

The Experience of Treating Battle Injuries of the Magistral Arteries in the Limbs in the Settings of the Civilian Multi-profile In-patient Hospital

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ABSTRACT

BACKGROUND: The modern military conflict is characterized by a significant number of wounded with the damage of the magistral arteries in the limbs. Such an injury is accompanied by the possibility of lethal outcome and by the high risk of limb amputation. The treatment of the injuries in the major arteries requires high qualification of the medical staff and sufficient equipment basis. The optimal tactics for this still remains the matter of discussion. **AIM:** to define the specific features of the surgical tactics in cases of injured magistral arteries in the settings of the civilian specialized in-patient hospital in the regions adjacent to the scene of military operations. **METHODS:** The analyzed data included the treatment results in 57 patients with battle injuries of the magistral arteries in the limbs, in which we have managed to track the direct result of restoring the arteries within not less than two days. The variety of manifestations observed in cases of injuries was demonstrated using 8 clinical cases. The surgical tactics was defined by the degree of ischemia in the muscles and the extent of damaging the tissues in the limb. Amputations were conducted in cases of developing the ischemic contracture or in cases of significantly damaged limb tissues. **RESULTS:** The resection of the artery with autovenous prosthetic replacement was done in 49 cases, while the circular resection of the artery with the direct anastomosis — in 8 cases. Within the earliest post-surgery period (first two days) due to the post-ischemic syndrome, the usage of the extracorporeal detoxication methods was required in 5 (9%) wounded. The restoration of the peripheral circulation was observed in 56 (98.2%) cases, the secondary amputation of the lower limb was done only in 1 (1.8%) operated patient. No fatal outcomes were reported (0%). **CONCLUSION:** In the modern military conflict, the battle contact line can be located in the direct proximity from the well-equipped civilian healthcare institutions, at the premises of which the high-tech medical aid is accessible. Our experience shows that, in case of performing the complex surgeries, the follow-up within the early period is practicable to be organized at the site with avoiding the immediate evacuation. In cases of damaging the magistral artery in the limb, the main parameter affecting the possibility of saving the limb itself, is the degree of ischemia in the muscles. The irreversible ischemia is often hard to define and the development of the ischemic contracture should be taken as the guidance. The time of injury, the absence of pulse, of the active movements or sensitivity cannot serve as an indication for amputation. The algorithm developed by us has shown its high efficiency.

Keywords: acute ischemia of the limb; injuries of magistral arteries; battle injury; limb amputation; prosthetic replacement of the vessel.

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BACKGROUND

The modern armed conflict has a number of specific features, which significantly affect the type of limb injuries and the medical aid needed by the wounded and the injured. New types of armament with special characteristics of the damaging elements specify the

unique types of wounds differing from all the ones described during the previous armed conflicts, with this, the battle contact line can be located at the direct proximity from the well-equipped large-scale civilian healthcare institutions, in which it is possible to provide the specialized and the high-tech medical aid. The

Опыт лечения боевых ранений магистральных артерий конечностей в условиях гражданского многопрофильного стационара

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АННОТАЦИЯ

Обоснование. Современный военный конфликт характеризуется значительным числом раненых с повреждениями магистральных артерий конечности. Такая травма сопровождается возможностью летального исхода и высоким риском ампутации конечности. Лечение ранений крупных артерий требует высокой квалификации медицинского персонала и достаточной оснащённости. Оптимальная тактика при этом до сих пор остаётся предметом дискуссий. **Цель** — определить особенности хирургической тактики при повреждениях магистральных артерий в условиях гражданского специализированного стационара в районе вблизи проведения боевых действий.

Методы. Проанализированы результаты лечения 57 пациентов с боевыми ранениями магистральных артерий конечностей, у которых удалось отследить непосредственный результат восстановления артерий в течение не менее двух суток. Многообразие проявлений ранений продемонстрировано на 8 клинических примерах. Хирургическую тактику определяли степень ишемии мышц и массивность поражения тканей конечности. Ампутации выполняли при формировании ишемической контрактуры либо при значительных поражениях ткани конечности. **Результаты.** Резекция артерии с аутовенозным протезированием выполнена в 49 случаях, циркулярная резекция артерии с прямым анастомозом — в 8. В ближайшем послеоперационном периоде (первые двое суток) в связи с постишемическим синдромом применение методов экстракорпоральной детоксикации потребовалось 5 (9%) раненым. Восстановление периферического кровотока отмечено в 56 (98,2%) случаях, вторичная ампутация нижней конечности выполнена только 1 (1,8%) прооперированному пациенту. Летальности не было (0%). **Заключение.** В современном военном конфликте линия боевого соприкосновения может находиться в непосредственной близости от хорошо укомплектованных гражданских учреждений здравоохранения, на базе которых возможна высокотехнологичная медицинская помощь. Наш опыт показывает, что в случае выполнения сложных хирургических операций наблюдение за пациентом в ближайшем периоде целесообразно организовать на месте и воздержаться от немедленной эвакуации. При травме магистральной артерии конечности основным параметром, влияющим на возможность сохранения самой конечности, является степень ишемии мышц. Необратимую ишемию зачастую определить затруднительно и ориентироваться следует на формирование ишемической контрактуры. Время получения ранения, отсутствие пульса, активных движений и чувствительности не могут служить показанием к ампутации. Разработанный нами алгоритм показал высокую эффективность.

Ключевые слова: острая ишемия конечности; ранение магистральных артерий; боевая травма; ампутация конечности; протезирование сосуда.

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majority of available publications on the battle-field surgery is devoted to the operations of the military hospitals of various levels, while the experience of the civilian institutions re-profiled for providing the medical aid to the servicemen, is practically not disclosed, while the developed Methodical Guidelines on the battle-field surgery do not take into account the specific features of the civilian multi-profile in-patient hospital [1, 2].

The institutions within the system of the Federal Medical-Biological Agency of the Russian Federation (FMBA of Russia), located near the areas of military operations, provide the aid to the wounded and injured from the first day of the conflict. The reinforcement of the local medical teams has resulted in the formation of the joint team of the FMBA of Russia, consisting of the highly qualified vascular surgery specialists of the Federal State Budgetary Institution "Federal Scientific and Clinical Center for Specialized Types of Medical Care and Medical Technologies under the Federal Medical-Biological Agency" (FSBI FSCC FMBA of Russia).

The trauma of the major vessels in the limbs is oftentimes the most critical injury and it is accompanied by not only the risk of amputation, but also by the possibility of lethal outcome [3, 4], due to which, the main tasks of the vascular surgeons are saving the life and salvaging the limb. Conducting the vascular reconstruction in cases of irreversible limb ischemia can further lead to the rhabdomyolysis and to the acute renal failure. The key prognostic parameter which should be used as the guidance when selecting the surgical tactics is the degree of muscle ischemia on admission and the predicted worsening of the ischemic burden, however, the objective evaluation of this parameter often presents serious difficulties.

Research aim — to define the specific features of the surgical tactics in cases of damaged magistral arteries of the limbs in the settings of the civilian specialized in-patient hospital operating in the area located near the field of military operations.

METHODS

Research design

This was a retrospective observational research of the hospital cases of treating the battle injuries of the magistral arteries in the limbs at the premises of the civilian re-profiled in-patient hospital.

Conformity criteria

Inclusion criteria: patients with battle trauma, admitted to the in-patient unit, which were diagnosed

and operated due to the damage of the magistral arteries of the limbs along with tracking the direct result within not less than two days from the moment of the surgical intervention.

Non-inclusion criteria: the presence of the leading (dominating) combined trauma in other areas.

