

Diagnosis and Treatment of Limb Fractures Associated with Acute Peripheral Ischemia

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Rezumat

Diagnosticul și tratamentul în fracturile de membre asociate cu ischemie periferică acută

Ischemia periferică acută (API) este cea mai severă complicație acută a fracturilor închise și deschise, având în vedere faptul că ischemia afectează nu numai vitalitatea membrului afectat, ci chiar viața pacientului, întrucât alterările datorate metabolismului anaerob consecutive ischemiei au consecințe redutabile locale și generale. Aceasta explică de ce diagnosticul precoce al ischemiei periferice acute este foarte important pentru prognosticul unui membru traumatizat. Autorii analizează cazurile când aceasta nu a fost diagnosticată imediat post-traumatic, ci după un oarecare interval de timp, fie datorită valorilor inițiale scăzute ale TA sistolice, fie datorită instalării tardive a ischemiei. Pacienții au fost evaluați din punct de vedere al tipului de fractură, motivelor diagnosticului tardiv, momentului efectuării acestuia și tipului de leziune arterială. În aceste cazuri, intervenția chirurgicală a fost efectuată cu maximă urgență, pentru a identifica și trata leziunile complexe (osoase și vasculare).

Cuvinte cheie: membre, fracturi, ischemie periferică arterială, tromboză

Abstract

Acute Peripheral Ischemia (API) is the most severe acute complication after both open and closed fractures, as ischemia compromises not only the vitality of the affected limb, but also the patient's life, because metabolic anaerobic changes following ischemia have serious local and general consequences. These explain why early diagnosis of API is very important for the prognosis of the traumatized limb. The authors analyse cases when API was not diagnosed immediately after trauma, but some time after the first examination, due to either low systolic BP or to late onset of API. The patients were analysed concerning the type of the fracture, the reason for delayed diagnosis of API, the moment of API diagnosis and the arterial injury. In all those cases, surgery was performed immediately after API diagnosis, in order to identify and treat the complex injuries (bone and vascular).

Key words: limbs, fractures, acute peripheral ischemia, thrombosis

Introduction

Modern traumatology is characterized by higher energy trauma agents, like high-speed vehicles (generating more severe road traffic accidents), high velocity missiles, complex technical procedures using inflammable materials, generating severe work accidents. When interacting with the victims, all of these produce severe injuries, because the energy of the trauma agent is almost entirely transferred to the affected tissue (except a very small amount, lost due to friction), producing

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different amounts of cellular and tissular disruptions. When acting on a part of one limb, traumatic forces are transferred to its structures, often producing a fracture, but high energy agents generate complex injuries: bone, muscular, vascular and nervous injury.

The proximity of the bones to the blood vessels of the limbs often generates vascular complications, which are so complex that a unique classification is difficult to be established, as many criteria are to be discussed: the type of the vessels affected (arteries, veins, or both), the size of the vessels (large, medium or small), the main effect of the injury (ischemia or hemorrhage) the amount of the vascular wall and diameter affected, the local consequences (functional and structural damages of the tissues produced by the vascular injury), systemic impact of the vascular damage (by itself and by local metabolic changes).

Considered to be the most severe of all the vascular complications of trauma, arterial injuries have both local and general consequences due to Acute Peripheral Ischemia (API), which can be defined as the syndrome consisting of metabolic disturbances, followed by structural changes of the affected tissues, with clinical correspondence, due to the imbalance between the local need of blood and the amount of oxygenated blood supply, diminished after arterial injuries. (1)

It is known that acute ischemia affects all tissues, depending on their sensitivity to hypoxia (which is the main consequence of ischemia), so the moment when the hypoxic injury of different tissues becomes clinically detectable, depends on the metabolism of each tissue, and especially on the oxygen-dependence of that metabolism (i.e., the more oxygen is involved in the metabolism of a certain tissue, the earlier that tissue becomes necrotic following acute ischemia). (2)

The importance of acute ischemia is not only local, but it soon becomes systemic, as necrotic tissues, especially the muscles, generates anaerobic metabolic products which produce liver and kidney failure. (3) That is why modern scoring systems of limb trauma refer not only to the fracture, but also to the vascular status following trauma, and one good example is the well-known MESS Score, which evaluates the prognosis of an ischemic limb, concerning both local and systemic factors: the age of the patient, signs of API, signs of shock and the energy of the traumatic agent. (4)

The Mangled Extremity Severity Score (MESS) may be used to decide whether to perform amputation in patients with injuries involving a limb. (Table 1)

Score doubles for ischemia > 6 hours.

