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LATE ARTERIAL REPAIR FOR LOWER LIMB OR KNEE SALVAGE

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ABSTRACT

The objective of this report is to prove that even after development of ischemic necrosis of the muscles and nerves, we can still save the extremity or the knee and even several days after arterial injury, perform arterial repair and other mentioned procedures. Thus we can retain a functionally satisfactory leg or knee joint, which is far better than classic above-knee amputation and utilization of an artificial leg.

28 cases have been chosen in this series, and arterial repair was performed 24 to 72 hours after arterial injury. The arterial injuries were at or above knee level, all the muscles of the leg were found to be necrotic at the time of arrival, and the leg was senseless below the knee or mid-shin.

23 cases underwent leg salvage, and in five who had fractured tibia or necrosis of the skin of the sole or around the ankle, mid-shaft amputation with knee salvage was performed, rather than above-knee amputation. Only three unsuccessful results were encountered, which the authors feel were due to improper case selection, and one mortality was reported, due to pulmonary embolism.

The comparative results were far better than above-knee amputation, both in below-knee amputation and leg salvage, and the patients did not consider themelves disabled either physically or mentally. With proper care, the patients were able to lead completely normal lives with no job opportunity limitations. The authors conclude that even several days after arterial injury and despite ischemic necrosis of muscles and nerves, lower limb or knee salvage is still possible, and classic "a-k"amputation is not the only alternative.[§]

INTRODUCTION

Ligation was the principal treatment of arterial injuries of the extremities in world war II. Gangrene followed ligation in about 50% of the cases. The incidence of gangrene following ligation of the principal artery was reported to be as much as 70% by Herrick[1] in 1932, Rose and Welch[2] in 1946 and Hughes[3] in 1985. Individual experience with arterial injuries in World War II were reported by Bradford and Moore[4], Kirtley[5], MacFee[6], Preston[7], Smith[8], Snyder[9], Stewart[10], Warren[11], and Rose, Hess and Welch[2]. Odom[12] reported arterial injuries as the cause of 23% of one large group of amputations in World War II. This subject was well reviewed by DeBakey and Simeone in 1946[13]. Treatment of arterial injuries by suture or with vein grafts, with or without Blakemore vitallium tubes, was often unsuccessful, probably because casualties were seldom seen earlier than ten hours after injury.

§- After preparation of this survey, 25 more successful cases of total leg salvage and one case of hind-foot salvage with fore-foot amputation were performed, but were not included in this series due to shortness of the follow-up period.

Experimental work by Miller and Welch[14] showed a 90% survival rate of the extremity when arterial repair was done six hours after injury; the survival declined to 50% for repairs after 12-18 hours and 20% after 24 hours. The ideal time for restorative surgery was considered to be under six or eight hours by DeBakey and Simeone in 1946[13]. They stated that not much hope has been held for success of anastomosis procedures after this time, insofar as salvaging the leg is concerned.

In the Korean War, helicopter evacuation of patients made surgical care possible a few hours after injury. In 1955, Spencer and Grewe[15] reported 97 arterial injuries in 85 patients. 89 arterial repairs were performed with a success rate of 83% and only 17% resulted in gangrene. They considered the time interval the most significant factor in determinig whether or not an arterial injury can be successfully repaired. The time intervals for surviving and gangrenous limbs overlap between nine to ten and 13 to 14 hours.

In the author's experience, There was only one case in which arterial repair after 14 hours resulted in full return of function of the muscles and nerves. Thus it was generally accepted that arterial repair for salvaging the extremity was futile if ischemic necrosis had already developed in the muscles, and the classic management was ligation of the injured artery and amputation above the level of ischemic gangrene. Another fact in favor of amputation is the current belief that an anesthetic leg is not worth saving.

The objective of this report is to prove that even after development of ischemic necrosis of the muscles and nerves, we can still save the extremity or the knee and even several days after arterial injury, perform arterial repair and other procedures stated below. Thus we can retain a functionally satisfactory leg or knee joint, which is far better than above knee amputation and utlization of an artificial leg.

MATERIAL AND METHODS

28 consecutive cases have been chosen in this series, and arterial repair was performed 24 to 72 hours after arterial injury. The arterial injuries were at or above knee level, all the muscles of the leg were found to be necrotic at the time of arrival, and the leg was senseless below the knee or mid-shin.