Medical procedure description

The patients were admitted both as the result of arranged evacuation after having received the medical aid provided by the front-line medical groups and directly after being injured and after being evacuated with the aid of the volunteers. On admission to the in-patient hospital, at the level of the admission department each patient was quickly examined by the multidisciplinary team of specialists consisting of the vascular surgeon, the trauma specialist, the neurosurgery specialist and other specialists depending on the type of wounds. In cases of detecting the signs of on-going hemorrhages and impaired vital functions (consciousness, hemodynamics, respiration) or in case of detecting the triad of death (hypothermia, acidosis and coagulopathy), the intensive therapy headed by the anesthesiologist-intensivist was initiated at once at the admission ward and the patient was immediately transported to the operation room.

Methods for registration of outcomes

If the status of the patient was applicable, at the level of the admission department, diagnostic procedures were arranged, combined with the basic laboratory and instrumental examinations. If necessary, the duplex ultrasound scanning (DUS) of the vessels was done along with the computed tomography (including the contrasting). The DUS was also performed intra-operatively.

In cases of damaged major vessels of the limbs, the clinical examination included the determination of the degree of limb ischemia based on the modified classification by V.A. Kornilov (table 1) and on the classification by I.I. Zatevakhin [2]. The following parameters were evaluated: sensitivity, active and passive motions, presence of pulse in the peripheral arteries and the data from the instrumental methods of examination. The surgical tactics was determined on an individual basis and based on the Methodical Guidelines on the battle-field surgery from the Main Military Medical Directorate under the Ministry of Defense of Russia (see table 1).

Table 1

The classification of acute limb ischemia in cases of wounds*

Degree of ischemia		Main clinical signs			Doppler signal		Prognosis	Surgery tactics
		Sensitivity	Active motions	Passive motions	Arterial	Venous		
Compensated (due to the presence of collateral vessels)		+	+	+	+	+	No risk of gangrene	No indications for emergency restoration of the artery; the ligation of the vessel is safe
Non-compensated	Early	+/-	+/-	+	+/-	+	The limb necrotizes within the nearest 6–8 hours	Emergency prosthetic replacement or restoration of the artery is indicated, along with the preventive fasciotomy
	Critical (with the duration of more than 6 hours)	-	-	+/-	-	+	Direct threat to the viability of the limb	Emergency temporary prosthetic replacement of the artery is indicated, along with the therapeutic fasciotomy, if possible — plasmapheresis
Irreversible (ischemic contracture)		-	-	-	-	-	Salvaging the limb is impossible	Indications for arranging the amputation, for the attempts to restore the artery can result in the death of the wounded due to the endotoxocosis

Note. * — cited as per [2].

In case of irreversible ischemia or significant destruction of the limb tissues, the primary amputation was done. In cases of the compensated and the uncompensated ischemia, vascular reconstructive interventions were arranged. The damaged area of the arterial vessel was resected, depending on its length with forming the direct anastomosis or with conducting the autovenous prosthetic replacement with the reversed segment of the great saphenous vein (*vena saphena magna*) or using the basilic vein (*vena basilica*). In case of detecting the damage of the major veins, if possible, they were sutured, if not — ligated. If necessary, the simultaneous fasciotomy was arranged in the lower limb. The surgical technique used for the fasciotomy was the classic semi-occlusive variant: from 1–3 single incisions with length of 2–3 cm at the border between the upper and the middle third of the shin, the fascial sleeve was opened and the Metzenbaum scissors were used to dissect the fascia in the projection area of fascial sleeves at the distal and the proximal directions.

Anticoagulant therapy in the standard variant included the subcutaneous administration of enoxaparin sodium 4000 anti-Xa IU twice daily.

Upon the progression of the post-ischemic syndrome, the methods of extracorporeal detoxication were used along with the secondary amputation of the limb.

RESULTS

Research sample (participants)

The direct treatment result was accessible for tracking in 57 wounded.

We have followed-up the damage of the major vessels in the limbs in 18% of the admitted wounded, however, due to various reasons (agonal state; significant destruction of the limb tissues; the dominant contribution of the trauma in another area; the formation of the ischemic contracture in the major joints etc.), the vascular reconstruction procedures were carried out in less than 1 out of 5 of such patients. In many cases, there was no full trackability of even the direct result due to the evacuation to the next stage of providing the medical aid resulting from the need to clear the bed capacity in the settings of the continuous flow of wounded.

The type of vessel wounds directly depended on the type of the damaging element. Only in 2% of observations, the reconstructive vascular surgery was

done due to the bullet wounds. In the absolute majority of cases, the cause was the mine-blast trauma, with only 33% operated patients having the damage caused by the primary damaging factors of the explosion (the detonation products and the blast wave), while the other observations were only the wounds caused by the secondary damaging elements (shell fragments).

Primary findings

Small fragments sized up to 1 cm (in 49% of the operated individuals), generally, were causing the perforation of the vessels with the formation of the restricted and pulsating hematomas, oftentimes with preserved distal circulation. The characteristic feature is that the small fragments were often resulting in the so-called “mine-like” wounds with the complex and irregularly-shaped wound channels, causing the combined injuries of veins and arteries. The discrepancy between the small entry hole and the vast inner damage of the soft tissues and the bones was reported in 75% of such wounds, which required the obligatory conduct of ultrasonic dopplerography, and in the complex cases — the computed tomographic angiography with contrast enhancement (CT-angiography), with obligatory thorough revision of the wound channel.

The medium size fragments — 1–3 cm (in 37% of the operated individuals) — were causing the variable damage: from the marginal defects to the complete transverse ruptures of the vessels. The specific feature of such wounds was the frequent combination with the damage of the adjacent nerve trunks. Large fragments — sized over 3 cm (14% of the operated) — were causing the extensive damage with vast defects of the vascular walls and with the massive tissue destruction. Such wounds were characterized by the formation of the vast zones of tissue contusion, by the high risk of secondary thrombosis and by the necessity of vast surgical processing.

The type and the number of conducted surgeries in the patients enlisted into the research are provided in table 2.

At the earliest post-surgery period (first two days) the post-ischemic syndrome has caused the need for extracorporeal detoxication in 5 (9%) wounded, the secondary amputation of the lower limb was done only in one (1.8%) operated patient in 9 hours from the initial surgery. No cases of lethal outcome were reported among all the operated patients (0%).

The multiplicity of the manifestations of the battle-inflicted trauma of the major vessels in the limbs is better to be demonstrated by the description of several clinical examples.

Clinical case description

Clinical example 1. To the Admission Ward, the 32-year old patient was admitted 6 hours after the mine-blast injury of the left shoulder. At the pre-hospital phase, the medical team has carried out the temporary bypassing of the brachial artery using the sterile plastic tube.

On admission, the status of the patient was considered stable with moderate degree of severity, with satisfactory blood supply in the distal areas of the limb and with the absence of signs of acute ischemia. The patient had a tear-contused wound with the size of 3.0×2.5 cm in the middle third of the left shoulder with insignificant blood discharge. The observed findings included the defect in the brachial artery with a length of up to 4 cm, replaced with temporary shunt. The pulsation in the peripheral arteries was preserved, though weakened. The neurological status remained intact: the sensitivity and the ability to move the palm and the fingers was completely preserved. Moderate swelling was found in the soft tissues in the damaged area. The instrumental diagnostics included the DUS of the vessels, on the results of which, signs of distal

Table 2

Types of surgeries

Wound location	Type of surgical intervention	Patients n=57 (%)
Upper limb n=21, 37%	Resection of the artery with autovenous prosthetic replacement using the reversed segment of <i>v. saphena magna</i> or <i>v. basilica</i>	16 (28)
	Circular resection of the artery with direct anastomosis	5 (9)
Lower limb n=36, 63%	Resection of the artery with autovenous prosthetic replacement using the reversed segment of <i>v. saphena magna</i> or <i>v. basilica</i>	33 (58)
	Circular resection of the artery with direct anastomosis	3 (5)
	Fasciotomy	29 (51)

hypoperfusion were found with persisting passability in the temporary shunt. The radiology examination has shown the presence of the radiopaque foreign body of irregular shape with the size of 2.0×1.5 cm within the soft tissues of the medial surface of the shoulder. No other injuries were revealed in the patient.

