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MUSCLE BLOOD FLOW AFTER AMPUTATION WITH SPECIAL REFERENCE TO THE INFLUENCE OF OSSEOUS PLUGGING OF THE MEDULLARY CAVITY

Assessed by 133 Xenon and Histamine

An Animal Experiment

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The muscle blood flow (MBF) in rabbits subjected to amputation of the crus was assessed by means of 133 Xenon and Histamine. It was shown that after the operation the flow in the amputation stump was initially reduced. MBF in the stump increased more rapidly and stayed at a higher level after closure by myoplasty than after amputation without myoplasty, and it was still further stimulated after osseous plugging of the medullary cavity.

Key words: amputation; medullary plugging; muscle blood flow; myoplasty; 133 Xenon-clearance method

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After amputation the muscle blood flow in the amputation stump is essential for primary healing as well as for future function. In clinical and experimental trials (Hulth & Olerud 1962, Erikson 1965, Erikson & Olerud 1966, Hansen-Leth & Reimann 1972), arteriography has disclosed a hypervascularization in the amputation stump. Myoplasty (Dederich 1963) as well as osteomyoplasty (Langhagel 1968) applied to the stump will further increase vascularization. However, arteriography is a morphological investigation method and the correlation between arteriographically demonstrated hypervascularization and muscle blood flow is uncertain.

The aim of this study is to investigate the vascular reaction after amputation in rabbits, and the influence of myoplasty and osteomyoplasty, by assessment of the muscle blood flow (MBF) by means of the 133 Xenon-clearance method.

MATERIAL AND METHOD

Twenty-six adult rabbits were amputated on the left crus. Amputation was performed without myoplasty in seven cases and with myoplasty in six. In thirteen animals, amputation was combined with osseous plugging of the medullary cavity, and six of these cases had myoplasty as well. The operations were performed with Nembutal anaesthesia and in sterile conditions. Amputation was performed at the level between the proximal and intermediate third of the crus. In the myoplastic cases a minor portion of the muscles was excised, while in the cases without myoplasty the muscles were cut at the same level as the bone. The medullary cavity was plugged by means of cortex obtained from the removed bone.

The amputation stump healed without complications in 21 cases, while minor primary defects developed in two animals. Most of the rabbits put weight on the stump, and a dry sore developed on the tip in three animals.

The MBF was assessed by 133 Xenon (Lassen et al. 1964) while the animals were under Nembutal anaesthesia. Assessment of 133 Xenon clearance in resting muscle fails to provide a true picture of the MBF (Tønnesen 1969). For this reason muscle hyperaemia was produced by Histamine (Lindbjerg 1969). Isotonic solutions of 133 Xenon (Radiochemical Center, Amersham) and Histamine chloridum (1 mg per ml) were mixed at a ratio of three to one in a Mantoux syringe, and 0.02 to 0.07 ml was injected centrally by Mantoux needle into the quadriceps and triceps surae muscles on both sides.

The rate of disappearance of the isotope was measured by a scintillation detector provided with NaJ-crystal, screened off by a lead-collimator and coupled to a ratemeter. Immediately after establishment of the depot, the detector was adjusted above it, and the clearance curve was plotted by a logarithmic potentiometer recorder for 8 to 12 minutes.

MBF was calculated according to Lassen et al. (1964) on the basis of the logarithmic clearance curve:

$MBF = -100 \times \lambda \times \ln(10) \times d\log C/dt = 161 \times D$ ml/100 g/minute where C denotes the concentration of isotope in tissue at a fixed time, λ is the isotope partition coefficient between tissue and blood = 0.7, and D denotes the fraction of a decade by which the tangent to the curve falls per minute.

