The Preservation of a Traumatically Amputated Limb Utilizing Crystalloid Cardioplegia Solution—A Case Report

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Abstract

This report describes a technique used to preserve a traumatically amputated arm of a twelve-year-old male.

Potassium cardioplegic solution was continuously perfused at 4°C via the brachial artery of the amputated limb. The perfusion was started approximately 40 minutes after the traumatic amputation occurred. Perfusion was discontinued prior to reattachment of the basilic, cephalic, and brachial vein and prior to reattachment of the brachial artery. Twenty-four hours post-operation, the limb was perfusing well and had excellent radial and ulner pulses and minimal edema. During the immediate postoperative period, the patient had excellent arterial flow and no evidence of venous obstruction. The patient is now five months post-replantation and demonstrates remarkable and early recovery of neuromuscular function.

In this case, the use of potassium cardioplegic solution provided excellent protection to the amputated limb until normal circulation could be re-established.

Introduction

The use of potassium cardioplegic solution for obtaining myocardial protection during open heart surgery is well documented[1,2,3,4,5,6,7,8,9]. The beneficial effects of cardioplegia in general, have led to its use in the majority of cardiac procedures performed in this country. This report describes the use of potassium cardioplegic solution to preserve an avulsed left upper extremity.

Methods

A twelve (12) year-old male was admitted to the emergency room approximately twenty-five minutes following the traumatic amputation of his left arm. The arm had been avulsed three inches below the left shoulder in an industrial dryer.

The patient had been treated initially at the scene of the accident by a physician and paramedics who wrapped the amputated arm in a towel and placed it in ice. The patient was taken to surgery immediately after arrival in the emergency room.

After the patient was anesthetized (Figure 1), the bladder was catheterized and oral endotrachial intubation was accomplished. The left upper extremity was dissected on a sterile table and the brachial artery identified and cannulated with a number twelve Longdwell catheter. The simple cardioplegic delivery system, shown in Figure 2, was primed and debubbled and connected to the Longdwell catheter (Figure 3). The Cardioplegic solution was infused at a pressure of 200 mm Hg at approximately four (4) degrees centigrade. The solution consisted of 960 milliliters of Ringers in-

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Presented at the 20th International AmSECT Conference, Hollywood, Florida, April 25–28, 1982.

FIGURE 1. Patient anesthetized prior to start of replantation procedure.

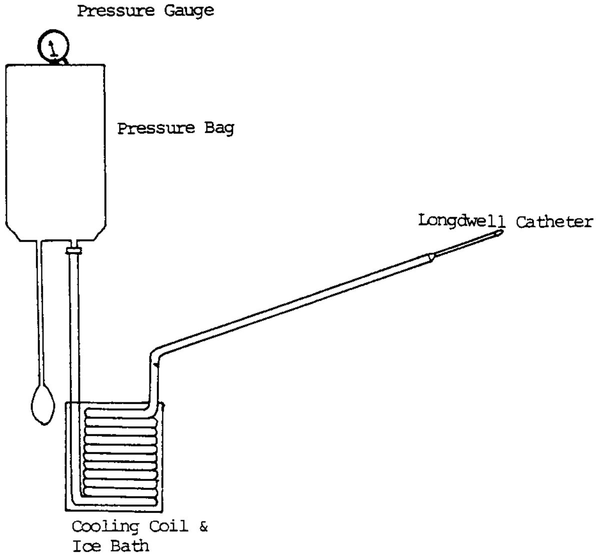

FIGURE 2. Schematic of the circuit used to infuse cardioplegia to the amputated limb.

jection, 16 milliequivalents potassium chloride, 2.68 milliequivalents sodium bicarbonate, and 6.75 grams of 25% mannitol. Five thousand units of sodium heparin were added to the first two liters of cardioplegia infused and eliminated on the subsequent liters.

The arm was then introduced into the sterile field and bony fixation of the humerus with lateral plates was accomplished following distal shortening of the humerus. The elbow was opened and a Knowles pin placed through the olecranon fracture and the radial head manipulated into place.

