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SOFT TISSUES GUNSHOT DEFECTS ULTRASOUND INVESTIGATION USE IN RECONSTRUCTIVE-RESTORATIVE SURGERY

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During the Joint Forces operation in Eastern Ukraine the provision of surgical care modern technology treatment and rehabilitation of wounded with soft tissues gunshot defects is one of the governmental priorities. The current state of this problem characterizes by soft tissue gunshot wounds incidence increase. 34 patients with soft tissues gunshot wounds among all admitted for medical care were selected and were treated using differentiated surgical tactics using blood vessels ultrasound duplex examination. We did not register any episode of complications in patients during intra- and postoperative period of treatment. Our data revealed vessels ultrasound duplex examination high reproducibility, easiness of use during intra- and postoperative care and effectiveness. The introduction of the original differentiated surgical tactics to wounded with a multimodal approach to the soft tissues gunshot defects reconstruction helped to reduce traumatic illness complications, number of postoperative purulent-destructive and thromboembolic complications.

Key words: ultrasound, diagnostic, treatment, gunshot defects, reconstruction, surgery, new concept.

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ЗАСТОСУВАННЯ МЕТОДУ УЛЬТРАЗВУКОВОГО ДОСЛІДЖЕННЯ ВОГНЕПАЛЬНИХ ДЕФЕКТІВ М'ЯКИХ ТКАНИН У РЕКОНСТРУКТИВНО-ВІДНОВЛЮВАЛЬНІЙ ХІРУРГІЇ

В умовах проведення операції Об'єднаних Сил на сході України надання хірургічної допомоги, лікування та реабілітація поранених з вогнепальними дефектами м'яких тканин є одним із пріоритетів держави. Сучасний стан цієї проблеми характеризується збільшенням питомої ваги вогнепальних ушкоджень з дефектами м'яких тканин. З числа всіх хворих, які надійшли для надання медичної допомоги, були відібрані 34 хворі з вогнепальними пораненнями м'яких тканин, лікування яких проводилося з використанням диференційованої хірургічної тактики надання допомоги з ультразвуковим дуплексним дослідженням судин. Нами не було зареєстровано жодного епізоду ускладнення у хворих в інтра- і післяопераційному періоді лікування. Отримані результати застосування методики ультразвукового дуплексного дослідження судин виявили її високу відтворюваність, простоту застосування протягом інтра- та післяопераційного періодів, а також про її ефективність. Впровадження розробленої диференційованої хірургічної тактики надання медичної допомоги пораненим з мультимодальним підходом до реконструкції вогнепальними дефектами м'яких тканин сприяло зниженню кількості ускладнень травматичної хвороби, післяопераційних гнійно-деструктивних та тромбоемболічних ускладнень.

Ключові слова: ультразвукове дослідження, діагностика, лікування, вогнепальні поранення, реконструкція, хірургія, нова концепція.

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During the Joint Forces operation in Eastern Ukraine the provision of surgical care modern technology treatment and rehabilitation of wounded with soft tissues gunshot defects is one of the governmental priorities. The transition of all key functions of the defense forces to NATO standards, including military medicine, should be considered an important direction in the development of the Ukrainian Armed Forces [2, 4].

The current state of the problem of the organization of surgical care for the wounded with gunshot defects of soft tissues is characterized by an increase in the proportion of gunshot wounds with defects of soft tissues in the structure of combat surgical trauma (6.9–35.9 %), the significant severity and number of unsatisfactory treatment results of the wounded, the presence of a high level of complications (9.3–81.0 %) and mortality (6.3–39.3 %). The organization of surgical care in the medical support system of the Armed Forces of Ukraine is insufficiently developed and needs further improvement [1, 4].

Analysis of the quality of surgical care at the initial stage of the Anti-terrorist operation showed the lack of effectiveness of the existing system of medical care for the wounded with gunshot defects of soft tissues [3]. There is a need to improve the content and scope of medical care with the possibility of strengthening of the first and second levels in order to bring surgical care closer to the combat zone and the introduction of differentiated surgical tactics for treating this category of wounded [1, 3, 5].

All above mentioned indicates need for a special comprehensive scientific study, the essence of which is to theoretically generalize and substantiate the methodological principles of improving surgical care for the wounded with gunshot defects of soft tissues in modern combat taking into account the experience of the Joint Forces operation.