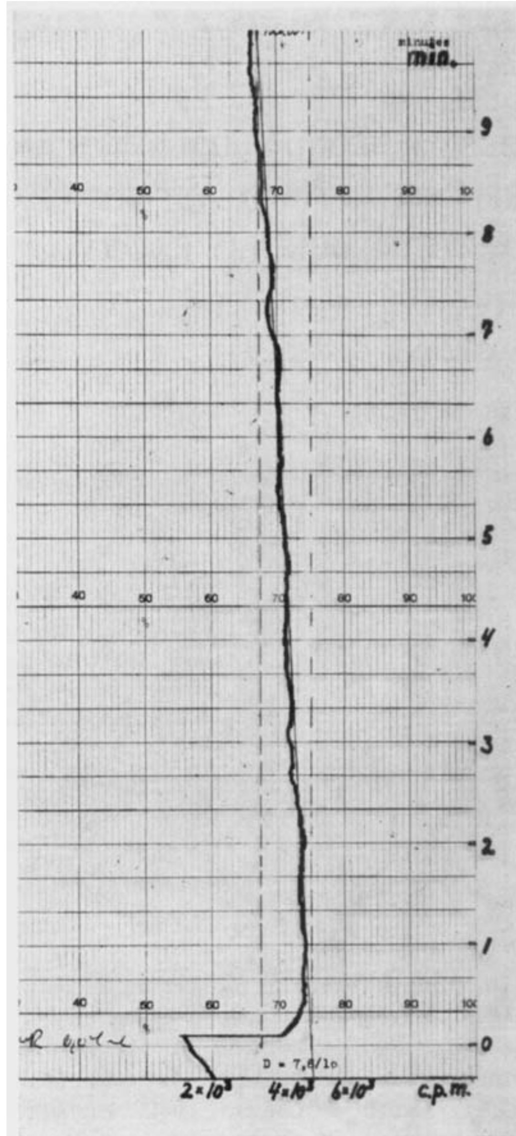

Figure 1. 133 Xe-clearance curve, rabbit R 38, right quadriceps 3 days after amputation with myoplasty.
D = 7.8/10,
MBF = 7.8/10 × 1.61 = 1.26 ml/100 g/min.

RESULTS

MBF was determined prior to operations on 20 rabbits and the postoperative blood flow was expressed in per cent of the preoperative mean flow. MBF in quadriceps and triceps surae, in the left and right leg respectively, was measured postoperatively on 121 occasions from periods of 1 hour up to 110 days after amputation.

The clearance curve generally followed a rectilinear course throughout the period of registration (Figure 1). A phase of adjustment might occasionally occur during the initial few minutes before the fall set in. In approximately one half of the measurements obtained at the stump, a third phase was seen during which the concentration of the isotope was rapidly reduced to zero 6 to 8 minutes after in-

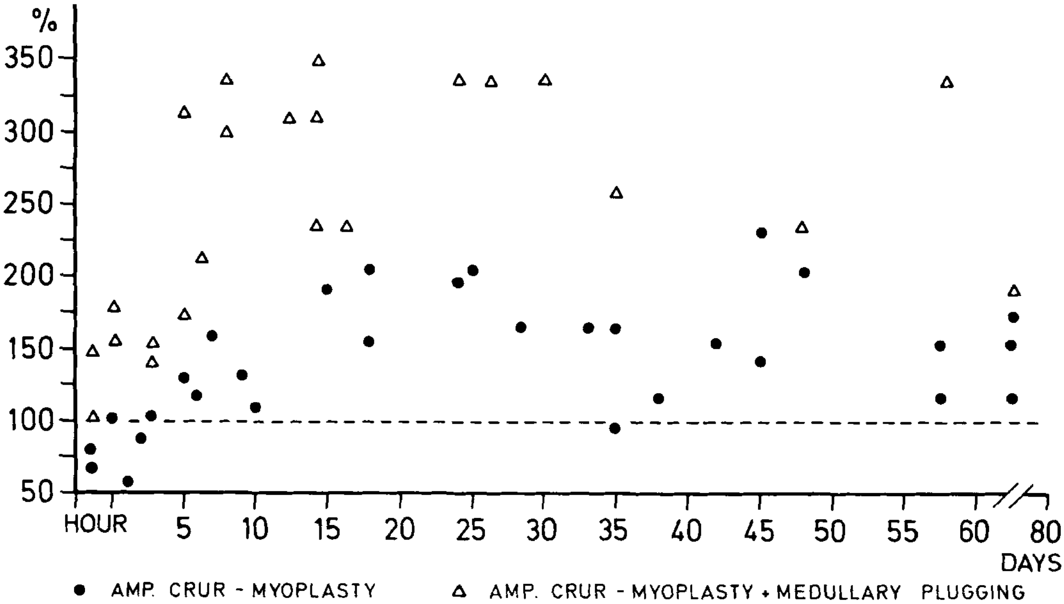

Figure 2. MBF in the amputation stump after amputation without myoplasty and after osseous medullary plugging from 1 hour to 80 days after operation.

