

Cadet Agustín Melgar and military peripheral vascular trauma approach during Chapultepec's Battle

El cadete Agustín Melgar y la atención del trauma vascular periférico militar durante la Batalla de Chapultepec

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Abstract

Trauma to peripheral vascular organ is a very frequent condition during military conflicts. Fortunately, comprehensive understanding of local and systemic pathophysiology, in addition to the development of innovative surgical techniques and technological advances, have improved the outcome regarding to survival and anatomic and functional conservation of the limbs. In this manuscript, we perform an historical and state of the art review related to the approach of the peripheral vascular trauma, on the basis of an heroic episode from the Mexico City's Campaign, during North American invasion 1846-1848: the defense of Chapultepec's Castle by cadet Agustín Melgar.

Key Words: Peripheral vascular organ. Outcome. Trauma.

Resumen

El trauma del órgano vascular periférico es una condición muy frecuente en los conflictos militares. Por fortuna, la comprensión integral de la fisiopatología local y sistémica, en adición al desarrollo de técnicas quirúrgicas innovadoras y avances tecnológicos, ha mejorado el pronóstico relativo a la sobrevivencia y la conservación anatómica y funcional de las extremidades. En este trabajo se hace una revisión histórica y del estado actual del abordaje del trauma vascular periférico, sobre la base de un episodio heroico de la Campaña por la Ciudad de México durante la invasión norteamericana de 1846-1848: la defensa del Castillo de Chapultepec por el cadete Agustín Melgar.

Palabras Clave: Órgano vascular periférico. Pronóstico. Trauma.

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Introduction

It was the morning of September 12, 1847, when the North American army initiated a fierce bombardment on the Castle of Chapultepec, headquarters of the Military Academy and last defensive bastion of the Mexican army to prevent the taking of Mexico City, during the North American Intervention that took place between 1846 and 1848. At 09:20 hours, on September 13, with the physical and moral exhaustion of the defenders (57 cadets and just over 800 professional military personnel), imposed by more than 15 hours of attack with artillery explosives, nearly 5,000 enemy soldiers began the assault on the fort by climbing the slopes of *Cerro del Chapulín*, a volcanic rock formation on top of which the castle was found. Upon reaching its yards, they encountered an unusual armed resistance by young cadets, military students aged between 13 and 19 years. After 40 minutes of struggle and nearly complete annihilation or capture of the defenders, the Chapultepec Castle was taken and the National Flag secured as a war trophy. Thus, at 10:00 hours on September 14, 1847, the Star Spangled Banner flag waved at the flagpole of the Viceroyal Palace (today the National Palace)¹.

The participation of cadet Agustín Melgar, one of the students of the Military Academy, stands out in this day of combat; together with Lieutenant Juan de la Barrera and his schoolmates Fernando Montes de Oca, Francisco Márquez, Vicente Suárez and private Juan Escutia, they are collectively known in Mexican official history as "*Los Niños Héroes de Chapultepec*" (The Boy Heroes of Chapultepec). Horse Artillery student, 19 years old and native to the city of Chihuahua, he had re-entered a few days before the assault on the castle, after temporarily abandoning the military training. On September 13, at the beginning of the battle, enraged as he observed how the enemies were murdering his comrades, he engaged in a titanic fight with his bayonet rifle. The chronicles of two witnesses, Sergeants Teófilo Noris and Ignacio Molina, narrate that Melgar wounded and killed several opponents before taking refuge in the school library. There, he built a parapet with furniture and straw mattresses, from where the defense continued. When he ran out of ammunition, he began hand-to-hand bayonet fighting, being outnumbered by enemy soldiers and sustaining stab wounds to his left thoracic limb and right thigh, profusely bleeding. Having lost consciousness, in a humanitarian act, his rivals took him to the field

hospital of the fortress, where, due to the lack of Mexican doctors, a North American surgeon amputated the wounded limbs a few hours later, after having observed their gangrenous state and in an attempt to control the bleeding and save his life. He was cured and bandaged, and left on a table for recovery. The next day, during the evaluation of the damages to the castle, he was found dead on the ground, with the bandages torn off, in a clear manifestation of zeal to continue the fight. His fierceness and bravery earned him recognition of his rank and name by Major Charles Winslow Elliot in the American War Reports².

