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Peripheral vascular trauma. A review of the literature

Trauma vascular periférico. Revisión de la literatura

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ABSTRACT

Since the beginning of mankind, there has been a permanent need to have a long and healthy life. In this way, initially, intuitive knowledge has been developed to control bleeding and preserve life. As history progressed, and wars and developed, practices, techniques, and knowledge regarding trauma management, specifically vascular trauma were also developed. This was achieved through trial and error until today, where not only efforts are made to preserve life, but also the functionality and integrity of the organs and limbs.

RESUMEN

Desde los comienzos de la humanidad ha existido la permanente necesidad de tener una vida larga y saludable; de esta manera se han desarrollado conocimientos, inicialmente intuitivos, para controlar hemorragias y mantener la vida. A medida que se han suscitado guerras y sus respectivas secuelas, han avanzado las prácticas, las técnicas y el conocimiento en cuanto al manejo del trauma, específicamente el vascular. Esto se ha logrado mediante el ensayo y error llegando al nivel de hoy en día, donde no sólo se realizan esfuerzos para conservar la vida, sino también la funcionalidad y la integridad de los órganos y extremidades.

INTRODUCTION

Major peripheral vascular trauma is defined as injuries to blood vessels (arterial and venous) greater than 4 mm.[1] 13% of all trauma injuries have a vascular component.[2] In Colombia, 0.67% of trauma admissions to the emergency department correspond to vascular injuries.[3-6] This type of trauma, although not of a high incidence, is a major public health problem given its complications and lethality. In this country, progress has been made in management of this type of trauma in public hospitals, given a high incidence of traffic accidents and suicides, coupled with more than five decades of internal conflict.[6] Through this review of the literature, the main components of peripheral vascular trauma will be reviewed.

HISTORY

Vascular trauma and the need to control bleeding have played an important role in the survival of mankind through history.[7] The earliest known records of this practice date from the 1600s BC, when, according to the Ebers papyrus (discovered by Ebers in Luxor in 1873), mixtures of mineral oil or vegetable matter such as lead sulfate, antimony or copper sulfate were used by the Egyptians to control bleeding.[3] On the other hand, the Chinese in around 1000 BC, described the use of tight bandages and metalized materials to control bleeding.[2] Galen, in the second century BC refers the need to differentiate between venous and arterial bleeding, since compression or the application of certain materials in the vein was sufficient to control bleeding, but in the

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case of arterial bleeding, ligation with linen was necessary.[8]

Wars have been the fundamental factor in the development of knowledge, experience, and progress in the management of vascular trauma. Hieronymus of Brunswick, a surgeon in the Alsatian army, described the use of ligatures as the best method for controlling bleeding from gunshot wounds in 1497.[8] In 1674, a military surgeon, Morel, introduced a rod into the bandage by twisting it until the arterial flow stopped; this gave more time to perform the ligature, and so the now controversial tourniquet appeared for the first time.[5] In 1759, the first vascular operation described by the Englishman Hallowell was performed. He repaired the humeral artery in a traumatic injury, applying an eight-shaped suture over a pin placed through the walls of the artery and holding the edges together.[4,8,9]

In this way, from small but constant discoveries and from of the sequels of the warlike acts, great advances in knowledge, techniques of homeostasis and vascular repair have been achieved.

EPIDEMIOLOGY

Vascular trauma is considered to account for approximately 3% of all trauma of trauma admissions to the emergency department worldwide. Vascular injuries are relatively few, representing only 0.67% of all patients.[5] Internationally, the estimated annual incidence in civilians varies from 0.9 to 2.3 per 100,000.[10] In Sweden, the annual incidence increased from 11.0 to 26.6 cases per 100,000 inhabitans over 10 years, due to increased iatrogenic vascular trauma, and overall mortality from vascular trauma is between 20 and 26%.[11] This kind of trauma has a lower frequency in civilians in the United States (1.5%) and Australia (1-2%).[12,13] In these countries, overall mortality resulting from vascular trauma is between 20 and 26%.[12] In global statistics, attempted murder or robbery accounts for 60% of vascular trauma mobiles;[3-5] however, the exact incidence in many countries is unknown because they do not have organized systems for reporting. Vascular trauma in Colombia is common, causing mortality in the population between 15-44 years of age; the main cause is sharp-puncture wounds in the upper limbs and firearms in the lower limbs.[14]