While bony stabilization was completed, interposition vein grafts were harvested from the right lower saphenous system. Cardioplegic solution administration was discontinued, and interposition vein grafts to the brachial artery and primary venography were accomplished between the distal basilic vein and proximal brachial vein. Bulldog

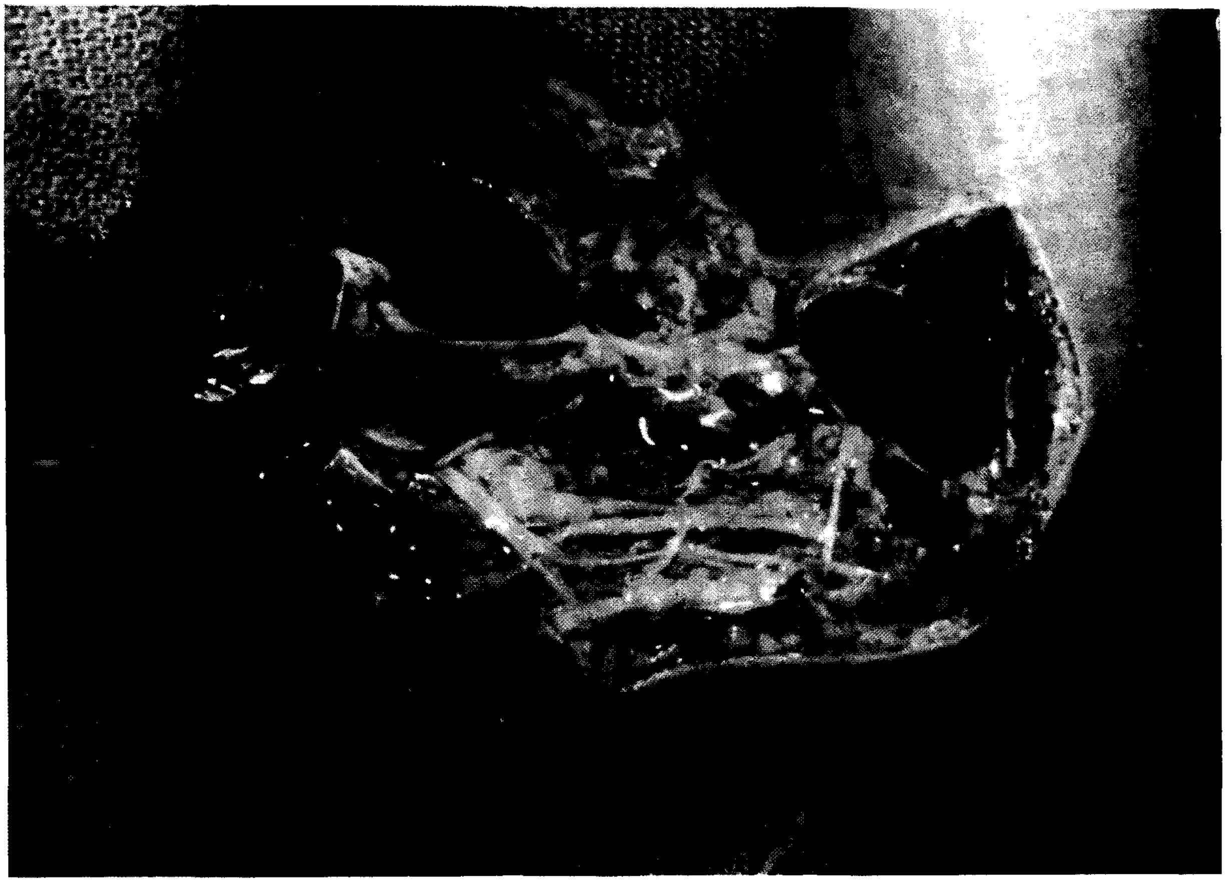

FIGURE 3. Cannulation site for the administration of potassium cardioplegic solution into the avulsed left arm.

clamps were released and immediate reperfusion of the extremity was appreciated. Total time of amputation prior to revascularization was four hours and forty minutes. Two interposition vein grafts were inserted from the distal brachial vein to the proximal cephalic vein and the distal cephalic vein to the proximal basilic vein.