A total MEES score of 7 or greater is predictive of amputation.

It is to be underlined that the modern tendency of scoring the injuries is highly valuable not only for multiple trauma, but for limb trauma, as well, as it reflects the severity of the injury. (5) Literature shows that API can complicate most skeleton traumas, that it can occur simultaneously with the skeleton injury, or after a certain period of time, called "free interval", after open fractures (type III C in Gustillo-Andersen classification), and closed fractures. The fact that the open

Table 1.

A. Skeletal\ soft – tissue injury	
Low energy (stab, simple fracture, low velocity gunshot wound)	1
Medium energy (open or multiple fractures, dislocation)	2
High energy (close range shotgun, high velocity gunshot, crush)	3
Very high energy (above end gross contamination, soft- tissue avulsion)	4
B. Limb ischemia	
Absent ischemia	0
Pulse reduced or absent but perfusion normal	1
Pulseless, paresthesias, diminished capillary refill	2
Cool, paralyzed, insensate, numb	3
C. Shock	
Systolic blood pressure always over 90 mm Hg	0
Hypotensive transiently	1
Persistent hypotension	2
D. Age (years)	
< 30	0
30-50	1
> 50	2

fracture needs immediate surgical debridement avoids the situation of not-diagnosing API, since the vessels are examined intraoperatively. When the fracture is closed, it is very important for the trauma surgeon to perform a thorough clinical examination of the injured limb, especially after certain types of fracture, when he must "expect" arterial damage.

As the correct treatment of arterial injuries, concerning the moment and the type of intervention, is vital not only for the limb, but also for the patient's life, early diagnosis of API is absolutely necessary, and this is performed primarily by clinical examination, which shows disappearance (or decrease, compared to the contralateral limb) of the peripheral pulse. After that, Doppler and arteriographic examinations show the location accurately and give information about the type of injury. (6,7)

Since peripheral pulse is the major indicator for the arterial status of the limb, it is also the most important factor used in clinical diagnosis of API. It is palpable only if systolic blood pressure exceeds 60 mmHg, when peripheral pulse will be palpable at the other limbs except the ischemic one. If systolic blood pressure is less than 60 mm Hg, peripheral pulse will not be palpable at any of the limbs, so API diagnosis is impossible until hemodynamic stabilization.

The purpose of the study is not to describe the treatment of closed fractures associated with arterial injuries, but to present two major problems concerning diagnosis of API complicating closed fractures, when API is not detected at the first clinical examination: the situations when systolic blood pressure is under 60 mm Hg (acute post-traumatic hypotension) and peripheral pulse is not palpable as well as those when there is a "free interval" between trauma and API onset.

Material and Method

Fifty-four patients were operated on in the Orthopedics and Trauma Clinic of Emergency Hospital Bucharest between 1.01.2001 and 1.01.2011 for API (complicating closed fractures) which could not be diagnosed by primary examination, but sometime after the first examination. None of the patients had any arterial pathology before trauma (revealed by the patients, by their families or according with to the clinical findings).

The patients were studied concerning the type of the fracture, the reason for delayed diagnosis of API, the moment of API diagnosis and the arterial injury.

Using the AO classification, the types of the fractures were: twenty femoral shaft fractures, sixteen fractures of distal femur, ten tibial fractures, and eight humeral fractures.