Cadet Agustín Melgar evaluation and treatment

The humanity whereby the enemies took care of Cadet Melgar is remarkable, although it should also be recognized that his heroism drove Major Elliot to assist him. After having sustained bayonet wounds, Melgar was taken to the Military Academy field hospital, where there were no Mexican doctors, since the physician assigned to the military establishment was Dr. Rafael Lucio, who had reported ill that day and who in postwar inquiries even stated "... That he had no obligation to attend that day."... This was the reason why several hours elapsed after his injury before a surgeon from the North American Army evaluated the penetrating wounds suffered by the Mexican military, and the pertinent treatment for the time and for the military campaign setting was instituted^{1,2}.

According to that which can be interpreted from the US documents, when Melgar was provided surgical aid, active bleeding persisted and there was already gangrene on his extremities. With great certainty, the surgeon appreciated lack of viability and bleeding from some penetrating wounds of a devastating nature, and decided to perform amputations to stop the bleeding, avoid infection and save his life. Since those days, "lack of nutritive fluids' circulation" and "unsuitability of tissues for life" were known to generate tissue necrosis, and that it was necessary to amputate the affected limbs to favor survival. Although, unfortunately, the military documentary sources do not describe the procedures by means of which the amputations were carried out, it is possible to deduce that they were performed in a far-from-ideal surgical theater, following the usual technical standards for the time, coming from the British war experience, using vigorous restraint of the patient by medical assistants, analgesia with ingested agents (in the best-case

scenario), use of a compressive tourniquet, cutting and sawing of the limb following the anatomical limits defined for each type of amputation, thermal coagulation with ignition and dressing with wine or molten sugar. It is almost certain that no attempt to resuscitate the cadet preceded, both due to the lack of knowledge on the importance of improving hemodynamics in traumatized patients and because of the haste the enemy military personnel had to resume battlefield activities³.

Although the historical narrative tries to attribute the “clear manifestation of zeal to continue with the fight...” as the reason for the pulling out of the bandages and the place where Melgar was found dead on September 14, 1847 (under the procedure table in the Military Academy library), the amputation surgical procedure surely must have inflicted intense pain on the patient. Therefore, it is possible that cadet Melgar, already a victim of a coagulopathic state, suffered great pain, and that in his agitated attempt to seek help and mitigate the local symptoms, would have removed the bandages, started bleeding again and fell off the table, which contributed to his death^{1,2}.

Description and historical interpretation of the case in modern terms

When analyzing the above, it is clear that Melgar was the victim of penetrating trauma to the peripheral vascular system by a low-velocity instrument (bayonet). However, according to the Johansen criteria, described by Dawson et al.⁴ and by García-Núñez et al.⁵, injuries of this nature are technically classified as “complex peripheral vascular trauma”. In postmodern trauma surgery, these injuries are classified with the American Association for the Surgery of Trauma-Organ Injury Scale (AAST-OIS) in grades I to V, with increasing severity. However, it should be noted that the grading depends on injury location and not on its magnitude. In addition, the scale also describes that increasing one grade for multiple grade III or IV injuries that involve more than 50% of the vessel circumference is necessary, as well as decreasing one grade when there are lacerations of less than 25% of the vessel circumference for grade IV or V injuries⁶.

Thus, Melgar possibly suffered grade III or IV arterial injuries in the left thoracic limb (axillary or brachial artery), combined with grade III venous trauma (axillary and brachial veins), while in the right thigh he could have suffered grade IV or V arterial injuries (common, superficial or deep femoral artery) and

grade III venous trauma (common, superficial or deep femoral vein); therefore, in case of having sustained only these wounds, 43 points are estimated on the Injury Severity Scale (ISS), which defines a high index of anatomical severity. In patients with trauma to the peripheral vascular system, combined arteriovenous injuries and an ISS score > 25 are known to determine high morbidity and mortality, increasing 12.5 times the possibility of complications and 22.4 times for death⁶⁻¹¹.

Although there are several signs and symptoms that lead to suspect the presence of peripheral vascular system injuries, bleeding as the main clinical manifestation and the most important cause of death in these cases, as well as obvious signs of ischemia of the limb, are what make them immediately apparent^{5,8-10,12}. Historical narrative points out that the North American surgeon observed active bleeding and data consistent with low perfusion (gangrenous state) of extremities, which makes the clinical suspicion that we can currently establish more compelling. Even today, contemporary surgical practice strongly recommends amputation when patient life is at risk or if there is indisputable evidence of non-viability of an injured limb. Thus, there is no question that the procedure was implemented following technical standards that are still in force^{3,13-16}.

