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WOUND HEALING IN ABOVE-KNEE AMPUTATIONS IN RELATION TO SKIN PERFUSION PRESSURE

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In 59 above-knee amputations healing of the stumps was correlated with the local skin perfusion pressure (SPP) measured preoperatively as the external pressure required to stop isotope washout using $^{131}I^-$- or $^{125}I^-$-antipyrine mixed with histamine. Out of the 11 cases with an SPP below 30 mmHg no less than nine (82 per cent) suffered severe wound complications. Out of the 48 cases with an SPP above 30 mmHg severe wound complications occurred in only four cases (8 per cent). The difference in wound complication rate is highly significant ($P < 0.01$). The postoperative SPP measured on the stumps was on average only slightly and insignificantly higher than the preoperative values, explaining why the preoperative values related so closely to the postoperative clinical course. We conclude that the SPP can be used to predict ischaemic wound complications in above-knee amputations as has previously been shown to be the case in below-knee amputations.

Key words: amputation; diabetes; $^{131}I^-$-antipyrine; ischaemia; occlusive arterial disease; skin perfusion pressure

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In spite of every effort being made to save the knee in patients subject to major amputation for arterial occlusive disease, an above-knee (AK) amputation must be considered the only possible treatment in regrettably many cases. The circulation below the knee may be so compromised that a below-knee (BK) amputation is doomed to failure or the general condition of the patient may be so poor that local complications of a BK stump cannot be tolerated.

However, a great number of wound complications also occur in AK amputations. In BK amputations wound complications can be predicted by preoperative measurement of the local skin perfusion pressure (SPP) (Holstein 1973, Lassen & Holstein 1974, Holstein et al. 1979). If wound complications can be predicted also in AK amputations then measurements of the SPP may influence the selection of stump length. The present study was undertaken to elucidate this problem.

PATIENTS AND METHODS

Patients. In a 2-year period (1.1.1972–1.1.1974) 62 AK amputations for gangrene and/or intolerable pain at rest were performed in the 58 patients studied. The distribution according to age, sex and the presence of diabetes mellitus is shown in Table 1. The duration of diabetes mellitus was 5 years or less in 5 cases and 10 years or more in 6 cases. Six patients were taking insulin and 12 patients were treated by peroral hypoglycaemics and/or a special diet. Nine patients had previously had a contralateral major

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amputation and in 15 patients the AK amputation was secondary to a failed major amputation at a more distal level: in 14 cases below the knee, and in one case through the knee (TK). Forty-nine of the patients undergoing AK amputation were capable of independent walking up to the period of major amputation.

The surgical technique used was simple amputation at midthigh or low midthigh level, the anterior flap often being longer than the posterior flap. Myoplasty was not used. Suction drainage was employed in most cases and the wound was dressed loosely (Tube gauze®). Sutures were removed on the 14th to the 21st postoperative day. The patients were mobilized as soon as possible in a wheel chair or on walking appliances. Prosthetic fitting was undertaken when the stump was well healed.

Measurement of the SPP. The SPP was determined as that external counterpressure, which was just sufficient to stop the washout of an intradermal depot of radioactive isotopes ($^{131}I^-$- or $^{125}I^-$-antipyrine mixed with histamine). The technique has been described previously (Holstein et al. 1977). The site of measurement preoperatively was 10 cm proximal to the upper margin of the patella on the anterolateral side of the thigh, i.e. in most cases within a range of about 5 cm from the selected level of amputation. In the 4th to 8th postoperative week measurements were again performed 10 to 15 cm proximal to the end of the stump. Thus the postoperative measurements were often made at a more proximal site than the preoperative measurements. Control measurements were performed pre- and postoperatively on the contralateral leg preferably below the knee.

Statistics. *P* values were determined by rank sum tests, by Fisher's exact test and by Wilcoxon's test for paired comparisons.

RESULTS

Mortality. Fourteen patients (24 per cent) died postoperatively during hospitalization, six of these (10 per cent) within 1 month after the amputation. Six patients (10 per cent) died with severe wound complications of the stump. Two of these had bilateral AK amputations; one died with bilateral stump necrosis and the other died with necrosis of one stump and with the sutures still *in situ* on the other – intact – stump. Six patients died with well healed stumps and two patients died with the sutures not yet removed from an intact stump.

Thus analysis of wound complications in relation to the preoperatively measured SPP (see below) could be made in 59 AK amputations in 56 patients – excluding the three intact stumps with sutures *in situ* at the time of death.

The preoperative SPP. Figure 1 and Table 2 (upper panel) show the healing of the stumps in relation to the SPP. The three cases with an SPP below 20 mmHg all had major wound complications. In one case the patient died with total rupture and severe necrosis of the wound. In two cases severe necrosis postponed the healing, which was not complete until after 4 and 5 months, respectively.