In the settings of the endotracheal anesthesia, the surgical intervention was done at the extent of the primary wound processing, the revision of the wound channel and the removal of the damaging fragment. Upon the revision, it was found that there is a segmental defect in the brachial artery with a length of 4 cm with crushed vessel ends. Resection of the damaged segment was done with further autovenous prosthetic replacement using the reversed transplant made of the great saphenous vein, extracted from the right thigh (Fig. 1). The vascular reconstruction was carried out using the microsurgery technique and the suturing material was the prolene 7/0. The surgery was completed with using the wound draining and the layered suturing.

The postoperative period was unremarkable (no complications). The control ultrasound examination has confirmed the complete passability of the reconstructed segment of the artery and the restoration of the magistral circulation. Other findings included the restoration of the full-fledged pulsation in the peripheral arteries. The status of the patient was deemed stable and he was evacuated for further treatment to the specialized institution in the rear areas.

Later on, during the after-treatment in another institution, his postoperative period was still unremarkable (no complications). The control DUS has confirmed the complete passability of the reconstructed arterial segment with preserving the magistral circulation.

This observation demonstrates the successful application of the two-staged treatment tactics for the major artery injury, including the temporary bypassing at the pre-hospital phase and further autovenous prosthetic replacement at the in-patient settings. The timely conducted vascular reconstruction allowed to prevent the development of ischemic complications and to salvage the limb, which emphasizes the importance of the continuity at the stages of providing the medical aid.

Clinical example 2. To the admission ward, a 28 years old patient was transported 2 hours after the multiple fragmentation wound of the right lower limb. The wound in the popliteal area was characterized as the non-perforating with supposed injury of the vascular bundle elements. The status of the patient on admission remained stable with compensated hemodynamic parameters and with the absence of clinical signs of acute ischemia in the limb.

Upon the local examination, in popliteal fossa, the visualized finding included a wound with a diameter of 2 cm with insignificant hemorrhage. The pulsation in the peripheral arteries of the foot was detectable but weakened. The sensitivity and the motor function in the distal areas of the limb were completely preserved. Moderate edema was found in the perivascular tissues.

The results of the DUS have revealed signs of combined injury of the popliteal artery and vein with the formation of limited hematoma. The blood supply in the distal areas of the limb was preserved. The radiology examination has confirmed the presence of the radiopaque fragment of irregular shape within the soft tissues of the popliteal region.

In the settings of the endotracheal anesthesia, a surgical intervention was carried out at the extent of

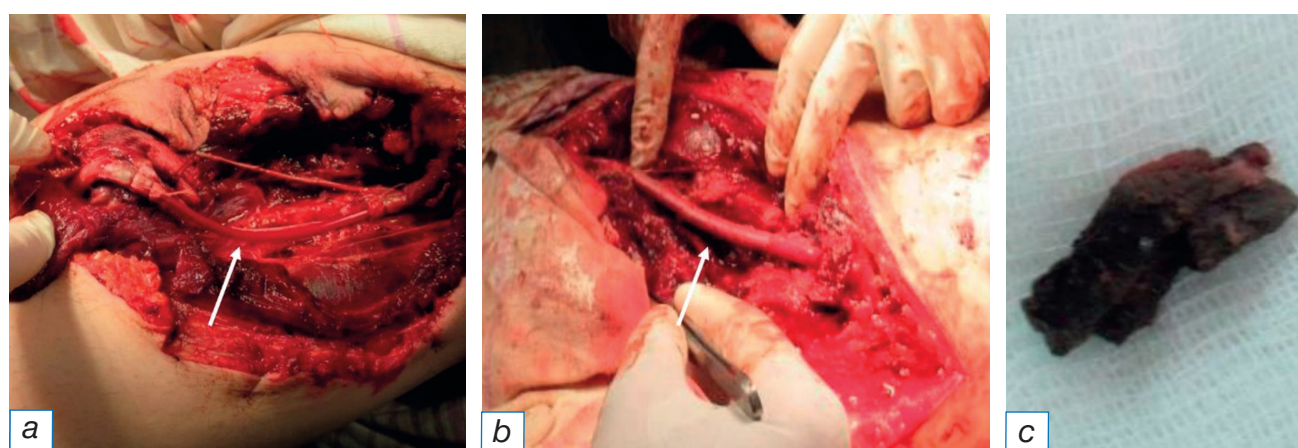


Fig. 1. Resection of the damaged segment. a — temporary shunting of the brachial artery (arrow); b — replacing the defect of the brachial artery with reversed auto-vein (arrow); c — removed shell fragment.

the revision of the wound channel, the removal of the fragment, the reconstruction of the artery and suturing of the vein defect. Intraoperatively, the marginal defects were found in the popliteal artery and vein with a length of up to 1.5 cm. Further procedures included the resection of the damaged areas of the popliteal artery with further autovenous prosthetic replacement using the reversed transplant made of the great saphenous vein. The vascular reconstruction was done using the microsurgery technique (Fig. 2).

The postoperative period was characterized by the complete restoration of the blood supply in the limb. The control ultrasound examination has confirmed the passability of the reconstructed vessels. The patient was mobilized on the next day and evacuated for further treatment.

The specific features of this observation were the combined injury of the popliteal artery and vein, the optimal timings of the evacuation after the injury and the absence of significant ischemia, which has specifically defined the possibility of conducting the primary vascular reconstruction with favorable prognosis in terms of the recovery.

Clinical example 3. The patient aged 35 years was transported to the Admission Ward 3 hours after receiving a non-perforating bullet wound in the soft tissues of the right shin. The status of the patient on admission was evaluated as severe due to the on-going hemorrhage out of the wound channel. At the pre-hospital phase of providing the medical aid, a tourniquet was applied above the wound location — to the upper third of the right thigh.

On admission, the characteristic signs of hemorrhagic shock were observed: pronounced paleness of the skin, cold sweat, tachycardia up to

120 bpm and arterial hypotension (80/50 mm.Hg.). The local status was described as the presence of arterial tourniquet at the upper third of thigh and a wound hole with diameter of 1.5 cm in the middle third of the shin with signs of on-going venous hemorrhage. No pulsation was found in the peripheral arteries of the foot due to the tourniquet applied.

An emergency ultrasound examination has revealed the damage of the great saphenous vein with preserved magistral arterial vessels. The radiography has confirmed the presence of a foreign body (bullet) within the soft tissues on the posterior surface of the shin. The laboratory tests have shown the critical decrease in the levels of hemoglobin — down to 78 g/l and hematocrit — down to 24%.

During the emergency surgical intervention, an immediate removal of the arterial tourniquet was done with further revision of the wound channel. Intraoperatively, a defect was found in the wall of the great saphenous vein with a diameter 1.0 cm. The defect was fixed by means of applying the vascular suture with prolene 6/0 suturing material (Fig. 3). The complete arrest of hemorrhage was achieved immediately. For the correction of the hemorrhagic shock, the hemotransfusion was done using 500 ml of erythrocyte concentrate and 600 ml of fresh frozen plasma.

The postoperative period was characterized by the rapid stabilization of hemodynamic parameters and by the restoration of the peripheral blood circulation parameters. The control ultrasound examination has confirmed the maintained passability of the reconstructed vein.

This clinical observation decisively demonstrates the iatrogenic complication expressed as the erroneous application of the tourniquet above the wound location in case of venous bleeding, which lead to the aggravation of the blood loss and to the development of severe hemorrhagic shock. The special complexity was observed in the differential diagnostics of the type of hemorrhage with the atypical trajectory of the wound channel.

Clinical example 4. A 31-year old patient was admitted to the in-patient hospital in 3 hours after receiving a fragmentation wound in his left thigh. At the pre-hospital phase, a tourniquet was applied at the level of the thigh, however, its application did not provide an adequate hemostasis. The status of the patient on admission was considered extremely severe due to the voluminous venous hemorrhage and due to the developed hemorrhagic shock.