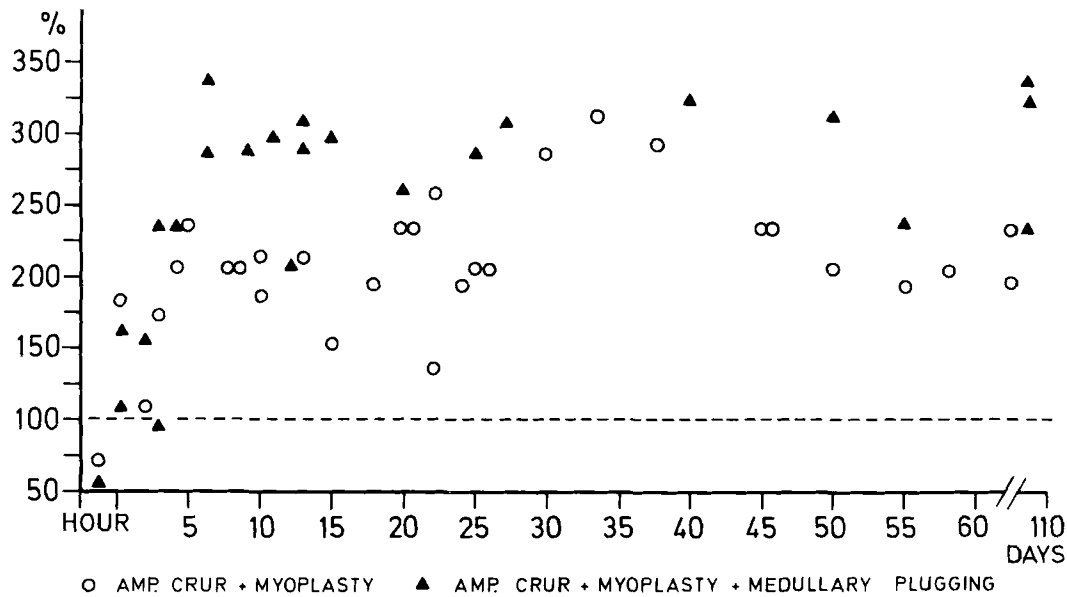

Figure 3. MBF in the amputation stump after amputation with myoplasty and after myoplasty combined with osseous medullary plugging from 1 hour to 110 days after operation.

jection. Out of a total of 464 single measurements, MBF could not be assessed in 52 cases because these curves did not follow an unambiguously rectilinear course.

The postoperative MBF in the amputation stump is illustrated in Figures 2 and 3. Within the first days after *amputation without myoplasty* the flow was reduced. About five days postoperatively, it was higher than the preoperative mean flow. Between the second and fourth weeks it achieved a mean flow equal to 176 per cent of the preoperative flow, and after that time MBF in the stump was again reduced in six out of seven animals, while in one rabbit there was a further increase up to more than 200 per cent above the preoperative level.

After *amputation with myoplasty*, MBF in the stump was initially reduced, but one day after surgery the flow was seen to rise, reaching a maximum about 30 days postoperatively. Up to 80 days after amputation the mean flow was over 200 per cent of the preoperative flow.

It appears from Figures 2 and 3 that MBF in the amputation stump will increase more rapidly and maintain a higher level for longer if the stump is closed by myoplasty. When myoplasty was replaced by osseous plugging for stump closure, the MBF was studied to find whether the method of closure was responsible for the improved perfusion. In Figure 2 it will be noted that the rise in MBF set in immediately after *amputation with medullary plugging*. Within the first five days the mean flow was 152 per cent, and up to 75 days the flow rose to nearly 300 per cent of the preoperative value. If medullary plugging and myoplasty were combined (Figure 3), the perfusion of the stump rises in the same was as after amputation with myoplasty, but the flow increases to a higher level thus equalling the increase observed after osseous plugging without myoplasty and it remains there for up to four months after surgery.

There was an initial increase in MBF in the *ipsilateral quadriceps* after amputation with myoplasty (mean flow 151 per cent) which returned to normal after one week whilst the flow in the stump rose. The same reaction was seen after amputation and medullary plugging. After amputation without myoplasty, the flow in the quadriceps was unchanged until four weeks after operation when it was seen to rise to a mean flow of 133 per cent in the period 33 to 80 days postoperatively.

The MBF in the *contralateral extremity* also changed after amputation. The initial reduction in the flow in the crus stump was followed by a similar decrease in flow in the contralateral triceps surae. When amputation did not include myoplasty, the flow in the contralateral quadriceps was also reduced during the first four weeks (mean flow 82 per cent), at which time the flow increased to a mean of 127 per cent in the period 33 to 80 days postoperatively. After closure by myoplasty, an initial increase in the flow in the contralateral quadriceps was observed; during the first week the mean flow was 139 per cent of the preoperative flow. The same reaction was seen after medullary plugging and myoplasty, while medullary plugging without myoplasty was followed by a more pronounced rise in MBF both in the quadriceps and triceps surae. It seems that the MBF in the contralateral quadriceps changes to equal the flow in the quadriceps on the side exposed to operation.

