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TEMPORARY COMPRESSION OF THE AORTA IN COMBAT SURGICAL TRAUMA

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The performed scientific analysis of our own experience of applying different methods of temporary compression of the aorta in combat surgical trauma allowed us to identify the optimal conditions to perform aortic occlusion with the use of abdominal bandage, resuscitation endovascular balloon occlusion of the aorta, and application of an atraumatic clamp on the aorta. We verified a total of 76 cases of temporary aortic occlusion and performed a statistical and expert analysis on the applicability of the mentioned methods during medical evacuation. As a result, we identified that abdominal bandaging should be used when providing "basic" prehospital care and during CASEVAC mission; the resuscitation endovascular balloon occlusion of the aorta should be used when providing "extended" pre-hospital care and during MEDEVAC mission; applying an atraumatic clamp to the aorta should be used at hospital stages during resuscitation thoracotomies. At the same time, all methods of temporary compression of the aorta cannot be considered as the alternatives to each other since they act as "bridge procedures" before the final surgical hemostasis.

Key words: temporary occlusion of the aorta, hemostasis, combat surgical trauma, resuscitation surgery.

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ТИМЧАСОВЕ ПЕРЕТИСКАННЯ АОРТИ ПРИ БОЙОВІЙ ХІРУРГІЧНІЙ ТРАВМІ

Проведений науковий аналіз власного досвіду застосування різних методів тимчасового перетискання аорти при бойовій хірургічній травмі дозволив визначити оптимальні умови для виконання оклюзії аорти із застосуванням абдомінального бандажа, ендоваскулярної балонної оклюзії аорти та накладання атравматичного затискача на аорту. Ми верифікували 76 випадків тимчасового перетискання аорти та провели статистичний та експертний аналіз можливостей застосування зазначених методів під час медичної евакуації. У результаті ми визначили, що метод абдомінального бандажу слід використовувати під час надання «базової» догоспітальної допомоги та під час місії CASEVAC; ендоваскулярну балонну оклюзію аорти слід застосовувати при наданні «розширеної» догоспітальної допомоги та під час місії MEDEVAC; накладання атравматичного затискача на аорту слід застосовувати на госпітальному етапі під час реанімаційних торакотомій. Водночас усі методи тимчасової компресії аорти не можна розглядати як альтернативи один одному, оскільки вони виступають як «процедури-мости» перед остаточним хірургічним гемостазом.

Ключові слова: тимчасове перетискання аорти, зупинка кровотечі, бойова хірургічна травма, реанімаційна хірургія.

The study is a fragment of the research project "Development of scientifically based principles of stratification, monitoring and prediction of the course of surgical diseases and trauma", state registration No. 0120U101176.

The violent war waged by Russia against Ukraine caused the emergence of crisis challenges for various state institutions, including the health care system and the military medical service of the Armed Forces of Ukraine. The conduct of hostilities in settlements with existing medical infrastructure and the deployment of advanced medical units of the hospital stage near the battle line created the prerequisites for the appearance of medical care of such combat injuries at the hospital stage that were previously considered incompatible with life. The widespread use of modern means and devices like AAJT and REBOA for temporary hemostasis is considered as another factor that influenced the significant increase of the resuscitated group of patients at the early hospital stage.

With the change in the quantitative and qualitative characteristics of combat surgical trauma, organizational and tactical changes in the work of the advanced medical units of the hospital stage were made based on the methodological principles of the concept of resuscitation surgery [5]. This approach made it possible to effectively and quickly implement and combine the technical methods of damage control surgery in polytrauma with the organizational and tactical reduction of the volume of medical care at a specific stage due to operational and tactical factors.

The mass use of individual armor protection did indeed reduce the frequency of chest and abdominal trauma compared to previous wars, but at the same time caused a significant increase of severe and extremely severe injuries in its structure. In the general structure of combat surgical trauma, chest wounds make up 8.3–15.9 %, of which 80.1 % are non-penetrating, and 19.9 % are penetrating. With

penetrating wounds of the chest, damage to internal organs is diagnosed in 11.2–20.3 % of cases, of which injuries to the pericardium, heart, and large vessels make up 10.6–15.1 % [1, 4]. The frequency of abdominal injuries in the general structure of combat surgical trauma is 1.9–9.8 %. The frequency of trauma to the major vessels of the abdomen is 1.7–7.8 %. Mortality rates fluctuated during the wars of the last century from 1.3 % to 29.3 % and averaged 8.1 % [1, 3].

The above confirms the urgent need to consider and discuss the issues of resuscitation surgery in general and in individual resuscitative surgical techniques. TPO acts as a resuscitation surgical technique that makes it possible to quickly control bleeding and create prerequisites for the deployment and implementation of resuscitation measures. The issue of TPO has a long history and dates back to the second half of the 18th century. The doctoral thesis of the famous surgeon M. Pirogov (1838) was devoted to the issue of aortic ligation. Certain provisions of his research are not only of historical interest but also allow modern military field surgeons to perform measures of temporary hemostasis without complications in the context of up-to-date knowledge about the physiology of hemodynamics [9].