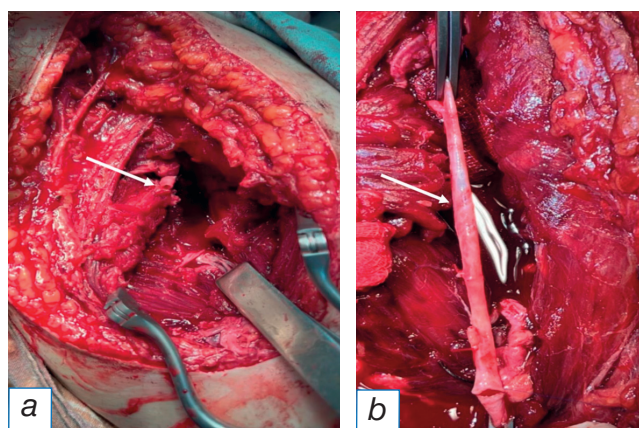


Fig. 2. Resection of the damaged areas of the popliteal artery. *a* — the defect of the popliteal artery (arrow); *b* — the prosthetic replacement of the popliteal artery with reversed auto-vein (arrow).

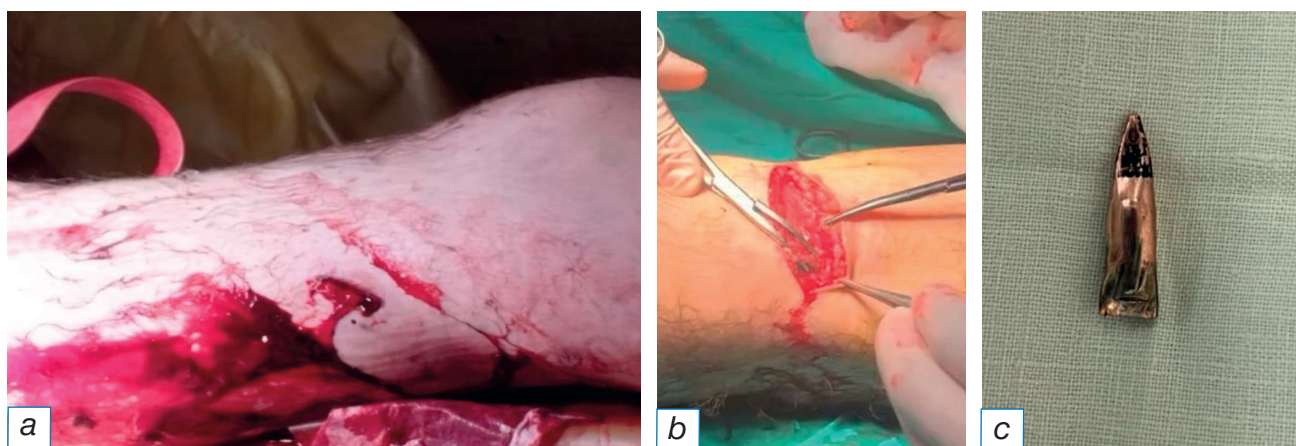


Fig. 3. Elimination of a defect in the wall of the large saphenous vein. *a* — the appearance of the wound; *b* — suturing the defect of the great saphenous vein; *c* — bullet extracted from the wound.

Upon the surgical revision, the findings include the damage of the femoral bone in the lower third with secondary injury of the popliteal vein with bone fragments. The removal of the tourniquet was done with further applying the vascular suture to the damaged area of the vein. Restoring the vessel integrity has allowed for achieving a complete hemostasis. The second step included the surgical processing of the bone damage with the repositioning and fixation of the bone fragments. The postoperative period was characterized by the stabilization of hemodynamic parameters and by the restoration of an adequate venous outflow in the limb.

This observation shows the specific features of the tactics in cases of combined injuries of the bone tissue structures and of the major venous vessels. It also emphasizes the importance of the staged treatment approach, where the principal attention is paid to restoring the vascular passability with further stabilization of the fractured bone fragments (Fig. 4).

The clinical observations 3 and 4, though not being directly related to the injuries of the arteries,

demonstrate the major importance of the differential diagnostics between the arterial and the venous hemorrhages at the pre-hospital phase, as well as the necessity of controlling the arrest of hemorrhage after the application of the tourniquet for the purpose of ruling out the cases of incorrect first medical aid for venous bleeding.

Clinical example 5. A 22-years old patient was transported to the Admission Ward with a mine-blast wound of the left shoulder with unknown exact timings of the wound. Upon the initial assessment, there was an absence of pulse in the radial artery, the absence of active motions in the elbow and in the radiocarpal joints with the absence of tactile sensitivity in the affected limb, however, the passive motions in the joints were preserved. During the intraoperative revision, the findings included a lengthy thrombosed segment of the brachial artery with the delamination of intima and with signs of contusion damage and rupture of the vascular wall. A decision was drawn up on conducting the thrombectomy with further resection of the damaged area of the artery. The vascular defect was replaced

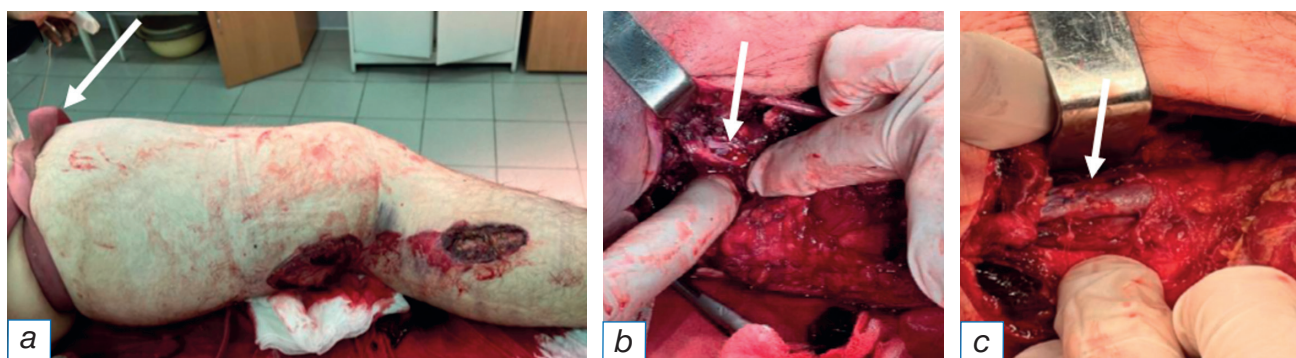


Fig. 4. Restoring the vascular passability. *a* — the appearance of the wound in the left lower limb, tourniquet applied to the upper third of thigh (arrow); *b* — the defect of the popliteal vein (arrow); *c* — suturing the defect in the popliteal vein (arrow).

with the autovenous transplant made of the great saphenous vein (Fig. 5).

After restoring the magistral circulation, the gradual improvement was observed in the perfusion of the distal areas of the limb. At the remote period, the complete restoration of the limb functions was achieved.

This observation confirms the efficiency of re-vascularisation even in case of visible signs of severe acute ischemia. The maintained passive mobility of the joints has served as the key prognostic sign determining the success of the reconstructive intervention.

Clinical example 6. After a total of 8 hours after the fragmentation wound, into the admission ward, the patient was transported, aged 48 years and with the isolated injury of the femoral artery, complicated by the development of the tense hematoma and with the clinical signs of acute uncompensated ischemia in the limb. Upon the initial assessment, there were characteristic signs of critical impairment of peripheral circulation: marbling of the skin, absence of capillary refill or distal pulse, impaired active motions and sensitivity in the lower limb. The passive motions in the ankle joint of the affected limb were preserved.

In the settings of the operating room, an emergency surgical processing of the wound channel was carried out with the revision of the damaged area. Intraoperatively, a segmental defect of the femoral artery was diagnosed, requiring its resection. The restoration of the arterial continuity was achieved by means of the autovenous prosthetic replacement using the reversed transplant originating from the great saphenous vein.