Concerning the mechanism of trauma, there are three main types: penetrating, closed and iatrogenic. A study in a trauma hospital in the United Kingdom found that penetrating trauma is the most common mechanism, with 56% of patients, consistent with what other authors have reported.[12,15,16] This type of trauma, in turn, generates more severe vascular injuries, with a higher mortality rate (26 vs 10%) and higher rates of limb amputation (12%), as well as longer times of hospital and intensive care unit stays.[15]

These aspects coincide with the regional epidemiology of trauma in Latin America, where it represents 0.65-1.14% of cases, of which 89% correspond to penetrating vascular trauma and 3% to other causes, including iatrogenic injuries, explosions and crush injuries.[5]

There are no statistics for trauma in Colombia that allow for an exact determination of its impact, although some local studies have been done in different hospitals. In a study at the Hospital de Kennedy in Bogotá, a prevalence of 0.3% of total trauma was observed, with the average presentation being 24.2 years more frequent in males;[17,18] while in another study at the Hospital San Vicente de Paul in Medellin, 59% of vascular trauma was caused by firearm injuries, 33% by stab wounds and 7% were secondary to closed trauma. As to location, in arterial injuries of the upper extremities, the brachial artery was the most frequently involved (40%), followed by the ulnar and radial arteries (25%) and the axillary artery in 30%.[2] In the lower extremities, the most common was the deep femoral artery (37.2%), followed by the popliteal artery (30.7%), the crural artery (11%) and the common femoral artery (8.7%).[19]

PHYSIOPATHOLOGY

Bleeding is the first consequence of vascular trauma; it can be visibly identified or it can be contained.[8] Ischemia occurs as a result of the sudden interruption of blood flow to the extremities or organs and, as there is a decrease in oxygen supply to the tissues, anaerobic metabolism is established with production of lactic acid along with inflammatory mediators.

Humoral and cellular inflammatory cascades are activated and, if the tissue does not again have an adequate supply of oxygen, cell death may occur.[18,20] Possible injuries from hypoxemia vary over time depending on the tissue; muscle tissue can endure hypoxic suffering for up to three hours and then recover its function, but nerve tissue can have progressive and irreparable injury in less time.[20]

When ischemia is reversed, as an effect of reperfusion there is a sudden and massive release of inflammatory mediators, lactic acid, potassium and other intracellular debri into the systemic circulation, which can cause severe myocardial depression and generalized vasodilatation, triggering the systemic inflammatory response syndrome (SIRS), and death.[18,20]

CLASSIFICATION

Vascular lesions can be caused by different mechanisms. They can be penetrating, the most common produced by firearms. In this case, the severity depends on the speed of the projectile. In those produced by long-range weapons, in addition to the direct destruction of tissue, lesions secondary to a cavitation effect are observed. Bone fragments can also produce penetrating lesions of the vessels. [2] Within these lesions, either a partial tear or rupture of a vessel can occur. Transection, which corresponds to the complete loss of continuity of a vessel, is the most frequent. Bleeding is greater in partial transections than in complete ones since in this latter case there is a retraction of both ends and vasoconstriction due to vascular spasm.[18,20]

For closed lesions, although the least common mechanism, the prognosis is more serious, since the lesion is crushed and diagnosis tends to be delayed.[2] In this case, there is a lateral disruption of the entire wall or a disruption of the intima (flap), which will lead to thrombosis or dissection and subsequent rupture. In the case of thrombosis, there is the possibility of distal embolization with its deleterious effects.[8] If the lesion is in a contained compartment, there will be a pulsatile hematoma, which will constitute a pseudoaneurysm. In this case, distal flow is preserved, which initially makes clinical diagnosis difficult and, in turn, changes over time as a pulsatile mass appears. The great danger is rupture distant from the initial trauma.[21,22] Arteriovenous fistula formation occurs when trauma extends from an artery to an adjacent vein. It manifests away from the trauma site through cardiovascular disturbances and/or rupture.[23]

Iatrogenic injuries can occur in procedures such as arteriography, central catheter installation, and laparoscopic surgery. The mechanism of trauma is very diverse, depending on the country and the socioeconomic levels of the population.