In all fifty-four cases, API was not detected at the first examination, but after some time, for two main reasons, so the patients were divided into the following two groups:

Group A – thirty-six cases, mean age 42.6 years (twenty-six to sixty-six years), with systolic blood pressure less than 60 mmHg at first examination. The patients in this group did not have palpable pulse at any of the peripheral arteries when they were first examined. After hemodynamic stabilization, peripheral pulse became palpable except on the distal part of the affected limb, and the mean time between first examination and the moment when API was diagnosed was sixteen minutes. (Fig. 1)

Group B - eighteen cases, mean age 32 years (fourteen to fifty-six years), with bilateral peripheral pulse palpable on the first examination at upper and lower limbs; after a certain period of time – mean value fourteen hours (twelve to eighteen hours) - API was clinically diagnosed at one of the limbs, as peripheral pulse was no longer detectable, and the signs of ischemia also appeared. (Fig. 2)

In all these cases, when API was diagnosed, arteriography was performed, and afterwards surgical treatment confirmed the arterial injury, described it precisely and repaired the associated injuries. Surgery consisted of the following standard procedures: bone stabilization, venous drainage restoration for humeral and femoral veins, major arterial axis restoration, associated injuries of muscles, nerves, tendons treatment, and decompressive fasciotomy, for reperfusion syndrome prophylaxis.

The patients from the two groups were studied for the type of the fracture, the moment of API diagnosis, and the arterial injury producing API.

Results

The fractures in group A were:

- twelve femoral shaft fractures,
- ten distal femoral fractures,
- eight tibia fractures,
- six humeral fractures.

The time between the first examination and the moment when API was first diagnosed was of an average value of sixteen minutes. This time was less than fifteen minutes (above ten

Group A

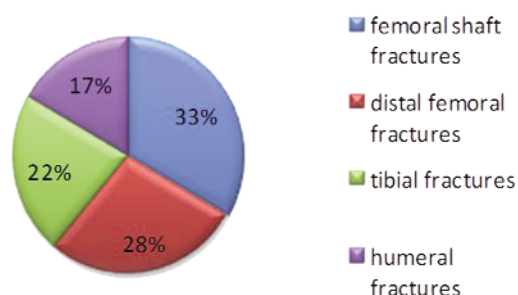


Figure 1.

Group B

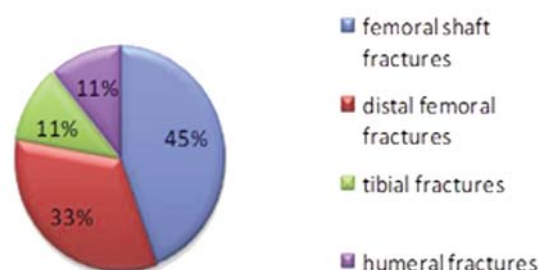


Figure 2.

minutes) in twenty-four cases, when acute hypotension produced by trauma was corrected by oxygen, intravenous fluid and drug administration, without requiring any surgical procedure. The time was longer than fifteen minutes (not exceeding thirty-three minutes) in twelve cases when hypotension was produced by associated injuries, which needed surgical treatment: eight ruptured spleens, which needed splenectomy, three liver injuries, which needed hepatorrhaphy, one mesenteric disinsertion, with haemoperitoneum, which required resection and haemostasis. (Table 2)

The arterial injuries in group A suggested by arteriography and precisely described intraoperatively, were (Table 3).

Group B - eighteen cases, mean age thirty-two years (fourteen to fifty-six years), with bilateral peripheral pulse palpable on the first examination at upper and lower limbs; after a certain period of time – mean value fourteen hours (twelve to eighteen hours) - API was clinically diagnosed at

Table 2.