In current prognostic terms, amputation and death are rare in axillary and brachial vessel injuries, even in the presence of associated nerve injuries. However, there is a high morbidity rate for axillary vessel trauma. Current military series describe that good results are obtained (complete hypoperfusion and neurological deficit resolution) in 25% of axillary vascular trauma cases and in 70% of patients with brachial vascular injuries^{8,9,13}. In victims of femoral vascular trauma, contemporary prognostic indices are also well defined. Although currently the mortality rate reaches 9%, and the possibility of amputation is 3%, morbidity can reach figures of up to 55%, including wound infection, arterial and venous thrombosis, compartment syndrome and perioperative hemorrhage^{7,9}.

Evolution on the approach to military peripheral vascular trauma

Although the care of wounds is an evident and ancestral need in the approach to military trauma, it was with Ambroise Paré (16th century) that the great operative advances occurred in an armed conflict, with a large volume of wounded being treated in austere conditions^{3,14-16}.

Control of bleeding subsequent to an injury has been a great concern since the beginning of Humanity. Since 1600 BC, resources such as vegetable threads, irons and boiling fluids, dressings and compression, which are described in the Eber Papyrus, have been used. In the first two centuries AD, Celsus described the tying (ligation) of bleeding sources, while amputation prevailed in cases of gangrenous limbs, which were also known to be a likely source of hemorrhage. Rufus of Ephesus, in the 1st century AD, noted that partial lesions of the blood ducts were more difficult to control than if they were completely sectioned, which drove Galen (2nd century) to warn that, in the former case, placing a finger to press the wound led to the formation of a clot and bleeding arrest. Paré, in 1552, with his vast experience, recommended ligation for hemostasis in open lesions, using the "*Bec de Corbeau*" ("crow's beak"), ancestor of the modern hemostat, to preliminarily secure the vessel. Later, collateral circulation was recognized, which allowed implementing the observational behavior even after ligation of large vascular structures, with the prudent hope of limb preservation. Finally, great importance was also given to perioperative cleansing as a factor of crucial importance to avoid infections, which in most cases were fatal^{3,13-16}.

Direct arterial repair of a military injury was described by Hallowell 243 years after Paré pointed at ligation as the therapy of choice in these conditions. Subsequently, Broca (1762), Gluck (1883), Postempski (1886), Von-Horoch (1887), Jassinowsky and Brucci (1889), Muscatello (1890), Heidenhain (1894), Sabanyeff (1896) and Murphy (1897) reported progressive success in primary angiorrhaphy, already in conjunction with the use of anesthesia and perioperative asepsis^{3,13-16}.

In Mexico, in the 16th century, Alonso López de Hinojosa, in his work *Summa y recopilación de Cirugía, con un arte para sangrar muy útil y provechoso*, reported arterial ligation for vascular trauma or pathology, which was used throughout the 19th century, especially in combat wounds. Noteworthy was the contribution in this regard by Aronssohn and Montes de Oca, whose principles were followed by Pierre Van der Linden, surgeon-in-chief during the Mexico City campaign in 1847¹⁷.

It was also by Murphy (1897), from Cook Hospital in Chicago, that the first end-to-end anastomosis was performed and described. In 1912, Carrel developed the triangulation technique for vascular anastomoses, which is an enormous contribution in this area that is

being used until today in vascular and transplantation surgery^{18,19}. In 1912, Guthrie first described the implantation of a vein graft to bypass an arterial defect, using the Carrel technique. Matas (1913) pointed at acral post-traumatic arteriovenous deformation (arteriovenous fistulas and pseudoaneurysms) as "a serious military problem" and recommended its surgical correction, after examining the malformation specific anatomy. Soubotitch (1913) described the military experience in the Serbian-Turkish and Serbian-Bulgarian wars, with an impressively low rate of infection and re-bleeding. In World War I, German military surgeons reported more than 100 cases of successful arteriorrhaphy, but also, in 1915, with the development of new and more powerful artillery explosives, they refined amputation techniques, as arterial repairs rendered impractical, since attempts at angiorrhaphy often led to gangrenous results and secondary hemorrhage^{5,7,8}.