The specific feature of the surgical tactics was conducting the fasciotomy aimed at preventing the development of the compartment-syndrome after restoring the magistral circulation. The direct result of the intervention became the complete

re-vascularisation of the limb with restoring the pulse at the operating table (Fig. 6).

During the postoperative period, gradual regress of ischemic manifestations was observed with the complete restoration of the limb functions. The control ultrasonic examinations have confirmed the persisting passability of the reconstructed arterial segment.

In this observation, despite the significant temporal delay of the admission, the consecutive procedures of surgical processing, the vascular reconstruction and the fasciotomy has allowed for achieving the favorable outcome. The case demonstrates the efficiency of using the autovenous stenting in the settings of the delayed provision of the specialized medical aid.

Clinical example 7. Four hours after the fragmentation wound of the shoulder area, to the in-patient hospital, the patient aged 21 years was admitted with the combined injury of the brachial artery and of the median nerve. Upon the initial assessment, the findings included the preserving of the passive mobility in the limb with the complete absence of peripheral pulse, of the active motions or the tactile sensitivity in the limb.

The intraoperative revision has shown a lengthy segmental defect in the brachial artery with a length of 4 cm along with the complete trans-section of the median nerve at the same distance. A decision was drawn up on conducting the simultaneous reconstructive intervention.

At the first stage, the autovenous prosthetic replacement of the brachial artery was done using the reversed transplant from the *v. basilica*. After the restoration of the magistral circulation, the second stage surgery was carried out — replacing the defect of the median nerve with the autotransplant of the sural nerve (*nervus suralis*) taken from the area of the medial malleolus.

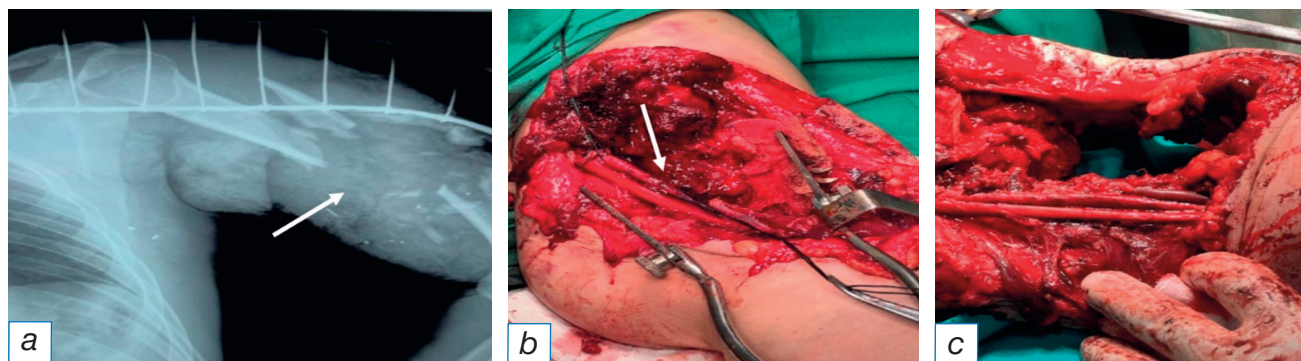


Fig. 5. The vascular defect was replaced with the autovenous transplant. a — radiography of the left shoulder (destruction of the humeral bone shown by the arrow); b — the defect of the brachial artery in the left shoulder (arrow); c — autovenous prosthetic replacement of the left brachial artery.

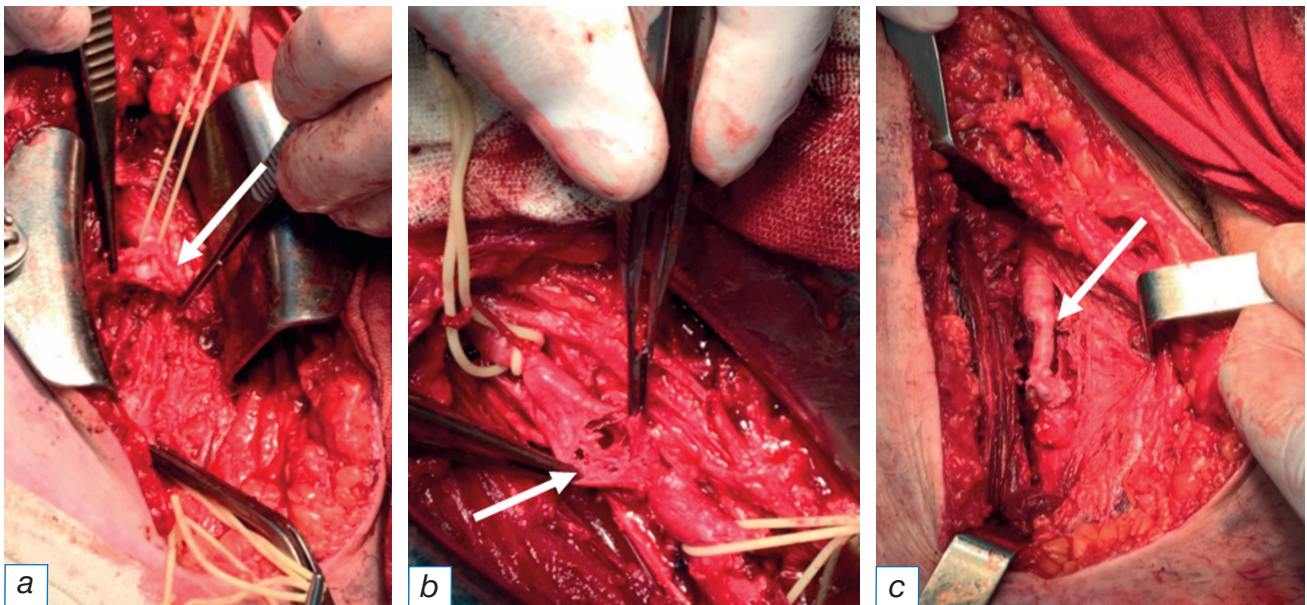


Fig. 6. Performing a fasciotomy. *a, b* — the defect of the femoral artery (arrows); *c* — autovenous prosthetic replacement of the femoral artery (arrow).

The postoperative period was characterized by the gradual restoration of the peripheral circulation and by the initial signs of re-innervation. Later on, the patient was reporting the progressing re-gaining of the motor and the sensory functions in the limb (Fig. 7).

This observation illustrates the possibilities of conducting the complex reconstructive interventions in the settings of the near-front line in-patient hospital. The absence of ischemic contracture has defined the possibility of arranging the simultaneous neurovascular reconstruction. The case demonstrates the importance of the combined approach in restoring not only the anatomical integrity, but also the functional substantiality of the damaged limb.

Clinical example 8. The patient aged 41 was transported to the Admission Ward 4 hours after receiving a fragmentation wound in his right axillary area. The status of the patient on admission was

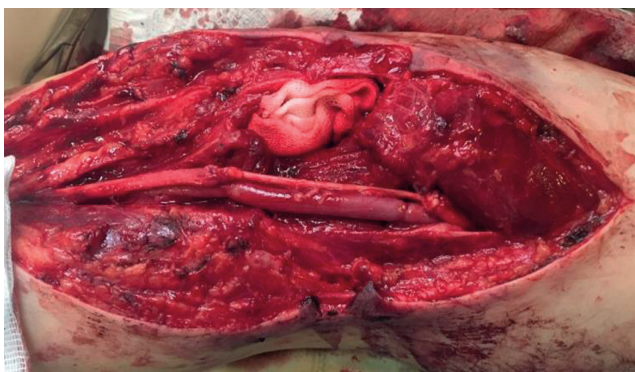


Fig. 7. Autovenous prosthetic replacement of the brachial artery using the reversed transplant from the *v. basilica*.

considered as moderate degree of severity, however, despite the relative stability of hemodynamic parameters, progressing paleness was reported in the skin along with increasing fatigue.

