	(0–98)	Mann-Whitney	(0–73)

* Significantly correlated with level of palpable pulsations: $P < 0.01$ (Rank-sum)

Infection. Infection of the amputation wounds was present in 24 out of 84 BK amputations (28 per cent) and in 3 out of 16 AK amputations (19 per cent). Surprisingly, the infection rate was about equal in diabetics and in non-diabetics: 9 out of 35 diabetic BK amputations (26 per cent)

Table 7. The preoperative skin perfusion pressure (SPP) compared with the postoperative SPP in 73 BK amputations

		Preoperative SPP mean mmHg	range mmHg	P value (Wilcoxon)	Postoperative SPP mean mmHg	range mmHg
Amputated leg	Sagittal technique $n = 41$	48.9	13–93	0.05<<0.10 <0.05	52.3 [53.4]	18–93 [18–97]
	Long posterior flap technique $n = 32$	51.6	8–108	<0.001 <0.001	58.2 [59.8]	23–118 [26–107]
	Total $n < 73$	50.1	8–108	<0.01 <0.001	54.9 [56.2]	
Contralateral leg	With sagittal technique $n = 41$	65.6	23–128	>0.1 >0.1	64.9 [64.8]	18–103 [15–90]
	With long posterior flap technique $n = 32$	70.1	33–108	>0.1 >0.1	69.7 [72.5]	33–118 [36–111]
	Total $n = 73$	67.6		>0.1 >0.1	67.0 [68.2]	

Figures in brackets: Values corrected for changes in systemic blood pressure.

Table 8. The healing of BK amputations in relation to the postoperative skin perfusion pressure (SPP) in 76 evaluable cases

SPP	<20 mmHg			21–30 mmHg			>30 mmHg		
	Prim. healing	Sec. healing	Failure	Prim. healing	Sec. healing	Failure	Prim. healing	Sec. healing	Failure
Without DM	0	0	3	0	2	6	23	12	0
$n = 45$	(a)		(b)	(a)		(b)	(a)		(b)
With DM	0	0	2	0	2	1	8	16	1
$n = 31$			(c)			(c)			(c)
Total	0	0	5* (100%)	0	4	7 (64%)	31	28	1 (2%)
	(d)		(e)	(d)		(e)	(d)		(e)

* This figure includes 3 cases with necroses of the entire stump, which by definition have been classified as stumps with zero pressures.
Prim. = primary; Sec. = secondary; DM = diabetes mellitus.
Distribution a: $P < 0.01$; b: $P < 0.0001$; c: $P < 0.05$; d: $P < 0.01$; e: $P < 0.0001$ (Rank sum tests)

and 15 out of 49 non-diabetic BK amputations (31 per cent). Wound healing failed in 14 out of the 24 infected BK amputations. Infection must be considered the main cause of failure in the case where the SPP was 68 mmHg.

The surgical procedures. The healing rates of BK amputations in the two different departments were equal: Department O: 78.3 per cent and Department T-2: 81.6 per cent ($P > 0.1$). In emphasizing that our study was not designed to compare the two different surgical techniques, it should, however, be mentioned that the healing rate for BK amputations with the sagittal technique was 76 per cent and with the long posterior flap technique it was 85 per cent ($P > 0.10$). The difference which is not significant can be ascribed to the finding of more low pressure stumps among the sagittal amputations. In both groups the healing rates were significantly correlated with the SPP (Table 3).

The postoperative SPP. Postoperative measurements, including control measurements on the contralateral leg, were made in 73 cases. Table 7 shows that the average SPP on the stumps was about 5 mmHg higher than the SPP at the identical site measured preoperatively ($P < 0.01$). On the contralateral leg no difference was found between the preoperative and the postoperative average SPP.

The figures for the postoperative SPP in relation to wound healing parallel the preoperative figures (Table 8). The average SPP in diabetic cases was again higher than in non-diabetic cases: 60.0 mmHg compared to 51.7 mmHg ($P < 0.01$).

Rehabilitation. The patients returned to their own homes in 58 out of 80 cases after BK amputations (73 per cent) and in 6 out of 15 cases after AK amputations (40 per cent). Of the 85 cases of BK amputations, where the patients were capable of independent walking prior to amputation, gait rehabilitation with a prosthesis was achieved in 59 cases (69 per cent). The ability to walk was not regained in the remaining 26 cases due to death in 7 cases, disability from other diseases in 5 cases, bilateral amputation in 4 cases and poor physical and mental condition in 10 cases. Of the 14 AK (or TK) amputees who were able to walk prior to amputation only 3 regained walking capacity with a prosthesis.

DISCUSSION

The predictive value of the SPP as regards wound healing after amputation for ischaemic disease (Holstein 1973, Lund & Sager 1977, Holstein et al. 1979a, b, Kolind-Sørensen & Marqversen 1970) has been confirmed in the present study. In fact none of the BK amputations with an SPP below 20 mmHg were successful, whereas the healing rate at above 30 mmHg exceeded 90 per cent.

Clinical level selection implies consideration of the general condition and situation of the patient as well as a number of local anatomical and functional findings. It may be difficult to evaluate the importance of each factor in the individual case. However, the SPP measurements can be used as a basis for the decision regarding the amputation level. In this series nearly all primary AK (or TK) amputations were made in cases where there were local signs of ischaemia and where the SPP confirmed that a BK amputation would have had only a poor chance of healing. This means that clinical signs of ischaemia at the site considered for surgery were reliable when they were present.