In World War II, DeBakey and Simeone analyzed the therapeutic results of more than 2,000 arterial injuries, and found that although nearly 100% of cases were ligated, only 49% required amputation. In the 81 cases subjected to arterial repair there was an amputation rate of 35%, while with venous graft implantation this rate was 58%. However, after D-Day devastation, the authors conclude that although there is no other more effective treatment than ligation for military vascular injuries, it is definitely not the procedure of choice, but rather a technique that has the basic purpose of arresting the bleeding to allow to later estimate the location, type, size and nature of combat wounds, and then offer the most convenient definitive treatment^{7-10,15,18}.

In Korea, Jahnke and Selley (1953), Hughes (1955 and 1958), and Inui, Shanon, and Howard (1955) reported significant improvements in the prognostic rates of limb survival, preservation and functionality, which was undoubtedly due to substantial advances in vascular surgery and anesthesia techniques, to the development of angiography, transfusion therapy and antibiotics, as well as aircraft availability for rapid transport. In Vietnam, Rich (1968) reported that, with the use of helicopters, 95% of those injured in the battlefield arrived alive at surgical hospitals despite the severity of their wounds. With their experience, Rich and Hughes¹⁷⁻¹⁹ developed the Vietnam Vascular Registry Report (n = 1000) in 1970, where certain essential aspects that characterized surgical practice are observed. The most common method for treating these patients was autologous vein graft interposition

(45.9%), followed by end-to-end anastomosis (37.7%) and lateral angiorrhaphy (8.7%); only 15 patients (1.5%) underwent vascular ligation. The mortality rate was 1.7%, and amputation rate was 12.7%, mostly patients with popliteal vascular injuries^{7,8,10,13,17,18}.

Since current military conflicts, in the political context of their definition, are not really frequent, it is the civilian experience that has allowed the evolution of vascular trauma approach to continue. While some innovations may be applicable to the military arena, others are not useful for the management of military injuries. Furthermore, it is necessary to recognize that the nature of war conflicts is undergoing dramatic changes. Battles are now not as frontal as before, and highly powerful and lethal military devices are being developed, which will also surely modify the vascular injury pattern. In addition, there is a tendency to withdraw medical services from the front line and move them to the rear, in order to preserve their precious human and material resources. This will undoubtedly affect vascular trauma approach, since many surgeons deployed in the battlefield will not achieve vast experience in the management of trauma in general, much less in appropriate treatment of vascular trauma.

In addition to the aforementioned lack of surgical skill development, interventional radiology availability and robotics last frontier also have an impact on the competence of military surgeons to manage vascular injuries. Undoubtedly, simulation and physical models will help to cover these educational deficits, improving the quality of surgeons' performance in the management of military injuries to the peripheral vascular system^{8,16-19}.

Modern standard for the treatment of peripheral vascular system injuries in the military arena

Several notable technical aspects regarding modern standards of treatment in patients with cadet Agustín Melgar's profile are discussed below.

Diagnosis

In patients with military injuries to the peripheral vascular system, physical examination is essential, as there may be "hard" and "soft" signs of injury that define the presence of this type of trauma. Duplex examination can aid decision-making, and arteriography should be performed whenever possible, even in austere environments. Computed tomography angiogram

is a tool that has been recognized as playing a revolutionary role in the diagnosis of peripheral vascular system injuries^{8,10}.

Exsanguination

In patients with peripheral vascular system injuries, "exsanguination" is a situation that demands a better concept, not only clinical, but also physiological and biochemical. Although Asensio defined it in 2003 as "the most extreme form of hemorrhage, with an initial loss of more than 40% of circulating volume and active bleeding at such a rate that, if not quickly controlled, it causes patient death", now there is great knowledge on the cellular and subcellular effects of bleeding and its pathological continuum²⁰⁻²². Timely detection of its presence, understanding its consequences and rapid implementation of the relevant therapy, including early establishment of a comprehensive damage control strategy, have proven to have a beneficial impact on a cellular aspect of great clinical significance: attenuating the decrease in erythrocyte alpha-spectrin ubiquitination, which is a cell structure support protein that, when it fails, leads to a decrease in rigidity and to deformity of erythrocytes in the microvascular beds during shock, to microthrombi formation, generalized hypoxia, multiple organ failure, and patient death²³.