Upon the clinical examination, in the area of the right axillary fossa, the visualized findings were the tense hematoma with a diameter of approximately 8×10 cm and with pronounced pulsation. The peripheral pulsation in the arteries of the forearm and of the palm was not found. Other signs included the decrease in the dermal sensitivity along the medial surface of the shoulder and of the forearm.

The emergency computed tomographic angiography with contrast enhancement has revealed the complete rupture of the axillary artery at a length of 3 cm with forming the vast pulsating hematoma.

In the settings of the operating room and under the endotracheal anesthesia, the surgical intervention was carried out. After opening and evacuating the hematoma, a segmental defect of the axillary artery was found with a length of 4 cm and with shattered margins. Further procedures included the resection of damaged area with further autovenous prosthetic replacement using the reversed transplant made of the great saphenous vein. The vascular suture was applied using the microsurgery technique. Intraoperatively, the restoration of the pulse in the peripheral arteries was reported (Fig. 8).

The postoperative period was characterized by the gradual restoration of the blood supply in the limb. The control ultrasound examination has confirmed

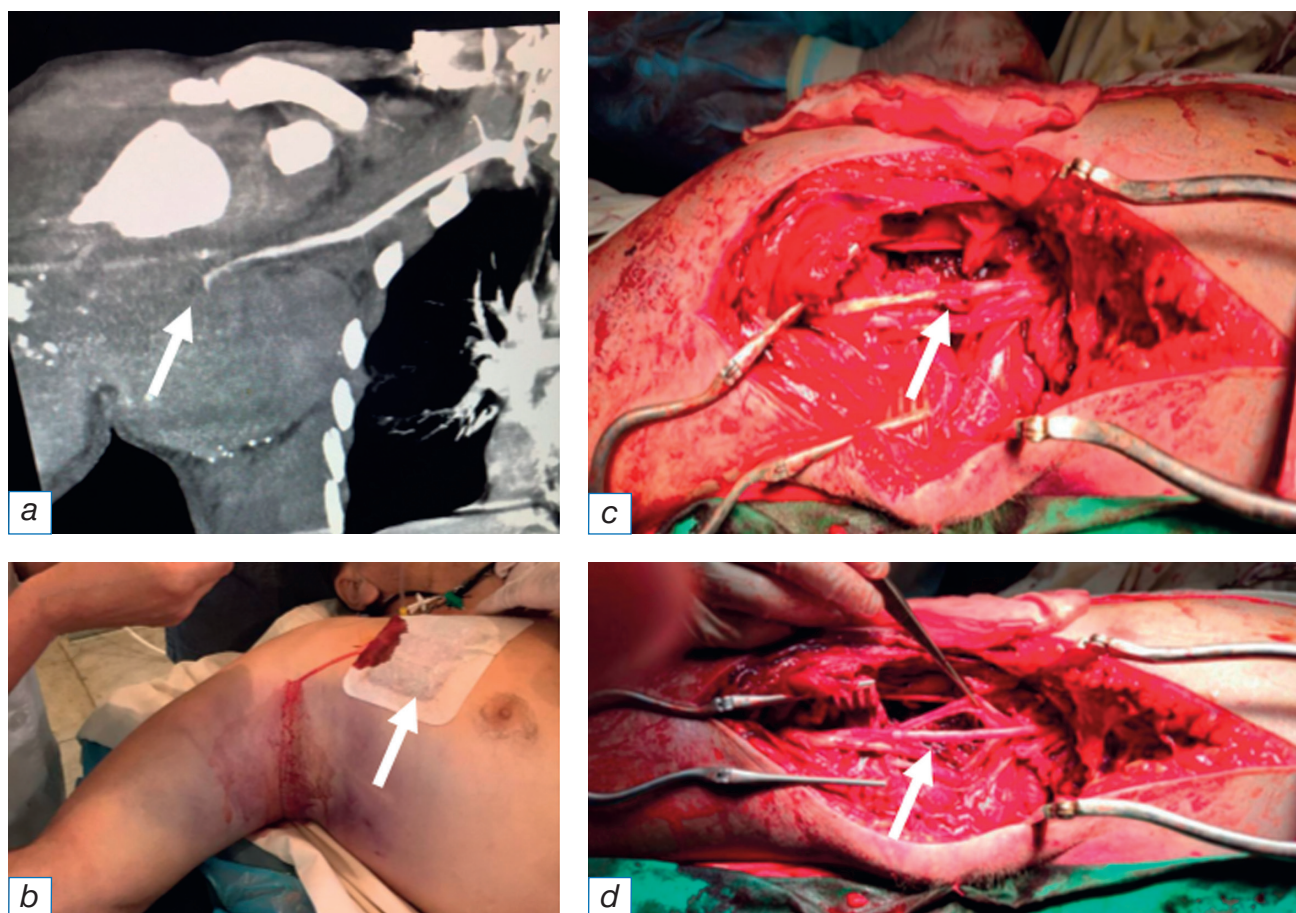


Fig. 8. The restoration of the pulse in the peripheral arteries. *a* — the computed tomographic angiography demonstrating the defect in the right axillary artery with the formation of the pseudo-aneurysm and the thrombosis (arrow); *b* — the appearance of the wounded (the entry hole is marked with an arrow); *c* — the defect of the axillary artery (arrow); *d* — the prosthetic replacement of the axillary artery with reversed auto-vein (the autograft is marked by the arrow).

the complete passability of the reconstructed arterial segment. Progressive restoration was reported in the sensitivity and in the motor functions of the limb.

The presented observation demonstrates the successful usage of CT-angiography for the precise local diagnostics of the complex proximal injury of the major vessel. The timely conduct of the autovenous prosthetic replacement has allowed for not only salvaging the limb, but also for restoring its full functionality, despite the initially severe type of injury and the developing ischemia. The case confirms the necessity of the possibility to perform the emergency CT-angiography in the settings of the multi-profile in-patient hospital at the near-front line territory.

DISCUSSION

Within the framework of the current research, a retrospective analysis was arranged for the clinical observations of the modern battle injuries of the magistral arteries in the limbs. The number of wounded admitted with such injuries is significantly higher comparing to

the experience from the previous conflicts (for example, during the Great Patriotic War, the vessel wounds were described in 1% of the wounded, and during the Chechen conflict — in 5–6%, we were registering the vessel injuries in 18% of the admitted wounded patients) [1–4]. Some role in this statistics, probably, is played by the improvement in the provision of first medical aid at the battlefield, but the main reason is the usage of new types of weaponry (cluster munitions and other types of modern shells). The combined nature of the wounds, which we observed, requires the participation of the multidisciplinary team of specialists (orthopedic traumatologist, vascular surgery specialist, neurosurgery specialist, abdominal and thoracic surgery specialist, anesthesiologist-intensivist and specialists from the diagnostic fields).

The diagnostics of the injured arteries of the limbs can pose difficulties when the input hole of the damaging element is located outside the projection of the vessel location area and there is no arterial hemorrhage. Our experience confirms the key role of ultrasonic

dopplerography, while the CT-angiography conducted in the setting of the stable hemodynamics provides the unique possibilities for the pre-operative planning in the complex situations, especially when there are multiple fragment wounds and the determination of the damage level is hampered.

In cases of the injured major vessels of the limbs, oftentimes there is a significant degree of destruction of the tissues along with the corrugated wound channels and with the contusion damage, which does not allow for objectively evaluating the sensitivity, the active motions and the degree of ischemia at the same time. During the research, it became clear that the specific features of the effects of damaging elements in the modern conflict lead to the absence of the absolute criteria for the development of the irreversible limb ischemia (including the time of injury, the pulsation, the ultrasonic dopplerography data, the absence of sensitivity and muscle rigidity), except for the development of ischemic contractures in the major joints.

