The potential benefit of pre-operative assessment of amputation wound healing potential in peripheral vascular disease

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Abstract **Choosing the most distal amputation level that will heal is difficult in patients with peripheral vascular disease. From 1984 to 1988, 965 patients underwent 1 563 amputations for lower limb peripheral vascular disease at King Edward VIII Hospital, Durban. The primary amputation revision rate was 51% with a mortality rate of 23,1%. Random pre-operative assessment of amputation wound healing potential using a transcutaneous oxygen pressure index was investigated over the 4-year period, 1987 - 1990. This was responsible for a reduction in the amputation revision rate to 8,2% in patients tested.**

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While peripheral vascular disease is generally thought to be uncommon in the black population of South Africa, its incidence in these patients appears to be increasing steadily. This is in keeping with the worldwide increase in the disease.[1] A feature of the disease in black people is the delay in presentation; 75 - 80% of patients present with threatened gangrene or gangrenous limbs. Many limbs are therefore unsalvageable and require amputation.

Choosing the optimal amputation level can be difficult. A change in the philosophy of amputation surgery now places emphasis on the preservation of as many functional joints as possible to facilitate better rehabilitation. Wound healing can generally be achieved with a proximal amputation, but at the cost of subsequent limb function and rehabilitation. The desire to ablate as distally as possible increases the chances of incorrect site selection, with subsequent wound failure necessitating revision amputation. This increases the likelihood of morbidity and mortality.

In 1978, Malone *et al.*[2] addressed the problem of amputation revision surgery and outlined a programme involving pre-operative assessment of amputation wound healing potential and immediate postoperative prosthetic fitting that would save the Veteran's Administration Hospitals 16 million dollars annually.

The cost of amputation revision surgery in our hospitals is unknown and the concept of pre-operative assessment of amputation wound healing potential has not gained much support in South Africa.

This study investigates the extent and cost of the problem of revision amputation surgery in patients with peripheral vascular disease at King Edward VIII Hospital and examines the potential savings that might accrue from a programme of pre-operative assessment of amputation wound healing potential.

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Method

The Natal Provincial Administration's centralised computer records of all patients admitted to King Edward VIII Hospital between 1984 and 1988 were reviewed. The following data on patients who underwent amputation for peripheral vascular disease were obtained: (*i*) the total number of lower limb amputees; (*ii*) level and number of amputations per patient; (*iii*) in-hospital mortality; and (*iv*) the duration of hospital stay.

Pre-operative assessment

Pre-operative assessment of amputation wound healing potential was investigated using transcutaneous oxygen pressure ($PtcO_2$) measurement. $PtcO_2$ measurements were made using commercially available oxygen monitors (Hellige Servomed and Hewlett Packard). After a 20-minute warm-up period, the probes were calibrated against air and a zeroing solution and corrected for barometric pressure. The sites to be measured were shaved when necessary and cleaned with an alcohol solution. The probe was attached to the skin with a double-sided adhesive ring, over a drop of contact solution. The heating element of the probe was set at 45°C and readings were made after 20 minutes, to allow time for hyperaemic stabilisation to occur.

$PtcO_2$ readings were taken at the routine amputation sites: (*i*) the mid-dorsum of the foot; (*ii*) 10 cm below the tibial tuberosity over the anterior compartment of the leg; (*iii*) 10 cm proximal to the patella over the anterior midline; and (*iv*) on the anterior chest wall 5 cm below the clavicle in the mid-clavicular line. The $PtcO_2$ index, i.e. the ratio of limb to chest $PtcO_2$, was calculated for each site.

In 1987 and 1988 patients with peripheral vascular disease who required lower limb amputation were randomly selected for pre-operative $PtcO_2$ measurement. $PtcO_2$ values were recorded at the routine amputation sites. The surgeon was not told the results, and selected the amputation level on clinical criteria. These were pulse status, general skin condition at the selected site and the amount of skin and muscle bleeding at the time of surgical incision. The patients were followed up postoperatively and a procedure was considered to have failed if revision of the amputation was required either at the same level or at a more proximal level.

From 1989 the surgeon was advised of the most distal amputation level at which wound healing could be expected. This was determined as being the most distal routine amputation site with a $PtcO_2$ index greater than 0,55.[3] The surgeon could, however, still decide to amputate more distally if, on clinical and intra-operative assessment, he considered that the more distal site would heal.

Results

During the 5-year period, 1984 - 1988, 965 patients required 1 563 lower limb amputations for peripheral vascular disease; 222 patients died in hospital. The primary revision rate, i.e. the number of first-time amputations that required revision, was 51%. The in-hospital mortality rate was 23,1% and the mortality rate per amputation was 14,3%. The number of patients per year who required a lower limb amputation for peripheral vascular disease, the number of patients who required one or more revisions and the number of patients who died in hospital after amputation are shown in Fig. 1.