Resuscitation in the field

Currently, there are several principles that govern this area in victims of military trauma to the peripheral vascular system. Oral hydration, trying to preserve the state of consciousness and radial pulse, is useful in austere environments. Another alternative, such as microvolumetric resuscitation with hypertonic saline, has great value when weighing up logistical aspects related to the transport of supplies, although its use in hospitals has not spread to the expected extent. Transfusion at fixed rates on the battlefield, observing the proportions that are to be maintained between different blood products, will surely be available in the near future, as technology for the preservation of these biological products improves^{5,8-10}.

Scoop and run

The best prognostic indices are known to be obtained with patient rapid transfer to a trauma center

and resuscitation on the way. Although air transportation is useful in patients with vascular trauma and other devastating injuries of the military arena, in urban trauma it only benefits those with poor hemodynamic status or who have suffered traumatic cardiac arrest. Thus, it is recommended for all patients with military trauma to the peripheral vascular system to be immediately transferred to a surgical facility, and to be resuscitated during transportation in order to obtain the best possibilities of survival and functional recovery^{8,12,13}.

Damage control

- Damage control resuscitation and bleeding control. The first intervention that has to be carried out in a patient with trauma to the peripheral vascular system in the military arena is to inhibit bleeding, using manual compression or advanced bandaging, with or without topical hemostatic agents. Then, at the surgical level, the modified principles of “permissive hypotension” and “deferred resuscitation” must be implemented, which, even when they are designed as guiding principles for advanced fluid therapy in central vascular injuries, their judicious use can benefit prognostic indices of these cases in the absence of coexisting head trauma. Deferred resuscitation is established in patients with uncontrolled or partially controlled bleeding who have immediate access to the operating room, and consists of maintaining two permeable peripheral venous lines ready for use. On the other hand, permissive hypotension is implemented if there are no immediately available surgical resources, and it is intended to maintain mean arterial pressure at 50-55 mmHg in order to avoid coagulation factors dilution and expelling clots formed in injured vessels with a high pressure gradient. Its adequate implementation has shown that, in cases of central vascular lesions, especially those of a penetrating nature, reducing the amount of infused crystalloids and the volume of administered blood products is achieved, thus increasing survival within the first 24 hours, which allows implementation of a larger number of life-saving maneuvers^{4,5,8-13,15,19}.
- Temporary intravascular shunts are tubular devices with a lumen that are placed inside an injured vessel to bypass defects in these

structures, quickly control bleeding, and maintain distal perfusion, thus fulfilling the premise of damage control. They are easily placed, do not require systemic anticoagulation, remain permeable for up to 1000 minutes, and distal bed irrigation can be recovered by up to 60%⁵. Dawson and García Nuñez^{4,5} point out that military injuries of the peripheral vascular system represent an ideal indication for the use of temporary intravascular shunts, since skeletal instability commonly coexists, there is serious contamination of the injured bed, definitive surgical management usually demands more than a simple repair and is time consuming, and the rule is that there are other injuries that require more urgent management^{4,5}.

- Undoubtedly, vascular ligation is a primary damage control strategy that, despite not being the treatment of choice, allows to arrest bleeding and significantly favors survival in patients with trauma to the peripheral vascular system of a military nature. After that, according to DeBakey and Simeone postulates, the ideal thing to do is to evaluate the anatomopathology of the injury and practice the pertinent definitive therapy. An alternative to ligation, which in turn is a conditional recommendation in favor of damage control implementation, is the placement of the aforementioned temporary intravascular shunts, which, in addition to controlling bleeding, have the advantage of maintaining distal perfusion to a certain degree^{7-10,15,18}.

Definitive surgical treatment of peripheral vascular system military injuries

- Primary angiorrhaphy and angio-angioanastomosis: primary repairs can be performed with non-absorbable monofilament synthetic sutures, with any currently accepted standard technique, if the lesion anatomy allows angiorrhaphy to be performed without a stenosis higher than 50%. In case this is not possible, choosing an alternative to avoid stenotic closure morbidity (thrombosis, circulatory failure, etc.) is recommended⁷⁻¹². End-to-end arterial anastomoses are performed if integrity of the artery is disrupted and the ends can be brought together with a standard technique. This may not be feasible in many cases due to the excruciating

and destructive nature of military trauma, giving way to interposition of a graft. Due to the high possibility of thrombosis in venous anastomoses, it is necessary to be judicious when attempting its performance, as this may not contribute to limb revascularization and be time consuming, thus increasing metabolic exhaustion-associated mortality⁷⁻¹².