DISCUSSION

This study demonstrates that it is possible to assess MBF in rabbits by means of 133 Xenon and Histamine. Correlation between flow rates is fair, and the unambiguous changes in MBF after amputation make is possible to evaluate the influence of amputation on MBF.

Preliminary studies of MBF in rabbits by means of 133 Xenon without Histamine failed to demonstrate any clearcut changes after amputation. The clearance curves were characterized by a distinct initial fall followed by a flattening of the curve. Tønnesen (1969) obtained a similar course for the resting flow in isolated gastrocnemius muscle from cats, and observed that after stimulation of the sciatic nerve the course was rectilinear and the clearance equalled the blood flow when measured directly. Lindbjerg (1969) suggested that the fluctuating flow in the resting muscle might be due to the fact that the isotope exchange between blood and tissues varies because of a heterogeneous distribution of open capillaries in resting muscle. Stimulation of nerves will result in a four-fold increase in the number of capillaries, and the same effect is obtained with Histamine. After Histamine stimulation, the muscle appears as a homogeneous tissue and the clearance curve runs a rectilinear course. Lindbjerg considered that blood flow might be influenced by different doses of Histamine and found that MBF reached a maximum after 4 to 100 μg Histamine. In this study, the dose of Histamine in the depot varied between 10 to 20 μg, and within the limits of 3 to 40 μg there was no difference in the Histamine effect. According to Lindbjerg, the size of the isotope depot might also influence the flow. Depots used in the present study were 0.03 to 0.08 ml, and within the 0.02 to 0.12 ml range the size of depots had apparently no influence on the MBF.

It has been demonstrated in this study that MBF in the amputation stump is reduced immediately after amputation. This is in agreement with the findings of Erikson & Olerud (1966) who, using arteriography on live rabbits after amputation of the crus with myoplasty, observed an initial constriction of arteries and veins, which may be explained by an involuntarily provoked spasm. Two to three days later they observed a dilation, which reached a maximum four weeks later and occasionally persisted for more than four months. In the present study, the MBF in the stump was seen to run a similar course after amputation with myoplasty, while after amputation without myoplasty the rise in flow did not set in until one week postoperatively, decreasing again after the fourth week. This difference was not observed by arteriography on young rabbits (Hansen-Leth & Reimann 1972) which showed hypervascularization of the amputation stump one to three weeks after amputation of the crus, irrespective of whether myoplasty had been used.

There are two aims when using myoplasty, first to reorganize the continuity of muscles, and secondly to close the medullary cavity with a view to normalizing the intraosseous pressure and venous reflux from the stump (Dederich 1963). In order to investigate this second problem MBF was assessed after osseous plugging of the cavity. The flow was found to be greater than after myoplasty and the increase was seen to set in immediately after the operation in contrast to the findings observed when the medullary cavity was left open after amputation. In clinical investigations with arteriography, Langhagel (1968) observed that osteomyoplasty intensified the vascularization in the stump for a period of one year, at which time vascularization equalled the state after spontaneous closure of the medullary cavity. Bone healing of the stump is analogous with healing of a fracture (Hulth & Olerud 1962), and it has previously been shown (Hansson 1967) that plugging of the medullary cavity serves to stimulate the growth of bone. These facts may be contributory causes to the intensified MBF in the stump after osseous medullary plugging.

It has been demonstrated in this study that amputation of the crus has a contralateral effect in the form of a change in MBF in the contralateral quadriceps, equalling MBF in the quadriceps on the side exposed to surgery. A contralateral effect has previously been described by

Jaya (1958) who observed that ligature of the femoral artery in rats and rabbits resulted in strictures at the same level in the contralateral femoral artery. Barnes & Trueta (1942) described an analogous effect which might occur if a tourniquet was applied. Liu (1968) and Lewis & Lim (1970) assessed the blood flow after a blunt trauma and observed that the flow was reduced in the contralateral extremity, while Rhinelander (1968), by means of micro-angiography, demonstrated a dilation of the cortical blood vessels in the contralateral limb after fractures in dogs.

These assessments of MBF have disclosed that the postoperative increase in the flow in the amputation stump is most pronounced when amputation is combined with osseous plugging of the medullary cavity. From a clinical point of view this observation may be of interest, but further research is necessary to show whether medullary plugging brings about a similar increase in MBF in man.

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