DIAGNOSIS

The diagnosis of vascular lesions is made by a thorough physical examination. The presence of hard signs is associated with a high suspicion of vascular trauma (100%) with a false negative rate of 0.7%; these signs are an indication for surgical exploration.[23-25] Soft signs direct the clinician to vascular injury, but do not indicate immediate surgical exploration; these patients will undergo complementary studies; their presence is associated with approximately 63% incidence of vascular injury.[2,8] Any soft signs are an indication of hospitalization and observation for 24 to 48 hours, and should not be explored immediately, since the possibility of injury is low[18] *(Table 1)*.

The ankle-arm index has a sensitivity of 100% for identifying vascular lesions of penetrating origin; some series have validated it for identification of lesions in closed trauma. It is an accessible tool with good results for the diagnosis of vascular injury.[3] In the case of pulse oximetry, these give rise to the suspicion of vascular injury, but can neither confirm nor exclude it.[26]

Echo-Doppler is a highly dependent test, but does not generate certainty. The presence of a Doppler signal gives a false sense of security and does not confirm the absence of injury. Conversely, if there is a palpable but decreased pulse, Doppler can provide guidance on a possible diagnosis, but does not certify the absence of injury.[27]

The limitation of the duplex echo is that it is operator-dependent. It combines Doppler echo imaging with B-mode pulse waves, allowing the detection of intimate tears, thrombosis, pseudoaneurysms, and arteriovenous

Table 1: Clinical signs of vascular trauma.

Hard signs	Pulsatile and/or massive bleeding		**Hard signs**	History of bleeding prior to admission	
	Pulsatile or expansive hematom			Palpable but diminished pulse	
	Thrill or murmur			Moderate hematoma	
	Distal ischemia			Proximity to large vessels or bone injury	
		Pain		Ipsilateral neurological deficit	
		Pallolr			
		Paralysis			
		Paresthesias			
		Decreased pulse			
		Distal coldness			

fistulas. It has high sensitivity and specificity, which is why it is considered a screening method for trained personnel.[18,28]

Angiography continues to be the gold standard to identify vascular trauma injuries, as well as enabling endovascular or temporary control therapy with angioplasty catheters until a definitive solution is achieved.[29]

TREATMENT

The traumatized patient should be given first aid, airway control, and management. However, the priorities for the management of patients with this type of injury are to stop the bleeding, restore normal circulation and avoid tissue suffering as much as possible. Primary control of bleeding is achieved by direct compression[18,30,31] If the wound is deep, temporary control of bleeding is achieved by installing a Foley catheter as deep as possible. The balloon is then inflated and gently tractioned, and may even be fixed to the skin if the patient needs to be transferred. [31] Blind clamping in the resuscitation room is not recommended since it is associated with a high probability of iatrogeny of structures adjacent to the damaged vessel.[8]

Volume replacement should be carried out in two phases, before and after control of bleeding. First, it should be limited, since as volume is increased coagulation factors are diluted, causing hypothermia and acidosis.[32] In this case, the goal is to maintain adequate blood pressure to ensure proper brain perfusion, which is clinically evaluated by evaluating basic functions.[8] In the case of a hypovolemic patient, inotropes should not be used, since these patients will already have vasoconstriction and myocardial hypoxia could be caused by the initial response to trauma.[32] Once bleeding is controlled, two good caliber peripheral lines should be secured to ensure adequate replacement of warm intravenous fluids.[32]