The extensive neurological injury was then repaired with both primary repair and interposition nerve grafts. The deltoid muscle was reinserted and the biceps reattached to its proximal stump. The triceps were debrided extensively since much of it appeared non-viable. Initial temporary skin closure was accomplished with skin graft coverage over the medial aspect of the arm (Figure 4).

Twenty-four hours postoperatively, the arm was still perfusing well and had excellent radial and ulner pulses. Edema, which usually follows replantation was minimal.

The patient was returned to surgery forty-eight hours postoperatively for secondary debridement of the arm and evacuation of wound hematoma. Multiple fasciotomy incisions were carried out to facilitate evacuation of serum and further skin grafts were performed. In addition, two veins were found to be thrombosed, thought to be from hematoma, and thrombectomy carried out with the re-establishment of flow in those vessels.

At one month post-replantation, the patient continued to have excellent radial and ulner pulses and was without clinical evidence of venous obstruction.

The patient is now five months post-replantation and has had remarkable functional recovery of the arm. He was able to lift the arm within weeks of replantation (Figure 5). He is now able to rotate the wrist and move his fingers. His thumb has no voluntary movement at this time; however, he can generate voluntary active resistance and is able to hold small objects between the thumb and index

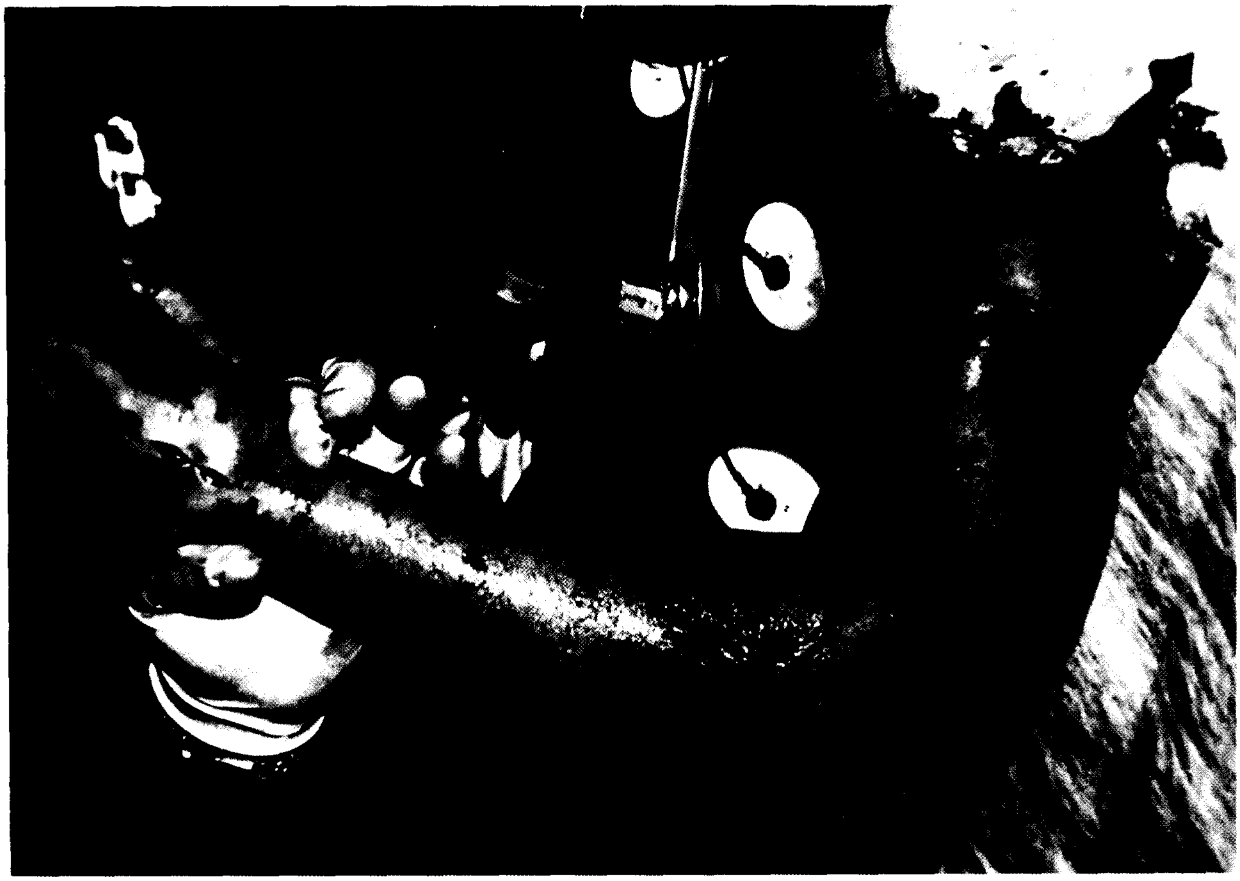

FIGURE 4. Replantation completed. Incisions are left open to facilitate drainage and help prevent edematous formation.

fingers (Figure 6). The patient is active athletically as a runner and is playing tennis and golf.

Discussion

There are numerous problems associated with the replantation of amputated parts including: patient transportation, ischemia of the amputated part, anesthesia, soft tissue loss, bone shortening and fixation, bone healing, timing of nerve repair, edema and vasospasm in the post-operative period[10,11,12,13,14,15].

Problems such as patient transportation may be overcome by making the health professional and the institutions aware of the locations and protocols of those institutions with replantation capabilities. Many of the other problems may be solved by experienced replantation surgeons.

In any traumatic amputation, the primary concern must be directed toward the patient's survival. Of secondary concern is the amputated part and the preventation of necrosis which is imperative to successful replantation. It is, therefore, important to institute preservation procedures as soon as possible after amputation.

It has been recommended, that in the immediate post-amputation period, that the amputated part be wrapped in a sterile saline-impregnated dressing, sealed in a plastic bag and placed in ice. This should lower the metabolic rate of the soft tissue and afford the part protection from tissue necrosis. The use of dry ice to further decrease temperatures is contraindicated as freezing may occur[10,13].