The purpose of the study was to conduct a scientific analysis of our own experience of applying different methods of temporary compression of the aorta in combat surgical trauma.

Materials and methods. The medical documentation of advanced medical units, medical institutions of the Ministry of Health, which are under the operational control of the Military Medical Clinical Center of the Northern Region (MMCC NR) was analyzed. We verified a total of 76 cases of temporary aortic occlusion (TPO). All patients were male. The average age was 42.3±2.4 years.

Depending on the severity and the state of the main vital functions, the patients underwent a full or reduced volume of examinations, which typically included a clinical examination, general clinical tests, biochemical blood tests, blood coagulation tests, determination of blood group and Rh factor, electrocardiography, radiography, FAST examination. Hemodynamically stable patients underwent computed tomography.

The following methods of aorta occlusion are presented in the work: the abdominal bandage (AAJT) (Fig. 1), resuscitation endovascular balloon occlusion of aorta (REBOA), and the application of Satinsky clamp on the thoracic and abdominal aorta (Fig. 2). These methods were used both for resuscitation surgical interventions and during management of intra-abdominal bleeding according to ATLS protocols.

Fig. 1. An example of the practical application of AAJT during a CASEVAC mission.

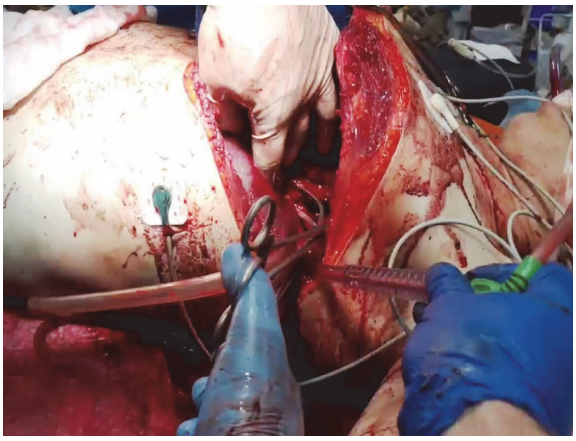

Fig. 2. An example of practical application of AACA in the supradiaphragmatic aorta during resuscitation thoracotomy.

Results of the study and their discussion. According to our data, the structure of combat surgical trauma by anatomical localization of gunshot wounds is as follows: head – 14 %, neck – 3 %, spine – 2 %, chest – 13 %, abdomen – 7 %, pelvis – 4 %, limbs – 57 %. Thus, damage to the major vessels of the trunk that are not subject to compression is probably possible in 7-20 % of casualties, which additionally actualizes the issue of verification and control of occult bleeding.

Among the 76 (100 %) cases of TPO identified by us, in 67 (88.2 %) patients the procedure was performed during resuscitation, whereas it was conducted in 9 (11.8 %) patients during surgical interventions for aortic injury.

AAJT was used in 7 (9.2 %) patients. In the AAJT group, bleeding has been taken under control in 4 (57.1 %) cases. In 3 (42.9 %) cases, the procedure was accompanied by a fatal outcome.

REBOA was used by us only once during medical evacuation, the procedure was accompanied by a fatal outcome.

We performed 59 (77.6 %) resuscitation thoracotomies with open heart massage and TPO. 32 (54.2 %) interventions were successful, and in 27 (45.8 %) cases, the resuscitation surgeries resulted in a fatal outcome.

In total, 36 (53.7 %) procedures were successful, while in 31 (46.3 %) cases they were accompanied by a fatal outcome.

The comparison of conducted methods of TPO during resuscitation in terms of survival is presented in Table 1.

Table 1

Mortality during resuscitation in combat surgical trauma using AAJT, REBOA, and AACA

	AAJT	REBOA	AACA	Total
Number of cases	7	1	59	67
Survived	4 (57.1 %)	0	32 (54.2 %)	36 (53.7 %)
Died	3 (42.9 %)	1 (100 %)	27 (45.8 %)	31 (46.3 %)

Intraoperative AACA was used for aortic injuries in 9 (11.8 %) cases. In the case of penetrating shrapnel wounds of the chest with damage to the aorta, a temporary application of the Satinsky clamp on the thoracic aorta was performed in 3 (33.3 %) cases. In the case of penetrating shrapnel wounds of the abdomen with damage to the aorta, a temporary application of the Satinsky clamp on the abdominal aorta was performed in 6 (66.7 %) cases. The Satinsky clamp was applied twice to zone 2 of the abdominal aorta and 4 times to zone 3. All cases of clamping of the thoracic and abdominal aorta were successful.