All patients were casualties of the Iraqi-imposed war against Iran. Although helicopter evacuation of war casualties to medical facilities capable of conducting arterial repair was available in the Korean War, the best and most closely located underground medical facilities were reported in the Iranian war fronts. In this system, war casualties are evacuated by highly-trained volunteer rescue forces and transferred to the front line emergency rooms, which are situated less than one kilometer from the war front. After primary medical treatment, which consists of control of bleeding, wound dressing, and treatment of hemorrhagic shock with fluids and blood, the casualties are immediately transported to highly equipped underground medical facilities by ambulance. These facilites, located within five kilometers of the front line, are constantly staffed by a team of general surgeons, and during an Iranian offensive, a vascular surgeon joins the medical team, thus making vascular repair possible in less than six hours after injury. In cases in which a vascular surgeon was not available or the vascular repair was unsuccessful, the muscles developed ischemic necrosis while the patient was being transferred to urban medical centers, such as the Shohada Medical Center and Shahid Mostafa Khomeini Hospital (where this series has been performed).

In the cases presented in this study, as mentioned above, rather than performing the classic and generally accepted amputation, we have been able to salvage the extremity.

Criteria For Selection Of Cases

1) SKIN: **Absence of necrosis of the skin of the sole and ankle joint. Patchy areas of necrosis of the skin of the shin, calf or tips of the toes are acceptable.**

2) BONES: **Absence of fractures at areas of muscle necrosis. If the limb is to be salvaged, the tibia must not be fractured. If the fibula is fractured, it may be resected. If a tibial fracture exists, only the knee can be saved.**

3) MUSCLE: **Absence of muscle or soft tissue necrosis at the site of arterial injury. With inadequate muscle or soft tissue for arterial graft coverage of performing an extra-anatomical bypass graft, the patient is excluded from the selected group.**

4) KIDNEY: **Renal function should be normal. If acute tubular necrosis exists and blood urea nitrogen and creatinine leves are elevated, salvage should not be attempted. This holds true even after arterial repair has been performed.**

5) GAS GANGRENE: **Evidence of gas gangrene as inferred by septic condition of the patient and presence of air in the soft tissue (crepitation on examination or air seen in roentgenograms) exclude the patient for limb salvage and amputation should be performed without further delay.**

INFORMED CONSENT: **The patient should be fully aware of the outcome, and be given the alternative of above-knee amputation.**

Preoperative Evaluation

With consideration to the fact that war casualties are usually multiple trauma cases, a thorough physical examination and careful attention to coexisting

Figure 1. Posterior view of salvaged left leg of a patient in comparison with his normal right leg.

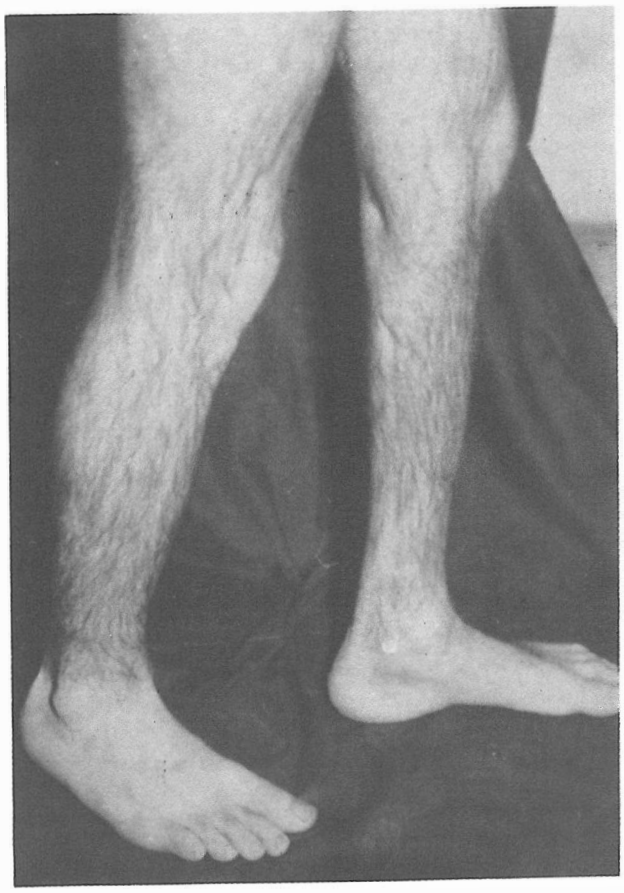

Figure 2. Lateral view of same patient.