Some investigators recommend flushing the limb with heparinized Ringer's solution or low molecular weight dextran[10,15]. These, however, have been used at room temperature to remove sludged or degraded blood, not for providing fur-

FIGURE 5. Patient at five (5) months post-replantation shows remarkable and early recovery of neuromuscular function.

FIGURE 6. At five (5) months post-replantation the patient is able to hold small objects between thumb and index finger.

ther hypothermic protection of the limb. Furthermore, solutions perfused at room temperature may increase the limb's temperature thus increasing metabolism and subsequent autolysis.

Although skeletal and cardiac muscle differ greatly in function and structure, they have similar basal requirements. These similarities, as well as its ready availability, prompted the use of hypothermic cardioplegic solution to preserve the amputated limb.

Mauroudis[16] has shown that hypothermia, coupled with high potassium cardioplegic solution, results in no fluid or electrolyte shifts in cardiac muscle after one hour perfusion and subsequent reperfusion with blood. It was theorized that the hypothermic cardioplegic solution would help to prevent both tissue necrosis and post-operative edema. In this particular case, edematous formation postoperatively was minimal even after four hours and forty minutes of ischemia. It is interesting that two weeks prior to this injury the patient suffered a fracture of the right hand and at forty-eight hours post-replantation there appeared to be more edema in the right hand than in the left.

Direct perfusion of hypothermic cardioplegic solution into the heart is superior to topical cooling because it provides for more uniform cooling of the myocardium. This should also apply to the perfusion of amputated parts and should allow for cooling of the bone. In addition, we have found during myocardial perfusion of crystalloid cardioplegic solution that the oxygen tension is 90 mm Hg or above. Digerness[17] has shown that unoxygenated asanguinous cardioplegic solution contains a small amount of oxygen at 10°C. We are, therefore, delivering some oxygen to the cells which may impart some additional protection during periods of cardiac or, as in this case, limb ischemia.

The many problems encountered in replantation make it difficult to evaluate to what degree the use of cardioplegic solution contributed to the successful outcome of this case. However, we do feel that it contributed significantly to the successful preservation of the limb.

The routine use of hypothermic crystalloid cardioplegic solution in the preservation of amputated parts prior to replantation awaits further experimental and clinical investigation. We are currently considering the use of canine limbs in a study designed to investigate the efficacy of hypothermic cardioplegic solution versus conventional topical cooling of amputated parts.

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