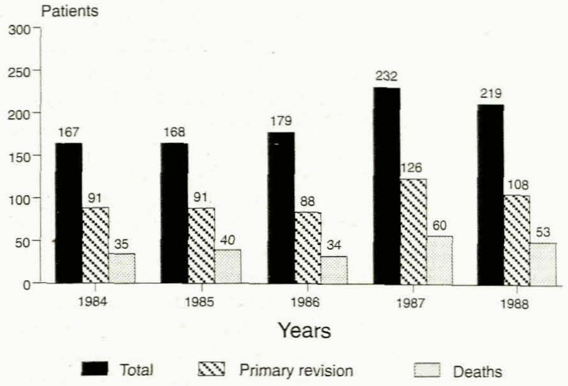

FIG. 1.
Total number of patients per year undergoing lower limb amputation for peripheral vascular disease, number of patients who required one or more revision amputations and number of patients who died after amputation (1984 - 1988).

The anatomical distribution of amputations based on the initial amputation site, the number of patients who required revision at the same or more proximal sites and the number of patients who died are shown in Fig. 2.

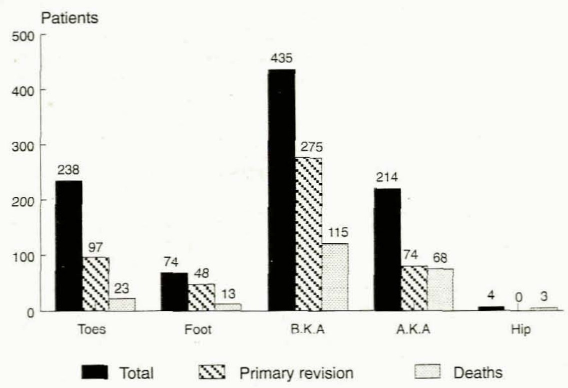

FIG. 2.
Initial site of amputation in 965 patients, number of these patients who required revision amputations and number of patients who died (1984 - 1988).

The primary revision rate is skewed because of the unit's policy of performing an initial guillotine amputation and subsequent definitive amputation in patients with septic non-salvageable limbs.[4] It was not possible from the available data to determine how many guillotine amputations were performed. The figure can, however, be approximated by counting the number of foot and below-knee amputations that were revised at the same level as the initial amputation. This would reduce the primary revision rate in the patients who survived to approximately 35%.

The total number of days spent in hospital was available for 1987 and 1988. The average number of days spent in hospital following an amputation that healed primarily was obtained for the different levels. The number of extra days spent in hospital after revision amputation was then calculated. The average increase in hospital stay is shown in Fig. 3. The total increase in hospital stay following revision amputation surgery in patients who survived was 4 980 days per year. The extra days spent in hospital by patients who subsequently died after one or more revisions was 1 371 days per year. Altogether, patients who underwent revision amputation surgery occupied 17,4 surgical beds per day per year.

In 1987 and 1988 $PtcO_2$ values were measured in 174 patients, 122 of whom met the following criteria: (*i*) the patient was undergoing a definitive amputation and not a guillotine amputation; and (*ii*) the patient had not undergone a revascularisation procedure in the affected

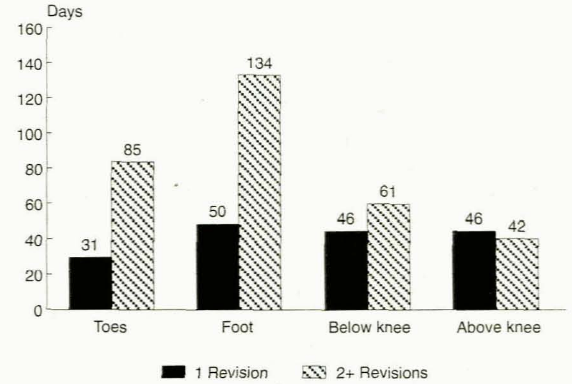

FIG. 3.
Average number of extra days spent in hospital following one or several revision amputations, based on the site of the initial amputation.

limb within the 2 weeks preceding $PtcO_2$ measurement. In 1989 and 1990 $PtcO_2$ measurements were performed in 218 patients, 148 of whom met the above criteria.

In 1987 the primary revision rate of patients who underwent pre-operative $PtcO_2$ investigation was 40,3%. Of all the amputations performed in 1987, 35,5% were performed at sites with a pre-operative $PtcO_2$ of less than 0,55. Based on the $PtcO_2$ index these sites were inappropriate and healing would not have been expected. None of these amputations healed. Of all the amputations, 4,8% failed to heal, despite a $PtcO_2$ index greater than 0,55. After informing the surgeon of the most distal site at which healing could be expected, the advice was overruled and a more distal amputation performed in 16,4% of patients in 1989 and in 6,6% of patients in 1990. All these amputations failed to heal. Informing the surgeon of the most distal amputation site at which healing could be expected significantly reduced the revision rate from 40,3% in 1987 to 8,2% in 1990 ($P < 0,0001$) (Table I).