- Use of grafts and patches: vascular (venous) patches can be placed to avoid stenosing closure in well selected cases. However, destructive injuries generally require resection of the vessel and interposition of a graft. Reverse saphenous vein grafts, usually obtained from the contralateral extremity when there are vascular injuries in the lower limbs, are a good option to interpose a biological graft, they are highly available and their liberal use is recommended as long as they do not compromise limb vascularization. When using synthetic grafts is decided, ringed grafts of a pertinent caliber should be used¹².
- Ligation: undoubtedly, ligation is emerging as the definitive treatment of a large proportion of peripheral venous injuries in the military arena, due to the high rate of thrombosis related to repairs that are more complex than simple lateral venorrhaphy. On the other hand, although it is desirable for continuity of arterial flows to be maintained, either by primary arteriorrhaphy or placement of autologous or synthetic grafts, the fact that that preserving life is a priority over preserving a limb should not be overlooked, since procedures that are prohibitively long and time-consuming increase the magnitude of the second hit and negatively modify the prognostic indices of survival and functionality^{4,5}. In these cases, arterial ligation is entirely justified as salvage intervention, based on the concept that, due to collateral circulation, it is estimated that only 35-50% of patients with peripheral vascular system injuries will require amputation, although the rate of functional morbidity can be significantly high^{7-11,15,18}.
- Adjunct limb salvage techniques: intra-arterial vasodilators, such as papaverine or tolazoline, can be used in these injuries to prevent spasm. Low molecular weight heparin anticoagulation is generally safe when there are no associated wounds, but patients should be closely monitored for the appearance of morbid bleeding complications. The use of low molecular weight dextran (500 ml

every 12 h) is a good adjuvant, since it induces a relative anticoagulation state and maintains vascular repairs permeable, without seriously predisposing to bleeding⁷⁻¹². Although it is rare for stents to be placed in these type of injuries, they can be a very useful resource in certain cases, mainly in patients with arteriovenous fistulas and pseudoaneurysms²⁴⁻²⁶.

Ischemia-reperfusion syndrome

Should bleeding only cause a state of shock, its management would be quite easy, and this statement also applies accurately to peripheral vascular system injury victims in the military arena. Unfortunately, hemorrhage gives rise to pro-inflammatory sequelae and these, in turn, promote the development of ischemia-reperfusion syndrome after resuscitation, manifested by sudden fluid and electrolyte alterations (hyperkalemia, hypocalcemia) and significant changes in acid-base balance, caused by the washing off of organic acids and anaerobic metabolism products in tissue beds. This drives the patient to arrhythmias and multiple organ failure. Post-traumatic endotheliopathy also drives the patient to capillary leak syndrome, persistent vasodilation and fluid-refractory shock and blood transfusion, which translates into high mortality^{4,5,8-10,13,14,19-22}.

Post-traumatic coagulopathy

Post-traumatic coagulopathy is relatively common in patients with peripheral vascular system trauma in the austere environment of the military arena. The factors that promote the appearance of this phenomenon are continuous bleeding, environmental exposure, aggressive fluid resuscitation techniques (without volumetric restriction) and definitive treatment delay. Fortunately, at present, the combination of rapid transportation, limited fluid resuscitation in the field and during the transfer route, policies of advanced fluid therapy and early and protocol-based hemotherapy, as well as pharmacological hemostasis, have decreased the incidence of this lethal condition¹⁹⁻²².

Compartment syndrome

In patients with peripheral vascular system injuries, compartment syndrome of the extremities is due to

an increase in interstitial pressure to a higher point than capillary pressure in a closed fascial compartment, which causes blood flow compromise and muscle and neural necrosis, which is associated with serious functional and life-threatening consequences. Although treatment can initially be medical and conservative, there are conditions that demand early surgical treatment, which generally consists of fasciotomy. Said conditions are: 1) male gender; 2) requirement of high amounts of red cell concentrates for patient resuscitation; 3) exposed fractures; 4) gunshot wounds to the extremities, especially high velocity injuries; 5) > 16 score on ISS scale; and 6) age older than 55 years. Compartment syndrome free evolution leads to systemic toxicity, gangrenous changes, multiple organ failure, sepsis and high mortality^{5,7-11,13-15}.