injuries are necessary. Special consideration must be given to the condition of the skin on the sole and ankle joint of the injured leg. If irreversible ischemic changes are apparent, leg salvation is no longer possible, and knee salvage is then considered. Arteriography was usually not performed, since it was either unnecessary or not constantly available. if additional arterial injuries were suspected, angiography was performed intraoperatively. Demonstration of an additional arterial injury below the knee where necrotic muscles are present places the patient in the knee-salvage group, and leg salvage is no longer considered. Preoperative laboratory tests consist of a complete blood count, administration of blood (until an adequate hemoglobin level is achieved), serum BUN and creatinine levels, a complete urinalysis, and radiographs of the injured extermity, with special attention to the tibia and fibula. A final evaluation is made under general anesthesia, where a thorough examination of the extremity is possible without undue pain for the patient.

Special attention must be paid to the site of the arterial injury, making sure that adequate viable muscle and soft tissue exists to cover the arterial graft. Otherwise, arterial hemorrhage requiring ligation and limb amputation will result.

Operative Procedure

In contrast to most reports, including Morris et al[16] who used end-to-end anastomosis or lateral repair for arterial injuries in war casualties, the authors used autogenous saphenous vein grafts or saphenous vein homografts from the vein bank to overcome the gap between the two arterial ends after debridement. This avoids tension at the suture line and decreases the rate of failure. The preferred anastomosis was end-to-end between the vein and artery when the muscles surrounding the neurovascular bundle were intact. In cases in which these muscles were necrotic due to energy release from the missile particle, after debridement of nonviable muscle tissue, the two ends of the injured artery were ligated. An end-to-side anastomosis was made between the proximal artery and the vein graft, which was passed between the viable muscles to the distal artery, and a distal end-to-side anastomosis was then performed. Fasciotomy of the anterior, lateral, and superficial and deep posterior compartments was routinely performed to allow swelling of the ischemic muscles and prevent exertion of undesired pressure on the artery, which may result in secondary arterial obstruction and thrombosis.

Fasciotomy should be performed via two long incisions, one over the anterior and the second over the posterior compartment. Care should be taken not to injure the long saphenous vein. The skin and superficial fascia should be separated from the muscles and left completely open. Leaving the skin open (in addition to the fascia) is mandatory.

In the technique presented by Patman et al[17] in which fasciotomy is performed through multiple small skin incisions, it is not possible to open all compartments and provide proper assessment of muscle viability. In the method utilized by the authors, the skin incisions are begun just above the ankle, extending to the uppermost portions of the anterior and posterior compartments. After decompression of the lateral compartment by incising the fascia separating it from the anterior compartment, the deep posterior compartment is decompressed by incising the interosseous ligament longitudinally and lateral to the anterior tibial neurovascular bundle. If the condition of the patient allows, a few of the necrotic muscles of the anterior compartment may be removed from their origins up to the tendinous portions. However, care should be taken not to remove the muscles covering the periosteum or the neurovascular bundle, since exposure will cause the periosteum to become dessicated and the veins and arteries to undergo thrombosis.

Contrary to the protocol mentioned above for lower leg injuries, in the thigh region, thorough and careful debridement of necrotic thigh muscles, especially those covering the arterial graft is obligatory and if a femoral fracture exists, an external fixator is utilized. If the wound is clean and no signs of infection exist, the skin and subcutaneous fascia are sutured following debridement.

It must be emphasized that the long saphenous vien of the injured leg must be kept in mind when performing incisions and fasciotomies, and this vein must not be exposed or traumatized. Naturally, the long saphenous vein of the opposing leg is used for the graft.

If injury of the principal vein exists, a vein graft should be used; a patch graft being used in cases of minimal injury. In some cases, end-to-end anastomosis of the vein without undue tension may be possible, in contrast to arterial injuries in which a vein graft must be used to restore blood flow.

If nerve injuries are found to coexist and the patient's condition allows, an end-to-end anastomosis of the severed nerve without tension may be performed during the same operation. Otherwise, the two ends are approximated using a few stitches and the proper anastomosis is perfomed two months later.

Management of other coexistant injuries is performed after the above-mentioned procedures, which obviously are of higher priority.