Only one out of eight cases (12 per cent) with a preoperative SPP between 20 and 30 mmHg healed primarily. In one case

Table 1. Age distribution in 62 cases of above-knee amputation

	41–50	51–60	61–70	71–80	81–90	Total
Cases without diabetes mellitus		3	12	18	12	45
Cases with diabetes mellitus	1	1	4	6	5	17

Male/female ratio: 38/24 = 1.58. Arithmetic mean age: without diabetes mellitus (DM) 74.0 years. With DM: 72.6 years.

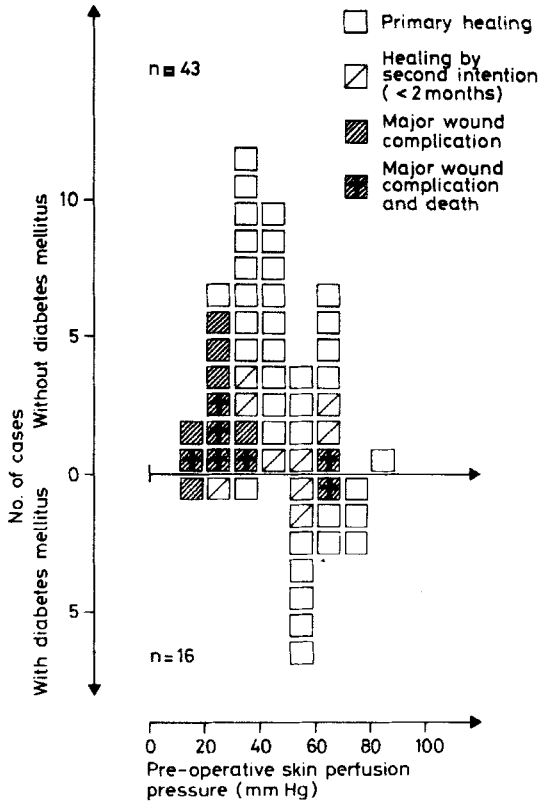

Figure 1. Wound complications in 59 AK amputations in relation to the local skin perfusion pressure measured preoperatively.

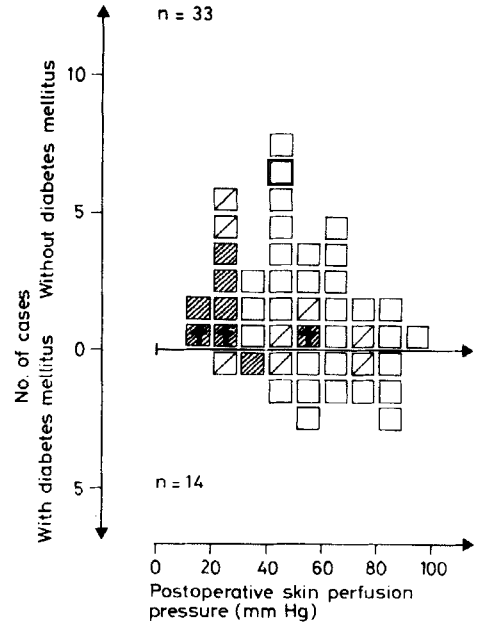

Figure 2. Wound complications in 47 AK amputations in relation to the local skin perfusion pressure measured postoperatively. (The symbols are identical to those used in Figure 1.)

healing of a minimal defect took place by second intention within 6 weeks. The remaining six patients all had major wound complications: in one case severe necrosis delayed the healing for 4 months, in two cases major surgical revisions because of necrosis and infection were necessary and in three cases the patients died with severe necrosis of the stumps. Thus, summarizing the cases with SPP below 30 mmHg, 9 out of 11 (82 per cent) suffered severe wound complications.

Thirty-six out of the 48 cases (75.0 per cent) with a preoperative SPP of above 30 mmHg healed primarily. In eight cases small defects healed rapidly, i.e. within 2 months. In four cases (8 per cent) major wound complications developed. In two of these cases – both with a preoperative SPP of 30–40 mmHg – i.e. on the borderline of the high risk group with an SPP below 30 mmHG – surgical revision because of severe necrosis was carried out. In one of these cases the patient died with necrosis of the revised stump. In two cases with normal SPP, i.e. 60 to 70 mmHg, the patients died with severe wound complications: in one case with infection of the wound and sepsis (Klebsiella) and in the other case with rupture of the infected wound (Staph. aureus). The clinical picture, a swelling, warm, red stump in these two cases with normal SPP and infection was very different from the necrotic appearance of the low pressure stumps.