Conclusion

Based on the historical and technical analysis herein presented, cadet Agustín Melgar was the victim of complex penetrating peripheral vascular trauma in the military arena. Having suffered such a serious anatomical condition in an austere environment, and having been approached following medical-surgical principles of those days, without having received appropriate resuscitation, early operative care, effective analgesia and management of post-traumatic coagulopathy, as well as due to the lack of postoperative follow-up, it is not surprising he succumbed. However, it is relevant pointing out that, today, under postmodern protocols for the management of military peripheral vascular trauma, the prognosis might have markedly changed and the cadet would possibly have survived, albeit with significant morbidity.

Conflict of interests

The authors of this manuscript declare that they have no conflicts of interest.

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Ethical disclosure

Protection of people and animals. The authors declare that no experiments were performed on humans or animals for this research.

Confidentiality of data. The authors declare that no patient data appear in this article.

Right to privacy and informed consent. The authors declare that no patient data appear in this article.

References

1. Departamento del Distrito Federal. El asalto al Castillo de Chapultepec y los Niños Héroes. Colección Conciencia Cívica Nacional. México, D.F.; 1988.
2. Bravo UJ. Folletos raros relativos a la Defensa de Chapultepec. Capilla Alfonsina, Fondo Fernando Díaz Ramírez. Ciudad de México; 1848.
3. Cheselden W. Chap. XXXVIII. Of amputation. En: Sharp S, editor. A treatise on the operations of surgery, with a description and representation of the instruments used in performing them: to which is prefix'd an introduction on the nature and treatment of wounds, abscesses and ulcers. 3rd ed. London, UK: Brotherton/Innys/Manby/Knapton/Rivington/Lengman/Birt/Hitch/Auften/Hodges & Hawkins Publishers; 1740. p. 211-25.
4. Dawson DL, Putnam T, Light JL, Inhat DM, Kissinger DP, Rasmussen TE, et al. Temporary arterial shunts to maintain limb perfusion after arterial injury: an animal study. J Trauma. 1999;47:64-71.
5. García-Núñez LM, Cabello-Pasini R, Decuir-Díaz A, Lever-Rosas CD, Padilla-Solis R, Gómez-García MA, et al. Lesiones vasculares periféricas complejas y shunts intravasculares temporales. El concepto y la institución del "control de daños" va mucho más allá del abdomen. Rev Sanid Milit Mex. 2005;59:201-7.
6. Moore EE, Malangoni MA, Cogbill TH, Peterson NE, Champion HR, Jurkovich GJ, et al. Organ injury scaling VII: cervical vascular, peripheral vascular, adrenal, penis, testis, and scrotum. J Trauma. 1996;41:523-4.
7. Asensio JA, Kuncir JE, García-Núñez LM, Petrone P. Femoral vessel injuries: analysis of factors predictive of outcomes. J Am Coll Surg. 2006;203:512-20.
8. Asensio JA, Meneu DJC, Márquez ME, Abradelo UM, Moreno EA, García-Núñez LM, et al. Traumatismos penetrantes en extremidades y lesiones vasculares asociadas. En: Asensio JA, Meneu DJC, Moreno GE, editores. Traumatismos. Fisiopatología, diagnóstico y tratamiento. Madrid, España: Japry; 2005. p. 575-84.
9. Asensio JA, Mazzini FN, Pérez-Alonso AJ, Petrone P, Ceballos J, García-Núñez LM, et al. Vascular injuries of the upper and lower extremities. En: Cioffi WG, Asensio JA, Adams CA Jr, Connolly MD, Britt LD, Townsend CM Jr, et al., editores. Atlas of trauma/emergency surgical techniques. Philadelphia, Pennsylvania, USA: Saunders Elsevier; 2014. p. 270-88.
10. Hernández-García EF, García-Núñez LM. Trauma de extremidades. En: Vega MAJ, Mayagoitia GJC, Ramírez BEJ, Pulido CA, Noyola VHF, editores. Tratado de cirugía general. 3.^a ed. Ciudad de México, México: Manual Moderno; 2017. p. 2010-7.
11. García-Núñez LM. Doctor: la pierna está azul... Manejo de las complicaciones del tratamiento del trauma vascular periférico. Ciruj Gen. 2011;33(Suppl 1):S70-2.
12. Feliciano DV. Management of peripheral vascular trauma. Disponible en: <https://www.facs.org/~media/files/quality%20programs/trauma/publications/peripheralvasctruma.ashx>
13. Arcaute VFF, García-Núñez LM, Noyola VHF, Espinoza MF, Rodríguez VCE. Mecanismos de lesión en actos de violencia extrema. Cir Cir. 2016;84:257-62.
14. Nanobashvili J, Kopadze T, Tvaladze M, Buachidze T, Nazvlishvili G. War injuries of major extremity arteries. World J Surg. 2003;27:134-9.
15. Sise MJ, Shackford SR. Extremity vascular trauma. En: Rich NM, Mattox KL, Hirshberg A, editores. Vascular trauma. 2nd ed. Philadelphia, Pennsylvania, USA: Elsevier Saunders; 2004. p. 353-9.
16. Helling TS, McNabney WK. The role of amputation in the management of battlefield casualties: a history of two millennia. J Trauma. 2000;49:930-9.
17. Rish FL, Castañeda GR, Sigler ML. Capítulo 1. Historia del trauma vascular. En: Castañeda GR, Sigler ML, Rish FL, editores. Trauma vascular. Ciudad de México, México: Alfil; 2007. p. 1-15.
18. Rich NM, Rhee P. An historical tour of vascular injury management: from its inception to the new millennium. Surg Clin North Am. 2001;81:1199-216.