In the structure of the use of TPO for injuries of the aorta, trauma to the abdominal aorta predominates over the thoracic aorta injury in the ratio ½.

We used three main methods of TPO, which can be conditionally divided into conservative, semi-operative and operative, and represented by AAJT, REBOA, and AACA. These TPO methods were used both during resuscitative and emergency surgeries, and during the medical evacuation (CASEVAC, MEDEVAC) of patients according to ATLS protocols [2].

Different TPO methods that are presented in the literature have different efficiency and depend on the severity of trauma, localization and the distribution of injuries, the amount of time passed after injury, the volume of infusion and transfusion [7, 8, 10, 11, 12]. In our opinion, the methods represented in this paper should not be considered as alternative TPO techniques but as those that can complement each other. Their application should be considered from the standpoint of expediency and technical capacity at a particular stage of medical care.

AAJT is an innovation for the management of bleeding from the inferior part of the torso that is not amenable to compression and cannot be stopped by standard tourniquets. AAJT has a simple tightening system and improved TPO materials. AAJT is shown to manage severe abdominal, pelvic, and inguinal junctional bleeding. The design and function of the AAJT device provide a large area of effective compression pressure with a high degree of accuracy and reliability for positioning the device in appropriate anatomical zones to stop bleeding. In addition, AAJT demonstrated the ability to maintain efficiency when treating the patient in a closed space, during rescue, dragging and hasty evacuation procedures. In addition to bleeding management, this method also stabilizes the pelvis. Hemostatic efficiency is similar to zone 3 REBOA [10, 12]. Considering the sufficient arsenal of effective resuscitation techniques for temporary and permanent hemostasis at the hospital care level with good survival of resuscitated patients, the feasibility of using AAJT at the hospital stage is doubtful. Only patients with a stable hemodynamic profile are subject to inter-hospital evacuation, even from advanced medical hospitals. The sources of scientific information do not cover the issues of AAJT complications. At the same time, the high risks of TPA for the physiological parameters of hemocirculation were shown in Mykola Pirogov's dissertation work. M. Pirogov (1838) has scientifically proved that the frequency and nature of complications are affected not only by earliness but also by the pace of occlusion, meaning the faster the aorta had been closed the more severe the complications occurred. Considering a number of technological features of a procedure that does not require the participation of qualified specialists, a clear palliative orientation, AAJT should be used when providing “basic” prehospital assistance in the evacuation of non-medical non-specialized transport, namely CASEVAC mission.

Unlike AAJT, it is possible to control not only distal bleeding (pelvic and groin areas) but also bleeding that is not amenable to compression much more proximally using REBOA i.e., bleeding from the pulmonary vessels, axillar areas, vessels of the abdomen, etc. REBOA application is considered in decompensated shock: systolic arterial pressure lower than 90 mmHg and blood lactate level higher than 4 mmol/l. There is currently no evidence that REBOA increases survival or improves treatment results compared to resuscitation thoracotomy [8, 10]. Available publications contain both data on the increase of survival rate due to the use of REBOA, and data that indicate that REBOA may actually increase mortality

[9]. Proximal aorta occlusion is considered zone I, whereas distal occlusion of the aorta is known as zone III. REBOA is performed in most patients with hemorrhagic shock in the zone I and can be used in all patients with traumatic cardiac arrest independently of the character of trauma, due to the advantages of maintaining mean arterial pressure of the patient [6, 14]. Given our insignificant experience with the REBOA procedure implementation, we take a careful position on its use, especially in the hospital stages. However, a thorough study of literature and projection of experience from other TPO methods allows us to make several significant remarks about the prospects of using REBOA in combat surgical trauma. Given the rather complex technology of this procedure that requires the involvement of qualified specialists, and its invasive nature, REBOA should be used when providing "extended" prehospital assistance during evacuation with specialized medical transport, namely MEDEVAC mission. Concerning clinical indications for the procedure, this should not be the actual presence of decompensated shock but the nature of the hemodynamic response to the initial infusion. Thus, a negative hemodynamic response to the initial infusion should be considered as an indication to the REBOA procedure. In our opinion, the timely and appropriate use of REBOA will soon allow to prevent a certain part of resuscitation thoracotomies.

Following the above-mentioned, the authors suggest not to consider the discussed techniques as alternatives to resuscitation thoracotomy (RT), because REBOA conducted during MEDEVAC can be transferred to RT in the hospital unit, or outside of it according to the canons of resuscitation surgery (outside the operating room). Traditionally RT is considered "surgery of desperation" but more and more authors are publishing encouraging results of the procedure, and the indications for its use are becoming clearer every year, nevertheless there is no evidence data to date. RT with open cardiac massage and TPO is a standard procedure both for advanced medical units of the hospital stage (Role-II) and for MMCC NR (Role-III) when indicated [7]. It is important to note that the individual authors of the article have personal experience of conducting RT with more than twenty clinical cases, which actualizes their expert opinion in the absence of evidentiary materials.