These differences in primary healing rate and in major wound complication rate in the various SPP groups are highly significant for the total number of cases and for the 43 non-diabetic cases (Table 2 and Figure 1). In the

Table 2. The skin perfusion pressure (SPP) in relation to wound healing

		<20 mmHg			21–30 mmHg			>30 mmHg			Total
		Primary healing	Secondary healing <2 months	Major wound complication	Primary healing	Secondary healing <2 months	Major wound complication	Primary healing	Secondary healing	Major wound complication	
Pre-operative SPP	Without diabetes mellitus	0 (a)	0	2 (100.0 %) (b)	1 (a)	0	6 (85.7 %) (b)	25 (a)	6	3 (9.0 %) (b)	43
	With diabetes mellitus	0	0	1	0	1	0	11	2	1	16
	Total	0 (c)	0	3 (100.0 %) (d)	1 (c)	1	6 (75.0 %) (d)	36 (c)	8	4 (8.3 %) (d)	59
Post-operative SPP	Without diabetes mellitus	0 (e)	0	2 (100.0 %) (f)	0 (e)	2	4 (66.7 %) (f)	21 (e)	3	1 (40 %) (f)	33
	With diabetes mellitus	0	0	0	0	1	0	10	2	1	14
	Total	0 (g)	0	2 (100.0 %) (h)	0 (g)	3	4 (57.0 %) (h)	31 (g)	5	2 (5.2 %) (h)	47

P value (rank sum test)

Distribution (a) 0.02
Distribution (b) 0.0006
Distribution (c) 0.006
Distribution (d) 0.0004

P value (rank sum test)

Distribution (e) 0.0016
Distribution (f) 0.0014
Distribution (g) 0.0018
Distribution (h) 0.0026

16 diabetic cases there were only two major wound complications (12 per cent) compared with 11 major complications (26 per cent) in the non-diabetic group ($0.5 < P < 0.10$). The SPP in the diabetic group (on average 58.1 mmHg) was, however, significantly higher than in the non-diabetic group (on average 42.9 mmHg) ($P < 0.01$) and only two of the diabetic cases had an SPP of below 30 mmHg.

The SPP correlated significantly with the presence of palpable pulsation in the femoral artery, but the healing rate did not (Table 3).

Among the 14 cases with AK amputations secondary to failed BK amputations the wound healed primarily in 12 cases. In one case the wound healed slowly (in 6 months) and in one case the patient died from wound infection. The average SPP at the BK level before the BK amputations in these 14 cases was 31.0 mmHg (range 8–63 mmHg), as against 54.3 mmHg (range 23–68 mmHg) at the AK level before the AK amputations ($P < 0.01$).

The postoperative SPP. It was technically possible to perform a postoperative measurement on the amputation stump in 47 cases. Primary healing and major wound complications correlated significantly with the postoperative SPP (Figure 2 and Table 2, lower panel) in the total number of cases as well as in the non-diabetic cases. Healing of the wounds in the 14 diabetic cases did not correlate significantly with the SPP. However, there was only one case with an SPP below 30 mmHg and the SPP was on average significantly higher in the diabetic group than in the non-diabetic group: 60.5 mmHg (range 18–98 mmHg) compared with 50.1 mmHg (range 28–88 mmHg) ($0.02 < P < 0.05$). The rates of primary healing and of severe wound complications were better in the diabetic group although the differences were not significant.

The average SPP in the 47 cases measured postoperatively was 53.2 mmHg (range 18–98 mmHg). This is slightly above the preoperative values: 52.0 mmHg. However, the site of the postoperative measurement was often more proximal than the preoperative site.

The amputation did not affect the SPP on the contralateral leg: the preoperative SPP averaged 56.7 mmHg (range 23–98 mmHg) and the postoperative SPP averaged 53.2 mmHg (range 23–88 mmHg) ($P > 0.10$). Correction of the postoperative SPP for changes in systemic blood pressure did not influence the result: corrected postoperative average SPP values: 53.4 mmHg (23–87 mmHg) ($P > 0.10$).