19. García-Núñez LM, Asensio JA. Trauma vascular central toracoabdominal. En: Vega MAJ, Mayagoitia GJC, Ramírez BEJ, Pulido CA, Noyola VHF, editores. Tratado de cirugía general. 3.^a ed. Ciudad de México, México: Manual Moderno; 2017. p. 1631-9.
20. Asensio JA, Bertelotti R, Mazzini FN, Esparragón CJ, Okwosa C, García-Núñez LM, et al. The syndrome of exsanguination: reliable models to indicate damage control. En: Asensio JA, Trunkey DD, editores. Current therapy of trauma and surgical critical care. 2nd ed. Philadelphia, Pennsylvania, USA: Elsevier; 2016. p. 422-35.
21. Asensio JA, Petrone P, O'Shanahan G, Kuncir EJ. Managing exsanguination: what we know about damage control/bail out is not enough. BUMC Proceedings. 2003;16:294-6.
22. Mohr AM, Asensio JA, Karsidag T, García-Núñez LM, Petrone P, Morehouse A, et al. Exsanguination: reliable models to indicate damage control. En: Asensio JA, Trunkey DD, editores. Current therapy of trauma and surgical critical care. Philadelphia, Pennsylvania, USA: Elsevier; 2008. p. 282-97.
23. Caprio K, Condon MR, Deitch EA, Xu DZ, Feketova E, Machiedo GW. Alteration of alpha-spectrin ubiquitination after hemorrhagic shock. Am J Surg. 2008;196:663-9.
24. García-Núñez LM, Carreño-Lomelí MA, Muciño-Bolaños MA, Béjar-Cornejo JR, Hernández-García EF. Fístula arterio-venosa iliaca-iliaca inducida por el fenómeno de cavitación temporal en una herida abdominal por proyectil de arma de fuego. Reporte de un caso. Rev Sanid Milit Mex. 2013;67:38-40.
25. García-Núñez LM, Soto-Ortega LE, Delgado-Arámburo JLG, Cabello-Pasini R, Macías-Millán JA. Tratamiento operatorio de las lesiones vasculares carótidas (Estudio TOLVAC I): cómo abreviar el tiempo de isquemia distal. Rev Sanid Milit Mex. 2009;63:1-8.
26. García-Núñez LM, Soto-Ortega LE, Delgado-Arámburo JLG, Cabello-Pasini R, de la O-García II, Macías-Millán JA, et al. Estudio comparativo de dos técnicas de reparación vascular en trauma penetrante de la arteria carótida, modelo animal. Rev Sanid Milit Mex. 2011;65:241-8.