TPO during RT precedes open cardiac massage and aims to control more distal bleeding to minimize it, or provide temporary hemostasis and maximize cerebral and coronary perfusion. [2, 3, 4, 8]. TPO results in temporary hemostasis and allows the surgeon time to identify the source of bleeding [2, 8]. In RT and cases of aortic injury, the Satinsky clamp is most often used for TPO [2, 5, 8].

All the methods of temporary hemostasis mentioned above are situational, and the final hemostasis is performed surgically. Thus, the final consequences of the traumatic process will be significantly influenced by the nature of the operative procedure, which in such cases must comply with the canons of damage control surgery.

Conclusions

1. Currently, in the clinical practice of combat surgery, there are three technologies for temporary aortic occlusion, namely: the conservative AAJT method, the semi-operative REBOA method, and the application of an atraumatic clamp to the aorta during thoracotomy.

2. The AAJT method should be considered when providing "basic" prehospital care and during evacuation by non-medical non-specialized transport (CASEVAC mission); the REBOA technique should be used when providing "extended" prehospital care and during evacuation by specialized medical transport (MEDEVAC missions); AACA method should be used in hospital stages during resuscitation thoracotomies.

3. All methods of temporary occlusion of the aorta cannot be considered alternatives to each other, as soon as they act as "bridge procedures" before the final operative hemostasis.

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CHANGE OF THE HEMOGLOBIN LEVEL DURING THE RESUSCITATION PERIOD IN PATIENTS WITH TRAUMATIC BRAIN INJURY, ACCORDING TO THE CHARACTER OF THE TRAUMA

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The purpose of the study was to determine a possible relationship between the nature of the injury and hemoglobin levels in patients admitted to hospital with traumatic brain injury. The study included 299 trauma patients admitted to the Clinical Medical Center within 1–1.5 hours after trauma. In addition to dividing the patients by gender, they were divided into age ranges and the origin of the injury. The patients were analyzed in 4 groups depending on the isolation of the traumatic brain injury or its combination with other injuries. In each group, hemoglobin levels were determined in blood samples 4 times on the 1st, 2nd, 3rd, and 4th days. The average level of this parameter in individuals with traumatic brain injury was 97.4±2.5 g/L (50.0–157.0 g/L). In 32 patients who suffered a mixed form of injury, the average value was 88.8±3.2 g/L (50.0–142.0 g/L). The results show that there were no significant differences between the hemoglobin level in the blood and the nature of craniocerebral injuries. However, it is undoubtedly important to conduct a study of patients with craniocerebral injury in the acute period of pathology.

Key words: traumatic brain injury, combined injuries, immunity, hemoglobin.

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ЗМІНА РІВНЯ ГЕМОГЛОБІНУ В РЕАНІМАЦІЙНОМУ ПЕРІОДІ У ХВОРИХ З ЧЕРЕПНО-МОЗКОВОЮ ТРАВМОЮ В ЗАЛЕЖНОСТІ ВІД ХАРАКТЕРУ ТРАВМИ

Метою дослідження було визначення можливого зв'язку між характером травми та показниками рівня гемоглобіну у пацієнтів, доставлених до стаціонару з черепно-мозковою травмою. До дослідження було включено 299 травматологічних хворих, доставлених до Клінічного медичного центру через 1–1,5 години після травми. Крім поділу пацієнтів за статтю, вони були поділені на вікові діапазони та походження травми. Пацієнти були проаналізовані за 4 групами залежно від ізольованості черепно-мозкової травми або її поєднання з іншими травмами, у кожній групі показники гемоглобіну визначалися у зразках крові 4 рази на 1–й, 2–й, 3–й та 4–й день. Середній рівень зазначеного параметра в осіб із черепно-мозковою травмою становив 97,4±2,5 г/л (50,0–157,0 г/л). У 32 пацієнтів, які перенесли змішану форму травми, середній показник становить 88,8±3,2 г/л (50,0–142,0 г/л). Результати показують, що не спостерігалося значних відмінностей між рівнем гемоглобіну в крові та характером черепно-мозкових травм. Однак, безперечно, дослідження пацієнтів з черепно-мозковою травмою важливо проводити в гострому періоді патології.

Ключові слова: черепно-мозкова травма, поєднані травми, адаптивний імунітет, рівень гемоглобіну.

The development of industry, and the increase in construction works and vehicles have further increased the intensity of traumatic injuries, which has led to an increase in deaths and post-traumatic complications [5, 7]. Common traumas have a special place among traumatic injuries, as many serious extracranial complications occur during these types of traumas [12]. Hemodynamic disturbances, cases of aspiration, intubation of the trachea, etc., may cause complications in the broncho-pulmonary system in the