The time of wound infliction was traditionally considered a significant factor for the development of irreversible ischemia, however, there is a whole number of reports, in which, using their own experience, the authors did not find any confirmation to this. S.R. Menakuru et al. [5], describing a series of 148 patients, report about the excellent results, despite the median delay of 9.3 hours from the moment of the admission of the wounded. W.H. Wagner et al. [6] have found no correlation between the ischemia time and the outcome in vascular injury. W. de Silva et al. [7] describe the brilliant results for 36 vascular reconstructions with the median time from the episode of injury being 10 hours. In our practice, in a number of patients, the successful vascular reconstructions were

undertaken after more than 24 hours from the moment of the wound infliction.

The analysis of the accessible literature shows that it is possible to use the tactics of restoring all the major vessels regardless of the degree of ischemia in the limb. Even in the absence of restoring the peripheral blood supply in the limb, it is possible to delay the conduct of the secondary amputation, for the ischemia can be mosaic and the staged necrectomies with a background of using the extracorporeal methods of detoxication allow for salvaging the limb [4–7]. However, the use of this approach requires significant efforts from the medical staff, the proper equipment basis and the continuity in the settings of the staged provision of medical aid.

In each case, the decision on the possibility of conducting the vascular reconstruction needs to be drawn up on an individual basis. It should be remembered that the main objective of the medical aid in the settings of the military conflict is saving the life of the maximum number wounded in case of their massive inflow. The choice of the general strategy of treatment at the stage of the sorting decision should be based on evaluating the vital functions (consciousness, hemodynamics, respiration) and on the presence of the “triad of death” (hypothermia, acidosis, coagulopathy). In the unstable patients with severe combined injuries, a fast and reliable arrest of the on-going hemorrhage is needed, while the surgical tactics should be based on the practicability principles.

We have developed a proprietary algorithm of selecting the treatment tactics (Fig. 9), which we used as a guideline during our operations and which has confirmed its high clinical efficiency. Three variants of the tactical surgical decision are possible: the vascular

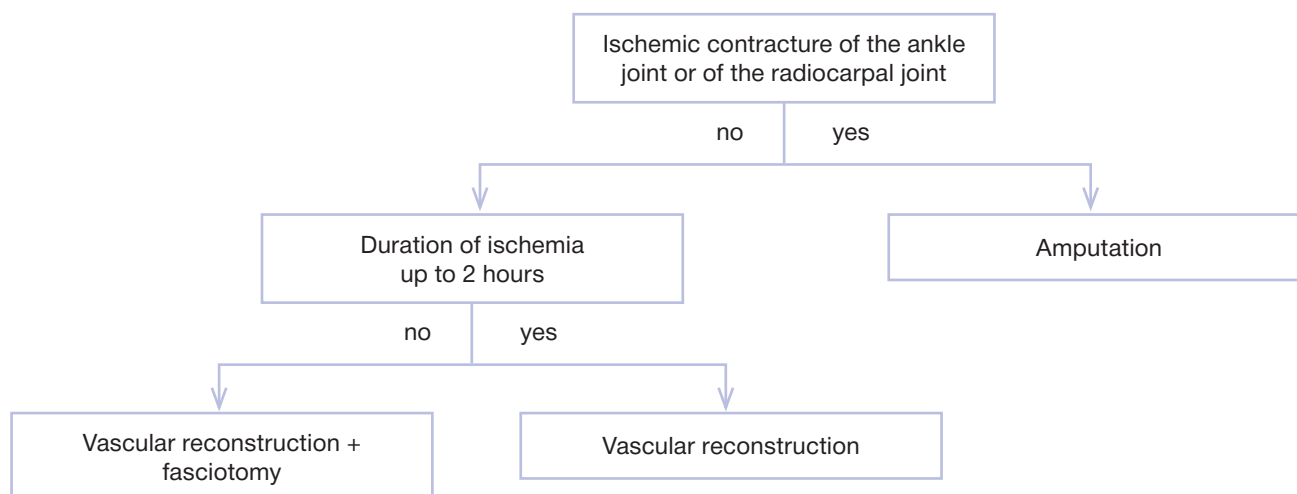


Fig. 9. The algorithm of selecting the treatment tactics in cases of injuries involving the magistral arteries of the limbs.

reconstruction, the vascular reconstruction together with fasciotomy and, finally, the amputation. Special significance when selecting the specific variant belongs to evaluating the passive movements in the damaged limb in its major joints as the more reliable prognostic criterion of its viability. The absence of active motions and of the sensitivity are reversible, besides, they can occur in cases of the concomitant damage of the nerves, not being an indication for amputation.

In cases of the damaged arteries of the lower limb, only in an ideal situation, when the wound was inflicted less than 2 hours ago and there is no significant destruction of the tissues, it is possible to skip the fasciotomy. In other cases, fasciotomy is indicated, and skipping it may further lead to the compartment syndrome and to the acute renal insufficiency. Though the necessity of fasciotomy is evident when detecting signs of swelling and pain in the distal muscles, it may not be the case when we are talking about the prevention [8, 9]. It was shown that early fasciotomy in cases of damaged vessels in the lower limbs promotes to the decrease of the rates of consequent amputations and to the shortening in the duration of treatment [10]. Fasciotomy for preventive purposes in case of acute ischemia in the upper limb can be unjustified. Thus, in the research by D. Jo et al. [11] performing the fasciotomy had no evident benefits and was associated with the increased rate of complications. In our research, in cases of traumas involving the vessels

of the upper limb, the fasciotomy was not performed on the routine basis.

With the concomitant damage of the bones, the majority of orthopedic fixations were the external ones and, with the traumatologist having the sufficient experience, they were done rapidly and in parallel to the operations conducted by the vascular surgery specialist. There were no staging problems and the majority of vascular anastomoses were conducted in the already stabilized limb. In rare cases, when the traumatologists needed significant time for the fixation of the limb, the restoration of the passability of the arteries was done as the first stage.

During the postoperative period, the observed findings may include the progression of ischemia and the development of the acute renal insufficiency, which will require the immediate response measures (secondary amputation and/or extracorporeal detoxication) (Fig. 10). We suggest that, after conducting the vascular reconstructions, the active follow-up is necessary within two days, and the premature evacuation of the patient can increase the risks caused by the untimely provision of the adequate medical aid.

The complex operative situation and the possibility of safe evacuation of the wounded and the injured can significantly modify the application of the classic concept of “multi-stage” treatment, which dictates the necessity of developing the flexible and adaptive protocols for evacuation and treatment.