Discussion

Revision amputation surgery increases morbidity and mortality. Apart from the cost to the patients, both

TABLE I.
Percentage of amputations requiring revision in patients who underwent pre-operative $PtcO_2$ measurement

	Percentage of amputations revised			
	1987	1988	1989	1990
Total revision rate	40,3	38,8	20,0	8,2*
$PtcO_2 < 0,55$	35,5	22,2	16,4	6,6
$PtcO_2 > 0,55$	4,8	16,6	3,6	1,6

*The reduction in revision rate between 1987/88 and 1990 is statistically significant; $P < 0,0001$. The total percentage of amputations that failed is divided into the percentage of all amputations performed at levels at which the $PtcO_2$ index was less than 0,55 and the percentage of all amputations performed at levels with a $PtcO_2$ index greater than 0,55. No amputations performed at a site with a $PtcO_2$ index less than 0,55 healed.

financial and in terms of subsequent rehabilitation, failed amputations are a burden on hospital resources. At an approximate bed cost of R200 per day, failed amputations cost the State an average of R1 270 000 per year.

The primary revision rate of 51%, while high, is in keeping with published figures. The primary revision rate in Ontario was 48% in 1978.[5] Analysis of several series reported by Hunter[6] shows a 46% failure rate for toe amputations, and a combined 33% failure rate for transmetatarsal and Symes amputations. Warren and Kihn[7] reported a 32% failure rate in below-knee amputations in 127 patients and more recently Keagy reported a 19% failure rate in 626 below-knee amputations.[8] It is suggested that a 20% failure rate is now the norm. Revision rates as low as 10%, based solely on clinical evaluation, have been reported.[9]

The solution to the problem, as described by Malone *et al.*[2] is pre-operative assessment of amputation wound healing potential. The difficulty associated with clinical assessment is well known. The most reliable criteria are skin colour and temperature and capillary skin bleeding at surgery. Numerous investigations have been used to try to predict wound healing potential. These include segmental measurement of Doppler pressure, xenon-133 skin clearance, thermographic assessment, measurement of muscle pH, fluorescein dye angiographic examination, pulse volume recording, photoplethysmographic assessment, laser Doppler velocimetry and $PtcO_2$ measurement.

Wound healing is dependent on many factors, both local and systemic. The problem common to all local non-invasive investigations is that information is gained about perfusion or oxygenation of either skin or muscle but not both. The problem is compounded by the fact that the circulation to skin and muscle at the site of amputation does not always originate at the same level of the axial arterial tree. Perfusion of skin and muscle can therefore be different. Because specialised information is gained about only one aspect of the complex healing process, these non-invasive tests are better predictors of wound failure than wound healing. In comparisons of investigations, $PtcO_2$ measurement appears at present to be the most reliable indicator of amputation wound healing potential.[10,11]

In 1987 and 1988 the revision rates in patients undergoing pre-operative assessment of wound healing were 40,3% and 38,8% respectively. At this time, surgeons were selecting the amputation site clinically. Reviewing these revision rates with regard to the $PtcO_2$ index at the site of amputation, it is apparent that the majority of wound failures occurred at sites with a $PtcO_2$ index of less than 0,55. These failures may therefore be attributable to poor site selection. In 1987, 35,5% and in 1988, 22,2% of all the amputations performed were at sites at which wound healing would not be expected. No amputations with a pre-operative $PtcO_2$ index below 0,55 healed.

In 1989, when the surgeon was advised of the most distal site that could heal, the revision rate fell to 20%. The suggested amputation level was ignored, however, and the amputation was performed at a more distal site with a $PtcO_2$ index of less than 0,55 in 16,4% of amputations. All of these amputations failed. Surgeon acceptance of the investigation increased and in 1990 only 6,6% of amputations were at sites more distal than advised. All failed to heal.

The pre-operative use of the $PtcO_2$ index as an aid to level selection has significantly reduced the revision rate in these patients to less than 10%. If this reduction can be carried through to all patients with peripheral vascular disease who require lower limb amputation, 14 - 15 hospital beds would be freed for other use, or if unused, would theoretically generate a potential saving of R1,07 million annually. The associated benefit to the patient in terms of reduced morbidity is unquantifiable.

In summary, the primary amputation revision rate at King Edward VIII Hospital was found to be high. A trial programme of pre-operative assessment of amputation wound healing using a $PtcO_2$ index significantly reduced the revision rate. Routine use of the investigation appears justified.

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