Number of cases	The time between the first examination and the moment when API was first diagnosed
24	less than 15 minutes, but above 10 minutes
12	longer than 15 minutes, but not exceeding 33 minutes
Total 36	Mean time 16 minutes

Table 3.

arterial section	seventeen cases	complete-twelve cases
		incomplete-five cases
injury of internal and medium layer, with intact external layer	eight cases	
thrombosis	three cases	
compression and spasm	eight cases	
incomplete section with subsequent thrombosis	five cases	

one of the limbs, as peripheral pulse was no longer detectable, and signs of ischemia also appeared: pallor, pain and decreased cutaneous temperature in all the eighteen cases, and paresthesia in two cases. The signs that alerted the patients, who required repeated ortho-pedically examination (which detected the absence of peripheral pulse) were: the sensation of "cold fingers" of the fractured limb - eighteen cases, pain - six cases, paresthesia - twelve cases. Since API was diagnosed in early stages, none of the neurological signs of irreversible ischemia (paralysis or anesthesia) appeared. (Table 4)

The fractures in group B were:

- eight femoral shaft fractures,
- six distal femoral fractures, two tibia fractures,
- two humeral fractures.

The arterial injury in group B (detected intra-operatory) was arterial thrombosis in all eighteen cases. In two cases minimal lateral injuries of the artery (a longitudinal 2 mm injury in one case and a round lateral injury with 3 mm in diameter) with subsequent thrombosis were detected; in these cases, the hematoma surrounding the artery had a medium size and acted as a compressive haemostatic mechanism.

Discussion

Arterial injuries complicating fractures are situations quite often described in literature and seen in trauma services, since agents with high traumatic force transfer their energy to all the tissues in the involved region. As Acute Peripheral Ischemia is a situation that needs immediate treatment, otherwise not only the affected part of the limb will be compromised, but sometimes the patient's life too, the early diagnosis of this condition is vital for the patient. (8) It is, first of all, very important to understand the traumatic mechanism and to evaluate properly all the features of the initial accident. This will allow the surgeon to look for all the potential injuries starting from the initial aspects. (9,10)

We suggest an algorithm which is aimed to establish the steps that the medical examiner has to follow for a proper medico-legal evaluation of API cases. (11) Because the medico-legal evaluation is done usually late after patient admission in the orthopedics clinic, the medico-legal case review is based on the patient clinical files. The subject of this algorithm is

Table 4.

Number of cases	The time between the first examination and the moment when API was first diagnosed
18	less than 18 hours, but above 12 hours
Total 36	Mean time 14 hours

represented by both clinical and etiopathogenic conditions of API.

A. Absent pulse in one limb after patient hemodynamic stabilization

1. Diagnosis of API is a clinical one – the absence of peripheral pulse is the major sign, detected by the physician, who has to evaluate the vascular status of the injured limb. There are certain situations when API cannot be diagnosed immediately after trauma, even if the arterial injury exists. Two of these situations are discussed in this study: the first refers to post-traumatic hemodynamic changes, which disturb clinical evaluation of the vascular status. This evaluation concerns the arterial and venous circulation - the arterial evaluation includes subjective elements, described by the patient, and objective elements - peripheral pulse, cutaneous temperature and colour, capillary pulse, active movements. (9) If the subjective elements cannot be described by the patient due to his status, peripheral pulse is the only reliable element. As acute ischemia is defined as an imbalance between the local needs and practical supply of oxygen determined by an arterial acute injury, peripheral pulse of the injured limb must be compared with the pulse of other limbs, in order to be sure that the pulse absence is not the consequence of a chronic disease, like arteritis.

2. If the peripheral pulse cannot be detected in any of the limbs due to acute post-traumatic hypotension, it is impossible to diagnose API in one of the limbs until hemodynamic stabilization, which leads to the presence of the peripheral pulse in all the limbs except the ischemic one.

That means that when the patient's blood pressure is critically low, and the peripheral pulse is absent in all the limbs, clinical examination of the injured limb must be repeated until the patient is stable and the pulse appears, in order to ensure that arterial damage has not occurred near the fracture. If the pulse is symmetrical at the upper and lower limbs, it means that there is no disturbance of the peripheral arterial flow in that moment.