Vessel ligation brings morbidity to the patient, as internal carotid artery ligation has a 10-20% risk of causing a stroke, so it is not done, as it is on external iliac or common femoral vessels. Most veins can be ligated, including the inferior cava, without adding high morbidity.[3] When the patient is at risk of limb loss or cerebral ischemia, an intraluminal shunt can be performed. Its role is temporary, but it ensures irrigation until a definitive repair is made. A Gifford study showed that in military trauma with lower limb involvement, the amputation rate is reduced by 9% by its use.[3,32,33]

Endovascular therapy, while increasing costs of care, improves outcomes and perfusion, and it reduces bleeding and risk of amputation.[34-36] A study by Piffaretti of several patients with peripheral arterial vascular trauma such as subclavian, popliteal, femoral, who had pseudoaneurysms and complete section, with endovascular stenting, showed a 100% limb preservation.[37]

Table 2: Mangled Extremity Severity Score (MESS) classification.

MESS index	Points*
Soft tissue and bone injury	
Low energy (stab or small-caliber firearm injury)	1
Moderate energy (open or multilevel fracture, moderate crushing)	2
Alta energía (arma de fuego de corto alcance o fuego de alta velocidad)	3
Very high energy (explosions, crushing)	4
Shock	
Normotensive	0
Transient hypotension (hypotensive on admission, but responsive to intravenous fluids)	1
Prolonged hypotension (systolic blood pressure less than 90 at the scene, responds to emergency department fluids)	2
Degree of limb ischemia	
None (pulse limb)	0
Mild (decreased pulses/signs of ischemia)	1
Moderate (no Doppler pulses, slow capillary filling, paresthesias and weakness)	2
Advanced (pulseless, cold, paresis, no capillary filling)	3
Age group	
Under 30 years of age	0
From 30 to 49 years of age	1
Over 50 years of age	2

* The sum of the score is obtained:
• Score greater than 6, has a predictive value of amputation close to 100%.
• Score of 0-6: Probably viable limb.
Taken from: Cronenwett J, Wayne K. Vascular trauma. Rutherford's vascular surgery. 7th ed. Toronto: Elsevier; 2010.
** If the ischemic time is greater than six hours, the score doubles.

When there is a complicated lesion in the limb, determined by the presence of bone, soft tissue, nerve, and associated vascular lesions, the possibility of limb amputation must be considered. Different indices have been used to assess the risk of amputation; the MESS (Mangled Extremity Severity Score) index is the most commonly used, including criteria such as the degree of skeletal and soft tissue injury, limb ischemia, shock and patient age[28] *(Table 2)*.

COMPARTMENTAL SYNDROME

A compartmental syndrome can be caused by two mechanisms: an increase in volume in a closed space and a decrease in the size of the space, which results in a decrease and absence of irrigation of a limb, which, if prolonged, causes cellular ischemia and the activation of inflammation mediators in response to alterations in vascular permeability.[38] Subsequent reperfusion may cause the limb to suffer generalized edema. The pressure in the compartment exceeds capillary and venous pressure, resulting in venous stasis, cellular ischemia, and ultimately death.[39] Clinically, it is evident that the first symptoms referred to by the patient himself are disproportionate pain and paresthesia.[40] Subsequently, the increased pressure in the compartment is felt, followed by pallor and paresthesia as a result of vascular involvement, and finally, the absence of pulse, this being a late sign.[41] Prevention is the best treatment for this complication, a fasciotomy improves the patient's symptoms and avoids the risk of a second episode of limb ischemia.[32]

CONCLUSIONS

Vascular trauma is an injury of low incidence, although if adequate and timely management is

not given it becomes important. The evolution of vascular trauma has gone hand in hand with warlike conflicts in different parts of the world. Today, despite the permanence of wars, the main causes of vascular trauma correspond to traffic accidents, civil violence, and iatrogeny.[2] The extremities continue to be the main site of vascular injury, which suggests defensive injuries and that civil violence continues to increase its statistics.[8] Diagnosis is usually made by physical examination in the presence of "hard" and "soft" signs. One of the main complications, if not detected and treated in time, is compartment syndrome, which can worsen the possibility of limb recovery. Definitive management should be done by properly trained personnel. If this is not possible at the moment, care should be taken to maintain the patient's vitals and all his/her organs until such personnel is available.

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