On the other hand, the lack of signs of local ischaemia is no guarantee against ischaemic failures. This is demonstrated by the fact that 7 out of 17 failed BK amputations – in spite of apparently normal skin – had SPP values of below 20 mmHg. Moreover 7 out of the 9 other failed BK amputations had SPP values in the grey zone, viz. of the order of 20 to 30 mmHg. These figures which are in agreement with previous studies (Holstein 1973, Holstein et al. 1979, Kolind-Sørensen & Marqversen 1979) show that a certain number of cases doomed to failure after BK amputation cannot be sorted out preoperatively by clinical examination alone. Consequently, objective measurements provide the possibility of reducing substantially the number of ischaemic failures. To save the knee in as many cases as possible requires, on the other hand, an occasional attempt at BK amputation even when the SPP shows borderline healing possibilities. Taking this concept into account, ischaemic failures can not be completely avoided.

Palpable pulsations are one of the clinical signs which can be analysed. Several authors have found that the rate of healing increases when the distance between palpable pulsations and amputation level decreases (Silbert & Haimovici 1954, Harris et al. 1961, Wheelock 1961, Lempke et al. 1963, Stahlgren & Ottemann 1965, Warren & Kihn 1968). As demonstrated in the present and in other recent studies (Burgess et al. 1971, Holstein et al. 1979a) the most reliable clinical finding is the presence of pulsations in the popliteal artery, which indicates about a 90 per cent chance of healing of a BK amputation. The SPP in this situation has invariably been found to be about normal and it is the authors' opinion that the healing rate ought to be very close to 100 per cent.

Measurement of skin temperature has not been proven to be of value for level selection in amputations, perhaps because paradoxical reactions often occur (Kövamees 1968, Jorfeldt 1978). The skin temperature was not measured in the present series, but in 5 cases a temperature demarcation line could easily be felt by hand at the below knee election site. This sign – and also cyanosis – indicated that wound healing would not take place. The presence and appearance of a skin lesion at the selected level and the bleeding at operation is undoubtedly of help in judging the circulation, but objective measurements are necessary because reliable clinical criteria, such as popliteal pulsations, temperature demarcation lines and cyanosis, are found only in a limited number of the cases.

Infection in amputation surgery was highlighted by Lempke et al. (1963) who classified stump break down as caused by either infection or ischaemia. Weaver et al. (1973) demonstrated the importance of external infection due to contamination in the operating theatre or in the ward and often with organisms identical with those found in the gangrenous lesions. Measurement of the SPP further elucidates the infection problem: in a previous investigation (Holstein et al. 1979a) infection was the main cause of failures in non-ischaemic stumps, i.e. with an SPP above 30 mmHg, and was a concomitant phenomenon to necrosis in cases with SPP in the "grey" zone. Lund & Sager (1977) found that infection was present in all failures regardless of the SPP and in

the present study infection was present in 24 BK amputations, including 14 out of the 17 failures. Lempke et al. (1963) used preoperative antibiotics as a routine but the healing rate (71 per cent) of BK amputations in their series was not superior to the results in our series in which antibiotics were not used routinely. Better antibiotics, however, are now available and there is a need for controlled studies to determine their impact in amputation surgery. It is likely that failures with a normal SPP, caused primarily by infection, can be eliminated as well as many cases of delayed secondary healing.

Although SPP values of above 30 mmHg allow healing of BK amputations in nearly all cases, there were, even at this pressure level, a substantial number of wound complications. Such complications are probably due to minor imperfections in the treatment program, viz. the surgical technique, the application of a suitable dressing and the pre- and postoperative care. Measurement of the SPP offers a tool for comparing the impact of new approaches.

Since postoperative values of SPP were known by the surgeons the possibility exists that laboratory data and not the clinical criteria were the determinants for revisions to the AK level. A failed BK amputation in this series implied, however, deep necrosis and pains in 15 out of 17 cases. One of the remaining two cases was revised to the AK level after 1 year of observation of a non-healing ulcer on the stump. Revision in the other case was necessitated by lack of soft tissue after several surgical revisions. "Failures" are thus based on clinical findings and events and not on the SPP values. Moreover the statistical analysis shows that wound complications *per se* were significantly correlated with the SPP, a finding which cannot be biased by open SPP values in the postoperative course.

The technique of measuring the SPP is only one way of determining segmental limb blood pressure. Systolic blood pressures by the Doppler ultrasound technique are also reported to be valuable in the determination of the amputation level (Barnes et al. 1976, Wagner & Buggs 1978). Systolic blood pressures of above 70 mmHg or an index (i.e. the segmental systolic blood pressure divided by the brachial systolic blood pressure) of above 0.45 have been found to indicate healing in more than 90 per cent of the amputations. Obviously the two different techniques should be directly compared before a detailed discussion is justified. However, it is the authors' opinion that whatever method is used, it is the absolute local pressure values and not the index which is important in level determination. This is so because the potential of tissue perfusion is determined by the driving pressure, i.e. the difference between the actual local arterial blood pressure and the local venous pressure. The pressure index yields in principle no information about the local perfusion. It is a measure of the arterial narrowing caused by the occlusive process between the aorta and the site of measurement.

Concerning the amputation level more information about healing at low Doppler ultrasound pressures is necessary. If the pressure values considered to be required for healing are defined too high, then too many knees will be sacrificed.

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