Postoperative Care

Considering the fact that we are leaving dead tissue behind (muscles which have undergone ischemic necrosis) and the removal of these tissues will be delayed, care should be taken to prevent development of gas gangrene and multibacterial infection. Absorption of necrotic material may affect renal function and for these reasons careful daily examination of the patient and attention to vital signs is mandatory.

Broad-spectrum antibiotics should be administered, serum BUN and creatinine levels checked every other day, and a postoperative CBC obtained. Hemoglobin levels should be kept above 14g/dl by administration of whole blood as necessary.

In this series, only one case demonstrated rising levels of serum BUN and creatinine and deterioration of renal function. The cause was found to be the presence of necrotic muscles in the thigh, which had unfortunately been missed during the initial operation. Inspite of existence of viable skin of the foot and leg, lack of adequate soft tissue coverage for the arterial graft in the thigh made amputation inevitable.

If a femoral fracture is present, the limb is elevated and placed in a suspended Thomas splint and Pearson attachment. If a fracture does not exist, elevation using a few pillows suffices.

Remaining postoperative management is performed as in any other multiple trauma case. All patients will have postoperative febrile course due to absorption of necrotic material and/or existing infection, and this should not cause undue alarm. Presence of high fever however is usually due to infection in a closed space, and should be drained adequately. Therefore, maintaining adequate drainage of all compartments is essential during the postoperative period.

The second operation, debridement of remaining necrotic muscle, should be performed only after sufficient time has elapsed and should be delayed until granulation tissue has covered the periosteum and neurovascular bundle, and necrotic muscle has undergone autolysis. This usually correlates to the tenth postoperative day. However, if during the operation, removal of any necrotic muscle would cause exposure of the neurovascular bundle or periosteum which is not yet covered by granulation tissue, complete removal is contraindicated, and a layer of at least five millimeters of necrotic muscle should be left covering these structures. Debridement of these remaining muscles is performed later during daily dressings, and rarely a third operation is required.

Daily dressings are done using guaze soaked in 2% acetic acid solution to prevent infection with *Pseudomonas aerogenosa*. Cleansing of the wound is performed with diluted hydrogen peroxide solution.

In cases where periosteal necrosis develops either primarily or secondary to exposure, multiple perforation of the cortical bone should be performed using a 2mm drill, with holes spaced five millimeters apart. Granulation tissue will then protrude through these perforations and subsequently cover the exposed bone.

After granulation tissue coverage of bones and neurovascular bundle is complete and there is no further necrotic tissue present, the defect is covered with a split thickness skin graft.

Ambulation of the patient should be started as soon as the acute phase is over, and patients are usually able to ambulate within seven days unless a fractured femur or other fractures prohibit. The ankle joint should be kept at 90° dorsiflecion to prevent heel cord shortening, even though some patients will eventually need Achilles tendon lengthening with or without posterior capsulotomy two to seven months later.

In some cases, for cosmetic reasons or due to difficulty in cleansing the grafted area (the gutter between the tibia and fibula), the skin graft was removed and primary closure of the skin by undermining was undertaken.

Tenotomy of the flexor tendons of the toes to correct hammer-toe or claw-toe deformity was necessary in five cases, one to two years after the primary operation.

Patient Education At Time Of Discharge

The patient is instructed to:
1) wash his foot with soap and lukewarm water and lubricate the skin of his foot with vaseline regularly.

2) Avoid walking without footwear, even in the home or for short intervals.

3) Use only comfortable, correctly fitted footwear along with a pair of thick wool stockings.

4) Avoid walking for lengthy periods of time without checking the condition of the skin over the pressure points, especially after wearing new footwear. From among the patients who continued to participate in offe nsives and were on occasion unable to remove their boots for up to 48 hours during some attacks, two developed superficial ulcers on the tips of their toes, prompting their referral behind the front lines for treatment. These ulcers usually heal spontaneously with regular dressing, except in situations where neglect and delay in seeking treatment causes a deep ulcer which requires a full-thickness skin graft. one patient, after five years of farming, became carelessly overconfident and required a cross-leg flap for treatment of an ulcer he developed as a result of an unnoticed piece of gravel in his shoe.

