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Predictive Value of Biochemical Markers for Extremity Vascular Trauma Outcome

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ABSTRACT

Objective: To evaluate the predictive value of some biochemical markers in the outcome of extremity vascular trauma.
Methods: This study comprised 30 patients with traumatic arterial injury and acute limb ischemia referred to Namazi hospital affiliated with Shiraz University of Medical Ssciences, over a period of 8 months, from Sep 2009 to Jul 2010. Venous blood samples were drawn from distal ischemic limb to determine pH, HCO_3^-, PCO_2, PO_2, Na^+, and K^+ before definitive surgical intervention. Comparable samples were also obtained from veins of non-ischemic upper extremities. The biochemical assays were compared after monitoring the revasculurized limbs and evaluation of viability during a period of 7 days.
Results: The mean age of the patients was 28.3 ± 7.8 (range: 18–56) years. Two (6.6%) patients underwent amputation because of developing irreversible limb ischemia after vascular reconstruction. Both patients had blunt traumatic knee injury accompanied by nerve, vein and soft tissue damage. The statistical analysis showed correlations between parameters, except for Na^+, of local (ischemic limb) and systemic samples. In this context, the highest correlation was observed in regard to HCO_3^-.
Conclusion: The correlation was most pronounced with respect to HCO_3^-. Ischemic limbs exhibited reduction in pH and PO_2 but, PCO_2 and K increased after ischemia of injured limbs. PO_2 reflects tissue perfusion and is of value in predicting the outcome. We believe that blunt trauma and associated nerve, vein and soft tissue injuries pose negative prognostic effects on limb survival postoperatively.

Keywords: Trauma; Limb ischemia; Vascular injury; Vascular reconstruction; Biochemical assay

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Introduction

Over the past five decades of experience in the management of extremity vascular trauma, a number of factors have been identified which directly influence patients' outcome. These include the time interval between injury and treatment, mechanism of injury, anatomic location, associated injuries, age, comorbidities and clinical presentation [1].

Knowledge of these prognostic factors is essential for the appropriate evaluation and treatment of afflicted patients. The time interval from injury to treatment is perhaps the most critical determinant of salvage of both life and limb, following extremity vascular injury, as it is for all forms of trauma. This is explained by the time-dependent nature of the two major consequences of vascular injury, hemorrhage and ischemia [2].

Strong correlation between delay in treatment of arterial injuries and limb loss was shown in multiple studies such as, World War II, Afghanistan War, etc. Several civilian clinical series have confirmed close correlation of limb loss with delay in revascularization, especially when extremity arterial injury is complicated by associated injuries to vein, soft tissue,

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and bone [1]. Even salvaged limbs are subject to functional disability, following treatment delay, due to nerve and muscle damage, as well as the development of potentially dangerous vascular complications such as pseudoaneurysms and arteriovenous fistulas (AVFs) [3]. Many studies have established the critical time interval, for restoration of limb perfusion and optimal limb salvage, to be at most 6-8 hours following extremity vascular trauma [4]. The degree of ischemia and extent of collateral circulation affect tissue tolerance of delay. Therefore, prompt diagnosis and treatment of vascular injuries must be a major goal of management of all extremity traumas [4].

Mechanisms of blunt injury involve a wider application of force, with greater damage to extremity vessels and surrounding structures than is imparted by penetrating trauma. Blunt vascular injuries are associated with a more difficult diagnosis and higher rates of amputation and severe dysfunction than simple penetrating vascular injuries which are typically clean, isolated, and more easily diagnosed and repaired [1]. Among Penetrating injuries, stabs impart the least destructive force and are associated with a small and discrete area of injury. High-velocity gunshot and shotgun wounds create a level of damage similar to blunt trauma, in terms of the complexity and extent of the damage, the difficulty of diagnosis and treatment, and the higher rates of limb loss.

If the interval between trauma and vascular reconstruction is prolonged beyond 4-6h, the possibility of surgical success is gradually reduced with increasing risk of kidney damage or even death. In these situations physical examination by surgeon is mainstay of decision making. Vascular reconstruction has to be performed when ischemic limb seems viable by examination and post-traumatic interval of less than 4-6 hours. On the other hand, when the limb is necrotic the decision making becomes very difficult [5,6].

But between these two states, taking decision to restore blood to the injured limb is controversial especially when the surgeon lacks extensive experience. Therefore, we should weigh the risk of reperfusion syndrome against the possibility of saving the borderline viable limb. In limb injuries involving amputation, laceration injuries, or compartment syndrome a circulatory insufficiency with a total or subtotal ischemia may occur and jeopardize the result of reconstructive surgery. Transcutaneous oxygen monitoring has been shown to reflect tissue perfusion and has been recommended for predicting the final outcome of major vascular trauma of the limb.

The effect of transient iatrogenic ischemia, caused by tourniquet pressure, on local and systemic blood gas analysis has been demonstrated in animals [7]. But similar studies have not yet been reported in humans. The present study was thus performed to determine whether biochemical assay can predict the outcome of traumatic acute ischemic limb after vascular reconstruction.