3. If the pulse is absent in one limb that limb is ischemic and we have to find out whether the ischemia is due to recent trauma or it precedes trauma. If that limb has a fracture and the clinical examination suggests that the arterial injury level is at the site of the fracture, the probability of direct fracture-arterial damage correlation is very high and it must be considered at once. An arteriographic examination is recommended and if, hazardously, this is not possible, immediate surgery must be performed. (12,13,14) The possibility of ischemia existing before trauma is very low, and this can be suggested by an obvious difference at the inspec-

tion of the ischemic limb, characteristic for chronic injuries (atrophy of the muscles, skin, hairiness, nails, or even signs of gangrene). This situation is quite rare, but it must be considered and if the patient cannot provide any useful information for a differential diagnosis, arteriographic examination may complete the clinical findings. Nevertheless, whenever the suspicion of acute injury exists, even on an arteritic background, surgical evaluation will clear up the diagnosis. (15)

B. The situation represented by the cases when there is a certain period usually called “free interval” between the trauma and the API onset (a few hours)

In our study, the arterial injury in the cases with a late onset of API was arterial thrombosis. Literature presents post-traumatic arterial thrombosis as a very serious complication, as it occurs late after trauma, the artery looking intact, but the mechanism is a microscopic one: the initial trauma is only a contusion which does not disrupt the arterial wall, but produces thrombosis or disruption of the vasa vasorum - generating ischemia of the arterial wall. The most sensitive structure to ischemia (of the entire arterial wall) is the internal layer (the intima). Subsequently to the initial trauma, the intimal layer is injured both directly (mechanical) and indirectly, through ischemia of the wall. The injury of the intima damages the connections between the endothelial cells, so the endothelium loses its continuity from place to place, exposing the subendothelial collagen fibres to the blood flow, which generates conditions for blood cell adherence, leading to thrombosis. (16,17,18) (Fig. 3, 4)

Conclusions

After trauma, ischemia is frequently diagnosed after “alarm signs” (the sensation of “cold fingers” of the fractured limb, pain, paresthesia) are reported by the patient to the physician, who performs a new examination, suspecting an ischemia. The earlier the ischemia is diagnosed, the better the prognosis of the patient will be.

A critical matter is represented by the situation when the patient is not conscious and he cannot alarm the physician. In this situation, the only possibility of an early diagnosis of API is repeated vascular evaluation, especially when the fracture has a certain location and features. We can use the term “dangerous environments” for the locations most likely to determine arterial complications of the fracture. In such locations, the proximity of bone to arterial vessels makes them sensitive to fracture displacement and post-traumatic injury.

We underline the importance of suspecting acute post-traumatic ischemia in a fractured limb and the necessity of confirming or excluding it firmly, by clinical and paraclinical examinations following the presented algorithm.

Certain locations can be considered “dangerous environments” and fractures occurring in these locations will be considered as potential arterial-generating injuries and must be carefully monitored. The key word in these cases is reevaluation.



Figure 3. API-toes cyanosis

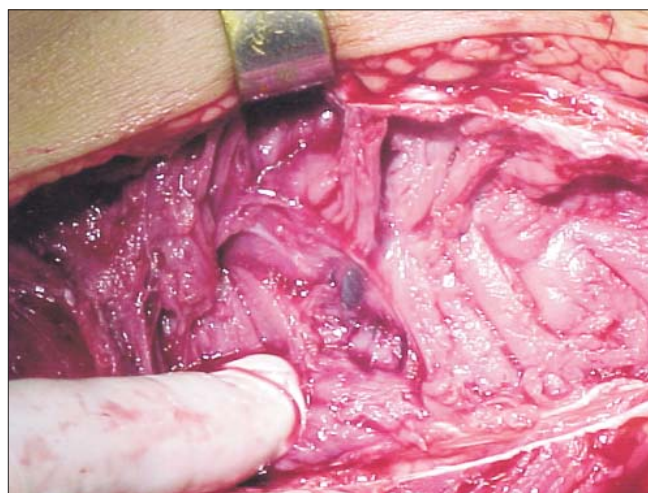


Figure 4. Intramuscular thrombosis

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