Many years of clinical experience have allowed us to carefully consider the features and benefits of non-invasive Doppler ultrasound, which is widely used in clinical medicine to obtain information about blood circulation [11]. This technique allows to clearly distinguish veins from arteries and detect various vascular pathologies, regardless of vessel diameter. It makes it possible to detect the presence of stenosis or occlusion with high accuracy and to distinguish between aneurysms or pseudoaneurysms [14]. Using this method, it is possible to study hemodynamics not only in large vessels but also in small ones with a diameter of less than 2 mm, for example, when assessing the pedicle of the free flap while performing reconstructive plastic interventions.

The purpose of the study was to determine the effectiveness of ultrasound examination in the postoperative period in patients with soft tissues gunshot wounds.

Materials and methods. Clinical examinations were performed on 342 patients with soft tissues gunshot wounds, who were treated at the South Region Military Medical Clinical Centre (SRMMCC). The wounded were randomized on 2 groups depending on the medical sorting-evacuation peculiarities. We compared the used groups and revealed their statistical identity on age, sex, type and mechanism of injury, blood loss, shock frequency and combat surgical trauma severity. We used planimetric characteristics of soft tissue gunshot defects, the universal AdTS scale and the perfusion index to assess the surgical injury severity and to determine the prognosis of survival.

34 patients with soft tissues gunshot wounds among all admitted for medical care were selected and treated in SRMMCC department of surgical infection during 2018–2020.

Differentiated surgical tactics of care with a multimodal approach to the soft tissue gunshot wounds reconstruction were used for the main group wounded treatment aimed to the operation's size and invasiveness reducing and the earliest possible evacuation to the third level of medical care.

The wounded of the control group received surgical care according to generally accepted methods, the severity of the injury was not considered. Primary surgical treatment in such patients was radical, with the excision of tissues being of questionable viability.

Doppler ultrasound examination (US) was performed according to the standard FAST protocol using an ultrasound system with linear sensor at a frequency of 7.5–10 MHz with the help of the “Logiq 500” device (“General Electric”, USA).

Three modes were used to study their legs veins: in the B-mode the diameter, lumen, presence of valves were evaluated, in the color mode – the complete staining of the vein lumen and the presence of turbulent flows were detected, in the mode of spectral Doppler – the blood flow phase was determined. Peak, mean and minimum velocities, R_i indexes and the diameter of different arteries were recorded in each study. R_i was calculated by Reynolds equation.

The recipient artery (which feeds the potential area of the skin and muscle flap to be transplanted) and, if possible, the control artery (contralateral to the recipient) were examined the day before surgery and on the 2nd, 5th and 10th postoperative days (the first period of observation), 15-30 days (second observation period) after surgery and after 3 and 6 months (third observation period), as well as whenever needed in case of suspicion of complications.

Our results were calculated statistically using statistical criteria.

Results of the study and their discussion. The color-coded duplex sonography (CCDS) we used to reproduce the anatomy of the perforant vessels of a potential free muscle-skin flap, and this method demonstrates high sensitivity and specificity of microvascular identification.

We used the standard method to assess the severity of bleeding not earlier than 20 min after the end of the formation of the anastomosis in order to give time for the arterial spasm to disappear, aiming to obtain adequate results. The effectiveness of the method and the adequacy of the acquired data are noteworthy, as neither blood pressure nor pulse rate affect the measurement results.

In all cases, after transplantation, adipose tissue tends to have a lower blood flow rate than muscle tissue. The hemodynamic pattern was similar in the flaps containing a large number of muscles (muscle, muscle-skin-muscle): the blood flow increased intraoperatively after the formation of the anastomosis, most likely due to a decrease in vascular resistance, which is associated with muscle retention.

In 5 cases, the features of body soft tissue damage and the clinics required us to use free flaps together with vascular shunting on the same lower limb – it is especially important to consider that microvascular transfer can regulate the flow of the recipient artery, leading to the redistribution of the blood flow.

The average intraoperative value of the blood flow in the venous graft of the operated area increases by approximately 50 % after the transplantation of the free flap, because the transplantation of the denervated muscle reduced the vascular resistance of the graft.

Here are some successful clinical cases of using a color duplex system to assess the functional status of implanted soft tissue flaps in order to cover the defect that occurred in the case of gunshot wounds of the right shin in patient P. (fig. 1).