Materials and Methods

The case records of 30 patients with acute arterial injuries included both blunt and penetrating (gunshot, shotgun, stab and iatrogenic) injuries. These patients presented with acute traumatic limb ischemia 4 to 6 hours after trauma, and viable ischemic limb based on Rutherford criteria. The study did not include patients undergoing primary amputation due to non-salvageable injuries, and those having injuries of ulnar or radial arteries. Other excluded cases were those without main arterial injuries such as branch damage as well as patients with injury to hands, feet and legs.

All traumatized patients were initially resuscitated by emergency trauma team. Bleeding was transiently controlled by packing or tourniquet pressure. Those with vascular injuries were evaluated by vascular and orthopedic surgeons to salvage the involved limb and the extent of damage to bone, soft tissue and nerve. The diagnosis of a vascular injury was mainly based on clinical findings. Only a few duplex ultrasound examinations were done, without performing any arteriographic studies. Venous sampling was taken from distal ischemic limb for determining pH, HCO_3^-, PCO_2, PO_2, Na^+, and K^+ before definitive surgical intervention. Comparable venous samples also were taken from non-ischemic upper extremities.

Standard incisions were made to expose the arteries. Methods used to repair the injured arterial segments included lateral arteriorrhaphy, resection and end-to-end anastomosis, autogenous vein graft, and synthetic graft interpositions. If possible, veins were repaired by lateral venorrhaphy or resection and end-to-end anastomosis, but graft interposition was not used. Fracture fixation preceded arterial repair in all cases. However, temporary shunts were applied to decrease warm ischemia time in patients with critically ischemic limbs.

Nerve injuries were repaired aptly and soft tissue cover was performed. Systemic heparinization was used during repair of isolated vascular injuries. Fasciotomies were used liberally especially with delayed presentation, extremity swelling and/or combined arteriovenous injuries. Associated organ injuries were managed as indicated by relevant surgical teams. Antibiotics, mainly Cefazoline, were administered, depending on the extent of associated injuries. Revasculurized limbs and viability were monitored and evaluated for 7 days.

All statistical analyses were performed with the

Statistical Package for Social Sciences version 15.0 (SPSS Inc., Chicago, IL, USA). Utilizing student's t-test was used to compare between parametric data sets. A *p*-value less than 0.05 was considered statistically significant.

Results

Over 8 months starting from Sep 2009 to Jul 2010, a total of 32 patients with traumatic arterial injuries and acute limb ischemia admitted to Nemazee hospital, participated in this project, excluding primary amputations and all patients with irreversible limb ischemia. Two patients died before 7 postoperative days, and excluded from the study, but their injured limb was preserved after arterial reconstruction. Right-sided pneumonectomy was conducted on one of them, because of concurrent right lung injury. Another one had received massive transfusion and developed multi- organ dysfunction. Of 30 patients under study, 28 were males and two females aged from18-56 years and the mean age of 28.6 ± 8.2 years.

Types of injuries were gunshot (6 cases, 20%), stab wound (17 cases, 56.6%), glass injury (1 case, 3.3%), blunt trauma (4 cases,13.3%) and iatrogenic (2 cases, 6.7%). Axillary artery was the most common injured artery (4 cases, 13.3%) followed by Brachial artery (8 cases, 26.6%), ulnar and Radial artery (4 cases, 13.3%), femoral artery (1 case, 3.3%), superficial femoral artery (4 cases, 13.3%) and popliteal artery (9 cases, 30%). Mean operative time was 160 (110–250) minutes. Vascular reconstruction was performed by synthetic graft interposition for two patients, reverse saphenous graft interposition performed in 11 cases, arterial repair in 10 patients and end to end anastomosis in 7 cases.

Four quadrants Fasciotomy was done in 9 patients with lower extremity injury. Also one patient underwent hematoma evacuation, and bone re-apposition was performed in 4 cases. Two patients were re-operated due to bleeding from sites of vascular repair and were successfully controlled.The limb-salvage rate was 93.3% (28/30). Of 5 patients (16.6%) having associated orthopedic fixation, 1 (20%) was before and 4 (80%) after revascularization.

Rhabdomyolysis did not occur postoperatively but hemodialysis was performed in one case.

After vascular reconstruction two patients developed irreversible limb ischemia and underwent amputation. They had blunt traumatic knee injury with accompanied nerve, vein and soft tissue damage. One of them had history of previous tibial fracture for which open reduction and internal fixation had been done. However, upper extremity vascular reconstructions were totally successful. As summarized in Table 1, the levels of pH ($p<0.001$), HCO_3^- ($p<0.001$), PO_2 ($p=0.003$), PCO_2 ($p<0.001$) and K^+ ($p<0.001$) were significantly lower in ischemic limb samples compared to systemic circulation. The level of Na^+ was comparable in systemic and ischemic samples ($p=0.939$).