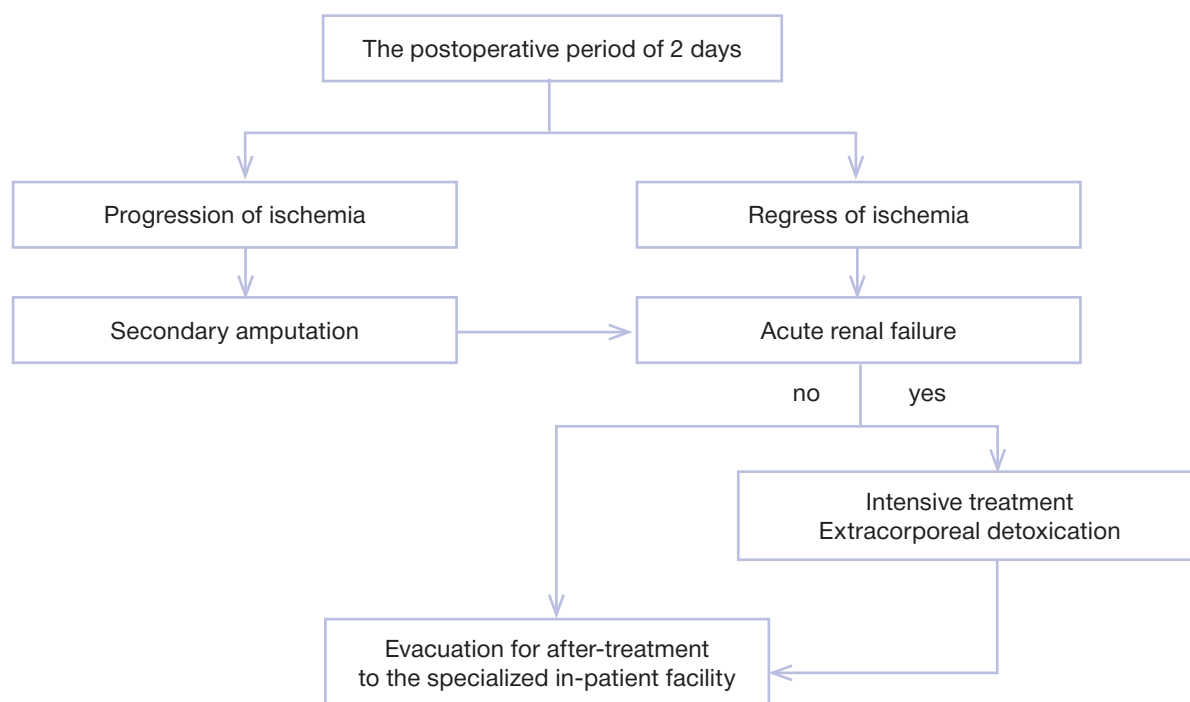


Fig. 10. Algorithm of managing the patient after the restoration of the magistral arteries in the limb.

Our experience demonstrates the high level of qualification among the front-line medical groups, which, in the settings of being at the zone with immediate danger, were conducting such surgical interventions as the temporary bypassing of the damaged blood vessels, which was providing the possibility of salvaging the limb. At the same time, a systemic risk was identified for the application of the arterial tourniquet in cases of isolated venous bleeding, which indicates the necessity of perfecting the educational programs of pre-hospital aid with an accent to the differential diagnostics of the hemorrhage type.

In the settings of the well-equipped civilian in-patient hospitals located near the areas of the military operations, it is possible to arrange the vascular reconstructive surgeries in cases of the injuries of the magistral arteries, however, due to the risk of developing the post-ischemic syndrome, it is practicable to avoid the immediate further evacuation and to arrange the follow-up for the operated patients lasting not less than two days (see Fig. 10). Due to the absence of direct contacts between the institutions providing medical aid at various stages, the continuity can be interrupted, which negatively affects the final result of treating the wounded.

CONCLUSION

In the settings of the modern battle conflict, a combination can be observed that includes the unique characteristic of the wounds and the complex operating environment, which requires the exceptional coordination of the forces and facilities when organizing the medical aid and defines the necessity of individual tactical decision in each specific patient. The battle contact line can be located at the direct proximity from the well-equipped civilian healthcare institutions, at the premises of which, it is possible to provide the high-tech medical aid, however, in case of performing the complex surgeries, the follow-up for the operated patient at the earliest post-surgery period is practicable for arranging on site with avoiding the immediate evacuation.

In cases of injuries involving the major artery in the limb, the main parameter affecting the possibility of salvaging the limb itself is the degree of ischemia in the muscles. The irreversible ischemia is often hard to define, and the guideline to be used is the development of the ischemic contracture in the major joints. The time of wound infliction, the absence of pulse, of the active motions and of sensitivity cannot serve as an indication for amputation. The algorithm developed by us has

demonstrated its high efficiency in saving the life and in salvaging the limb.

ADDITIONAL INFORMATION

Author contributions: A.V. Smirnov, R.I. Khabazov, S.V. Deryabin, general concept, collection and analysis of material, writing the article, editing; S.V. Deryabin, M.V. Khruslov, P.Yu. Orekhov, P.Yu. Parshin, A.R. Abasov, execution of operations; A.V. Troitskiy, general concept, general management. Thereby, all authors provided approval of the version to be published and agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

Ethics approval: The study was approved by the local ethics committee of the Federal Scientific and Clinical Center of the Federal Medical and Biological Agency of Russia (protocol No. 9/2025 dated Sept 15, 2025). All patients included in the study signed informed voluntary consent for treatment and surgery, as well as for the use of anonymized health data for scientific purposes.

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REFERENCES

1. Разработка плана действий объекта здравоохранения (лечебно-профилактического учреждения) в чрезвычайных ситуациях: методические рекомендации. Москва: Защита, 1999. 23 с. [Development of an action plan for a healthcare facility (medical and preventive institution) in an emergency situation: method. recommendations. Moscow: Zashchita; 1999. 23 p. (In Russ.)]. ISBN 5-93064-013-0
2. Самохвалов И.М., Чуприна А.П., Бельских А.Н., и др. Военно-полевая хирургия: учебное пособие / под ред. И.М. Самохвалова. Санкт-Петербург: Военно-медицинская академия имени С.М. Кирова, 2021. 494 с. [Samokhvalov IM, Chuprina AP, Belskikh AN, et al. Military field surgery: textbook. Samokhvalov IM, editor. Saint Petersburg: Military Medical Academy named after S.M. Kirov; 2021. 494 p. (In Russ.)]. EDN: RPOGDB
3. Тришкин Д.В., Крюков Е.В., Алексеев Д.Е., и др. Военно-полевая хирургия. Национальное руководство / под ред. И.М. Самохвалова. 2-е изд., перераб. и доп. Москва: ГЭОТАР-Медиа, 2024. С. 1017, 1019. Серия: Национальное руководство. [Trishkin DV, Kryukov EV, Alekseev DE, et al. Military field surgery. National guidelines. Samokhvalov IM, editor. 2nd ed, revised and updated. Moscow: GEOTAR-Media; 2024. P. 1017, 1019. Series: National Leadership. (In Russ.)]. doi: 10.33029/9704-8036-6-VPX-2024-1-1056 EDN: AYGWWM
4. Штейнле А.В., Дудузинский К.Ю. Статистика боевых ранений сосудов и классификации ишемии конечности // Вопросы реконструктивной и пластической хирургии. 2007. № 3-4. С. 131–135. [Steinle AV, Duduzinsky KY. Statistics of vascular combat wounds and classifications of limb ischemia. Issues of reconstructive and plastic surgery. 2007;(3-4):131–135. (In Russ.)]. EDN: JWMEJD
5. Menakuru SR, Behera A, Jindal R, et al. Extremity vascular trauma in civilian population: a seven-year review from North India. Injury. 2005;36(3):400–406. doi: 10.1016/j.injury.2004.06.017

6. Wagner WH, Yellin AE, Weaver FA, et al. Acute treatment of penetrating popliteal artery trauma: the importance of soft tissue injury. *Ann Vasc Surg.* 1994;8(6):557–565. doi: 10.1007/BF02017412
7. De Silva W, Ubayasiri RA, Weerasinghe CW, Wijeyaratne SM. Challenges in the management of extremity vascular injuries: a wartime experience from a tertiary centre in Sri Lanka. *World J Emerg Surg.* 2011;6(1):24. doi: 10.1186/1749-7922-6-24 EDN: JLOWSX
8. Field CK, Senkowsky J, Hollier LH, et al. Fasciotomy in vascular trauma: is it too much, too often? *Am Surg.* 1994;60(6):409–411.
9. Abouezzi Z, Nassoura Z, Ivatury RR, et al. A critical reappraisal of indications for fasciotomy after extremity vascular trauma. *Arch Surg.* 1998;133(5):547–551. doi: 10.1001/archsurg.133.5.547
10. Farber A, Tan TW, Hamburg NM, et al. Early fasciotomy in patients with extremity vascular injury is associated with decreased risk of adverse limb outcomes: a review of the National Trauma Data Bank. *Injury.* 2012;43(9):1486–1491. doi: 10.1016/j.injury.2011.06.006
11. Jo D, Abbas F, Jou C, et al. Outcomes of upper-extremity revascularization following acute limb ischemia. *J Hand Surg Am.* 2025;S0363-5023(25)00443-5. doi: 10.1016/j.jhsa.2025.08.005

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