Rehabilitation. The patients returned to their own homes in 28 out of 48 cases (58 per cent). Of the 49 patients who could walk prior to major amputation, rehabilitation as

Table 3. Wound healing and skin perfusion pressure (SPP) in relation to the presence of pulsations in the femoral artery

	Pulsations in the femoral artery		
	No pulsations $n=22$	Pulsations present $n=37$	P value
SPP mean	30.2 mmHg	56.4 mmHg	$P < 0.01$
SPP range	18–48 mmHg	18–88 mmHg	
Severe wound complications	8	5	$P > 0.05$
Primary healing	11	11	$P > 0.05$

Table 4. Number of weeks spent in hospital in relation to primary or secondary AK amputation and to rehabilitation

No. of AK amputations	No. of patients	Type of AK amputation	Weeks in hospital preoperatively mean*	range	postoperatively mean*	range
47	43	Primary	1.8	(0.1–8.0)	10.2	(0.5–52.0)
15	15	Secondary to failed BK or TK amputation	16.9	(4.0–39.0)	12.1	(0.5–48.0)
No. of AK amputations	**No. of patients**	**Rehabilitation**	**preoperatively mean***	**range**	**postoperatively mean***	**range**
20	20	Discharged walking	6.8	(0.1–38.5)	15.3	(3.0–31.0)
8	8	Failed attempt at walking	8.8	(0.5–24.0)	24.1	(6.0–56.0)
34	30	No attempt at walking	3.5	(0.5–9.0)	4.7	(0.5–40.0)

* Arithmetic mean per AK amputation.

regards walking with a prosthesis was obtained in 20 cases (41 per cent). The walking ability was not regained in the remaining 29 cases due to death in 9 cases, to poor mental and physical condition in 15 cases and to bilateral major amputation in 5 cases.

The average time spent in hospital per AK amputation was 15.8 weeks. Table 4 shows that the *preoperative* period was about nine times longer in patients with failed major amputation at a lower level. Rehabilitation or an attempt at rehabilitation as regards walking increased the *postoperative* time about three to five times. Wound complications did not on average increase the period of hospitalization, but some of these patients died in the early postoperative period.

DISCUSSION

The high mortality (24 per cent during hospitalization) reflects the often poor condition of the patients undergoing AK amputations. Our figure falls within the range of mortality rates of about 10–40 per cent in larger series in the literature (Dale & Capps 1959, Lempke et al. 1963, Warren & Kihn 1968, Hansson 1964, Otteman & Stahlgren 1965, Hall & Schucksmith 1971).

The healing of the AK amputations correlated significantly with the pre- and postoperative SPP. The poor results in patients with an SPP below 30 mmHg agree with previous findings in BK amputations (Holstein & Lassen 1977, Holstein et al. 1979). Apart from a preliminary report on this series (Holstein 1973) no studies of wound healing in above-knee stumps in relation to objective measurements of the arterial supply have previously been published. Our rate of primary healing (62.7 per cent) is, however, of the same order as that reported in larger series in the literature (Dale & Capps 1959, Schlitt & Serlin 1960, Warren & Kihn 1968, Hall & Schucksmith 1971, Kihn et al. 1972).

In discussing the consequences of the SPP in relation to AK amputations one must distinguish between two different groups of patients. The first group consists of patients

who have lost the ability to walk for reasons other than the peripheral ischaemia and in these patients the aim of the amputation is to relieve a painful useless extremity with a minimum of discomfort. In 13 cases in our series the patients belonged to this category. In six cases the patients suffered wound complications which in four cases were related to an SPP below 30 mmHg. These findings point towards the selection of a short stump in cases of inadequate blood supply in a weak patient. Only if the blood supply is adequate should a long stump, which is more comfortable during sitting and when moving in bed, be chosen.

The level selection is more difficult in the second group where the patients have been able to walk up to the time of amputation. In these cases the result of the treatment should be considered satisfactory only if the ability to walk is regained by means of a prosthesis; 41 per cent achieved this in this series. In principle a long stump facilitates walking with a prosthesis and when this advantage is added to the previously mentioned comfort during sitting and moving in bed it seems justified to take the risk of ischaemic wound complications in order to obtain a long stump. Slow healing may be obtained even when the SPP is of the order of 20 to 30 mmHg. But this must be balanced against the risk of loss of ambulation in the event of a long period with a painful, slowly healing ulcer prohibiting prosthetic training – and early surgical revision should be considered in case of ulcers in order to shorten the healing time.

There were fewer wound complications amongst the diabetic patients. This result can be explained by the significantly higher average SPP in the diabetic group. This finding parallels the results in our series of BK amputations (Holstein et al. 1979) and is discussed in that paper.

Compared with our figures for BK amputations (Holstein et al. 1979) the average duration of hospitalization for AK amputations was less. This finding agrees with Weaver & Marshall's observation (1973). A high mortality, a number of patients discharged to nursing homes soon after surgery and only a few reamputations, reduced the average period of hospitalization in patients undergoing AK amputations.

To summarize: the SPP is a very reliable means of predicting ischaemic wound complications in AK amputations. The implications of wound complications are, however, very variable, ranging from healing by second intention with preservation of stump length to a life-threatening complication. If ischaemic wound complications are to be avoided meticulous surgery is required and in non-mobile weak patients a short stump length is advocated in the case of a low SPP.

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