Surgical Technique For Knee Salvage

In cases where a fractured tibia is not covered by healthy muscle, or necrosis of the skin of the sole or around the ankle obviates foot salvage, amputation of the leg at the level of the fracture or mid-leg is performed after arterial repair. Simultaneously, all necrotic muscles are removed, and the skin is closed over the trimmed bone tip while being left open on either side. For proper removal of necrotic muscles, the fishmouth incision is extended up to the knee and left open for future debridement of muscles left covering the neurovascular bundle and periosteum. Also in these cases, exposure and damage of the neurovascular bundle and periosteum must be avoided and less than adequate debridement is always better than extensive debridement with periosteal exposure and resultant bone necrosis or thrombosis of exposed vessels. Postoperative care is similar to that mentioned for foot salvage.

RESULTS

28 war casualty cases with arterial injuries to the main vessel of the leg causing irreversible muscle necrosis of the leg underwent late arterial repair, rather than classic amputation, for salvage of the entire leg or knee. In these cases, necrotic muscles were removed subsequently, along with other surgical procedures which are detailed above. Of these cases, 23 underwent leg salvage instead of above-knee amputation, and in five who had a fractured tibia or necrosis of the skin of the sole or around the ankle, mid-shaft amputation with knee salvage was performed rather than above-knee amputation. The age of the patients ranged form 15 to 60, with a mean age of 22. The length of hospitalization was from 32 to 110 days, with a mean of 70 days. It should be mentioned that the lengthy hospitalizations were often due to coexistant injuries such as fractures and osteomyelitis. 19 of the 28 cases had coexisting injuries which are listed below.

Coexisting Injuries	No. of Cases
fractures of upper extremity	7
fractures of opposite leg	5
amputaion of opposite leg	3
fractured femur of same leg	7
fractured tibia of same leg	4
abdominal injury necessitating laparotomy	7
miscellaneous injuries	7

The time interval between arterial injury and restoration of blood flow of the limb was between 14 and 96 hours, with a mean of 48 hours. The site of injury was the popliteal artery in 15 cases, the superficial femoral in 12 cases, and the common femoral in one case. The number of operations performd on each patient was between two and seven, with a mean of four.

All patients had fever postoperatively, lasting between 4 to 45 days with an average of 20 days. The cause of prolonged fever was usually the coexisting injuries.

From among the 28 cases presented in this study, we had three unsccessful results, two of which were felt to be due to improper case selection. In the first case, arterial bleeding occurred as a result of disruption of the anastomosis due to infection. Since the site of injury was in the popliteal region and an

extra-anatomical bypass passing through non-infected tissue was not possible, arterial ligation was performed. This resulted in subequent gangrene, necessitating amputation. In the second case, serum BUN and creatinine levels began to rise, and during the second operation, the cause was found to be missed necrotic muscles in the thigh as a result of energy release of the missile particle. After extensive debridement of all necrotic muscle tissue, adequate tissue did not exist to cover the arterial graft or sustain a functional leg, and mid-thigh amputation was performed. In the third case, one month after a successful result was achieved, the patient developed arterial bleeding of the graft due to osteomyelities. Ligation of the artery resulted in subsequent gangrene and amputation of the leg. We had one mortality on the eighth postoperative day after a successful result, due to pulmonary embolism. The patient, who had been ambulatory for two days, suddenly developed severe chest pain and dyspnea upon returning to bed to receive an injection by a nurse. He subsequently underwent cardiac arrest and did not respond to resusctitation.

DISCUSSION

Patient follow-up for a period of one and a half to five years indicates that results are far better than above-knee amputation. The patients did not consider themselves disabled either physically or mentally, and all were able to return to the front lines and participate actively in war offensives. Desire to return to the front lines was especially high among commanders, both of the volunteer army and in active duty, due to their special skills and training they felt were needed in the war effort. Those patients who completed their military service had no disability in selecting jobs or performing all types of manual labor.

Special care needed to keep the leg functioning is far less than the special precautions required to keep an above-knee stump healthy. In cases of below-knee amputation, the special management precautions are similar to the conventional below-knee amputation, and the superiority of a below-knee to an above-knee amputation is obvious. Some of these patients required stump revision or excision of neuromas, as may be expected in any amputation case. A major advantage of these patients over those undergoing amputation becomes obvious at time of marriage, because the family of the spouse does not consider the patient disabled. The appearance of the salvaged left leg of a patient in comparison with his normal right leg is shown in Fig. 1 and 2.

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