Discussion

Vascular injuries of the extremities remain the most important causes of limb amputation, if not treated early and competently. The mainstay of diagnosis in these patients was critical clinical assessment, keeping in mind both the hard and soft signs of vascular trauma, and the elapsed time from injury [8,9].

There has been more improvement in outcome following vascular injury in recent years, because of better understanding of the pathophysiology of reperfusion injury and development of injury severity scoring systems. Surgical management in these areas is usually dependent on clinical examination and perioperative anatomical diagnosis [9]. It has to be noted that the classical signs of limb ischemia (i.e. pain, pallor, lack of pulse, paraesthesia, and paralysis) are not always evident [10,11].

Vascular trauma from civilian gunshot or stab injuries is usually associated with few, if any, concomitant injuries and this leads to expedient management and successful outcomes. Patients with blunt trauma typically have severe associated injuries involving bone, soft tissues, nerves and viscera. This accounts for a higher mortality and morbidity of these patients, which was also evident in our study The delay between injury and restoration of perfusion to the injured limb is an important factor in determining the outcome [8].

Any limb which has absent distal pulses with no ischemic signs after 4 to 6 hours of injury is eminently salvageable. This is due to availability of adequate collateral circulation to keep the distal tissues alive, thus guaranteeing a good functional outcome. There is no specific time limit for salvageability [1].

If the time interval between trauma and vascular reconstruction is extended beyond 4 to 6 hours,

Table 1. Comparing the biochemical markers between the systemic circulation and the ischemic limb.

	Ischemic limb	Systemic circulation	*p*-value
pH	7.352 ± 0.025	7.386 ± 0.037	<0.001
HCO_3^- (mEq/L)	16.73 ± 6.28	19.17 ± 2.36	<0.001
PO_2 (mmHg)	46.71 ± 20.8	58.87 ± 19.6	0.003
PCO_2 (mmHg)	45.73 ± 16.6	41.92 ±18.3	<0.001
Na^+ (mEq/L)	142.2 ± 21.6	142.3 ± 25.8	0.939
K^+ (mEq/L)	4.31 ± 0.9	4.82 ±0.8	<0.001

the possibility of successful surgery to salvage the limb will be gradually reduced with increasing risk of kidney damage or even death. In this situation, physical examination by surgeon is crucial in decision making. Vascular reconstruction must be conducted if ischemic limb seems viable by examination, and post-traumatic interval is less than 4 to 6 hours. On the other hand, when the limb is necrotic taking decision is not so difficult.

But between these two states, decision to restore blood to the injured limb is controversial especially when the surgeon does not have sufficient expertise. Therefore, we should weigh the risk of reperfusion syndrome against the possibility of saving the borderline viable limb. In limb injuries such as amputation, laceration injuries, or compartment syndrome, a circulatory insufficiency with a total or subtotal ischemia may occur and jeopardize the result of reconstructive surgery.

Our study revealed significant correlations among all biochemical parameters in local ischemic limb and systemic samples except sodium which did not show any significant correlation. HCO_3^- exhibited highest correlation in ischemic and systemic laboratory analysis. HCO_3^-, pH and PO_2 decreased in ischemic limbs but, PCO_2 and K^+ increased significantly after acute ischemia of injured limbs. However absolute amount of these parameters was not of any predictive value for the outcome of vascular injuries.

Furthermore, age and sex did not have any significant effect on the outcome of injured limb.

Transcutaneous oxygen monitoring has been shown to reflect tissue perfusion and has been recommended to predict the final outcome of major vascular trauma of the limb. In normal air, the transcutaneous oxygen values in the traumatized limb were significantly lower than in the nontraumatized limb. But, neither the absolute PCO_2 value nor the ratio between PCO_2 of the traumatized and that of non-traumatized limbs can predict the final outcome with regard to amputation [11]. Blunt trauma and associated nerve, vein and soft tissue injuries have negative prognostic effects on limb survival postoperatively, as most vascular injuries due to limb trauma can be managed successfully, unless associated with severe damage to bones, nerves or soft tissues [9].

In conclusion, all biochemical parameters correlated together in ischemic limb and systemic samples except sodium. HCO_3^- had the most remarkable correlation. HCO_3^-, pH and PO_2 decreased in ischemic limbs but, PCO_2 and K^+ increased after ischemia of injured limbs. However absolute amounts of pH, HCO_3^-, Na^+ and K^+ does not seem to have any predictive value for the outcome of vascular injuries. Age and sex, also, did not have any significant effect on outcome of injured limb. PO_2 (through transcutaneous oxygen monitoring) reflects tissue perfusion and is advocated to predict the outcome of major vascular trauma of the limb. But, in respect of amputation, PCO_2 does not have such a predictive value for the outcome. Also, we believe that blunt trauma and associated nerve, vein and soft tissue injuries have negative prognostic effects on limb survival postoperatively.

Conflict of Interest: None declared.

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