SKIN BLOOD FLOW AND HEALING
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INTRODUCTION

The objectives of the Prosthetic Research Program at the VA Hospital San Francisco are:
1. To examine the feasibility and application of immediate postoperative prosthetic fitting to a large group of patients undergoing lower-limb amputation for vascular insufficiency.
2. To establish quantitative criteria to aid in the preoperative determination of an amputation level which contains adequate blood flow for primary healing.
3. To develop additional prosthetic devices to be used for immediate postoperative prostheses at levels distal to below knee, such as transmetatarsal and Syme amputations.

METHODS

Since the commonest amputation for vascular insufficiency at our hospital has been at the below-knee level, a program of below-knee amputation with immediate postoperative prosthetic fitting and ambulation was instituted in the summer of 1967. At that time, it was our impression that there existed no suitable way to determine preoperatively a proper amputation level from the standpoint of circulation. For this reason, it had been our practice to routinely perform amputation at the below-knee level regardless of the status of peripheral pulses, the angiographic distribution of arterial occlusive disease, or skin temperature. The only contraindication to amputation at the below-knee level is the extension of the gangrenous process to the line of incision. Since we had considerable experience with below-knee amputation using conventional operative and rehabilitation techniques, our previous results would serve as guidelines against which we could compare results obtained by using immediate postoperative prosthetic fitting and ambulation according to the Burgess technique.

In order to work out methods for amputation level determination, it seemed most appropriate to direct our investigation toward skin blood
flow determination. Since amputation healing success depends upon skin healing, and since the ability of skin to heal is a function of the blood supply at the level of amputation, then a method which would accurately measure blood flow through the capillary system at a proposed level of amputation ought to provide sufficient data to judge the healing potential at that level. The utilization of the radioactive isotope of Xenon as a means of measuring capillary blood flow in skeletal muscle and skin has been described in the Scandinavian literature. Xenon 133 is an inert, lipophilic substance, whose only means of removal from a depot injection is by passage across capillary cell membrane. The rate of transfer across capillary cell membrane is dependent upon the blood flow through the capillary system since the transport is by a mass-action effect. Thus, if one locally injects Xenon into a tissue and monitors, by the level of radioactivity as a function of time, the rate with which the isotope is removed, blood flow rates can be determined by using a standard clearance formula. This formula states that 

\[ F = \frac{\log_{10} T}{\lambda T} \]

where \( F \) is equal to flow in ml. per 100 gm. tissue per minute, \( \lambda \) is equal to the partition coefficient for Xenon between skin and blood, and \( T \) is equal to the Time for a complete decade of radioactivity at the injection site. In order to utilize this method in the skin of lower limbs, our initial evaluation consisted of preoperative measurement of skin blood flow at a point 10 cm. below the tibial tuberosity in the anterior midline over the tibial plateau which corresponds to the anterior skin incision of patients undergoing below-knee amputation. Fifty microcuries of Xenon 133 were removed by a syringe and an intradermal injection was made at that point. A probe capable of measuring radioactive emission was lightly taped to the limb and connected via a rate meter to a strip chart recorder so that the rate of removal of radioactivity at the point of injection could be monitored (Fig. 1). The level of skin blood flow determined preoperatively would then be correlated with healing results in all patients in the amputation series.

**RESULTS**

In 1972 we carried out a comparative statistical analysis of the two amputation groups. From 1961 to 1966, 55 below-knee amputations were performed on 53 patients using the standard operative technique without immediate postoperative prosthesis. From 1967 through 1971, 53 below-knee amputations were performed on 47 patients with immediate application of a prosthesis combined with postoperative ambulation. Both groups were analyzed for comparability with regard to age, the incidence of diabetes, the level of distal palpable pulse, preoperative ambulatory status, angiographic patterns of disease, and previous vascular reconstructive procedures. An analysis revealed that the two groups were entirely comparable. However, when one compared the results of
operation there was a striking difference. The healing rate of patients with immediate postoperative prosthesis was 89 percent in comparison to 76 percent using standard amputation techniques. There were no postoperative deaths in the patients with immediate postoperative prostheses. However, the mortality rate was 15 percent in the standard amputation group; the most frequent causes of death in the standard amputation group were pneumonia and myocardial infarction. The results of prosthetic rehabilitation in the two groups also bear comment. All patients who were ambulatory prior to the development of gangrene which necessitated amputation in the immediate postoperative prosthesis group were successfully rehabilitated and became ambulatory on a below-knee prosthesis. In the conventional amputation group, however, 19 percent of the patients who had been ambulatory prior to the need for amputation failed to become ambulatory on a prosthesis. In those patients who did become ambulatory, the time for fitting a permanent prosthesis was only 32 days in the immediate fitting series, in comparison to 125 days in the conventional amputation group. The results of this comparative study demonstrate the clear superiority of immediate postoperative prosthetic fitting not only as a means of accelerating rehabilitation but also as a means of improving the results of postoperative healing.

In reviewing the results of preoperative blood flows and correlation with postoperative healing, the following data were obtained. Thirty-one patients about to undergo 33 below-knee amputations had preoperative skin blood determinations using Xenon 133 clearance. The range in blood flows varied from 2.2 ml. to 15.26 per 100 gm. of tissue per minute. In this group of patients there were three amputa-
tions that failed to heal due to ischemic necrosis. The blood flows in these three amputations, 2.2, 2.24, and 2.36 ml. per 100 gm. of tissue per minute, constituted the three lowest flows in the series. All amputations that had preoperative blood flows in excess of 2.7 ml. per 100 gm. of tissue per minute healed primarily. The high degree of correlation of preoperative skin blood flows using Xenon 133 clearance with ultimate healing success has been most encouraging in this preliminary study.

FUTURE PLANS

Currently armed with information relative to the minimum blood flow required for skin healing, we can begin to apply this information to more conservative levels such as transmetatarsal or Syme amputation. In this manner we hope to be able to offer a more distal amputation level to patients that would otherwise be turned down for a distal amputation based on conventional criteria such as level of distal palpable pulse or angiographic patterns of disease. It is also apparent in our studies that measurement of one point on the circumference of an amputation incision may not adequately reflect the critical area of blood flow; for this reason we are currently studying the use of multiple point flow determinations made possible by employing the Gamma Camera as a radioactive sensing device. Further development in amputation techniques and the use of newer designs of immediate postoperative prostheses for these conservative levels is currently underway.

REFERENCES