Fig. 1. Patient P., a ‘propeller’ on the shin as the result of gunshot blind shrapnel wound of the external ankle, which, being untreated, provoked a gunshot osteomyelitis of the right shin external ankle with a flaccid-granulating wound on the external surface of the right shin lower third. **A:** The 21st day from the moment of injury. The local status of the wound after the admission to the SRMMC Surgical Infection Department. **B and C:** Peri- and intraoperative preparatory moments. Flap fixation (fragment B) and lifting (fragment C) for subsequent complex treatment. **D:** The 10th day after operation. The surface of the wound is dry, clean, the sutures are adapted. The wound heals by primary intention.

Doppler ultrasonography was done on the surface of the displaced tissue flap. We used Doppler imaging to assess the skin flap velocities characteristics which confirm the correct execution of the displaced tissues. (fig. 2). The integration of the displaced tissues into the defect zone has also been demonstrated.

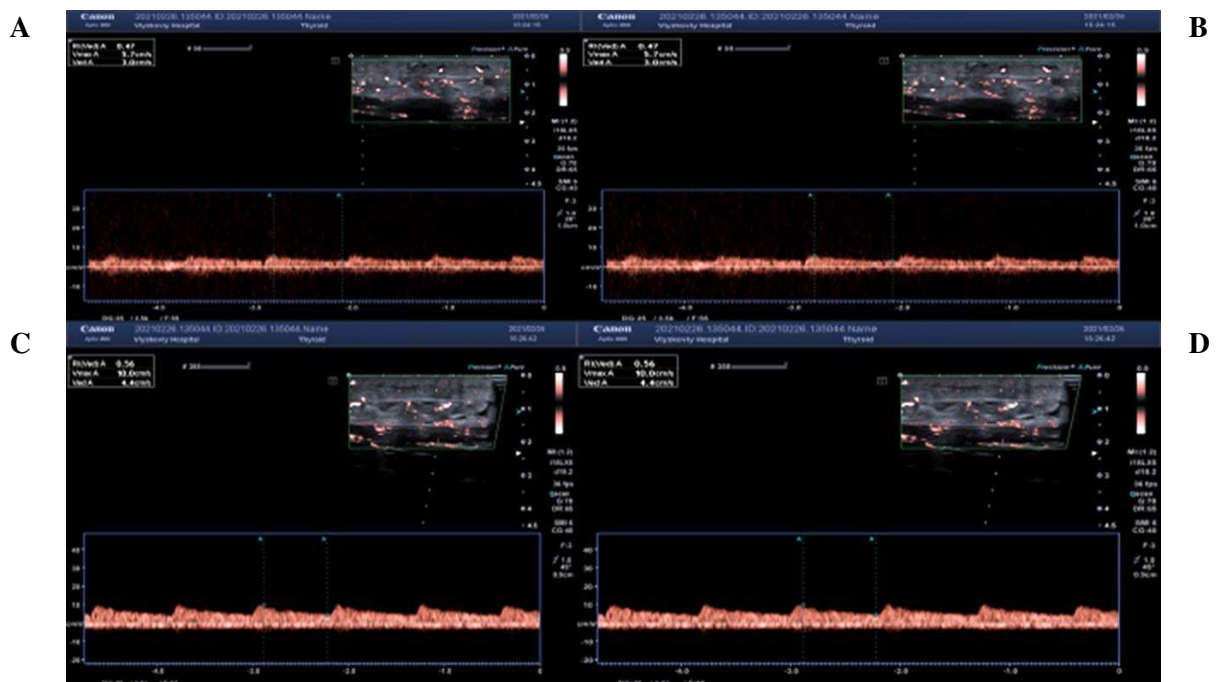


Fig. 2. Ultrasonic microvascular imaging using real-time CDS in high image quality of the patient P left (boxes A and C) and right (boxes B and D) legs. **A and C:** Left leg Doppler ultrasonography at the level of the middle and lower third of the left shin frontal surface. **B and D:** Right leg Doppler ultrasonography at the level of the middle and lower third of the left shin frontal surface.

One could see the equality of the bloodflow velocities indexes using the obtained Doppler ultrasonography visualizations of both lower extremities at the indicated level.

Another difficult case with the original method of treatment we used in the treatment of left limb gunshot wounds in soldier S. Figure 3 shows an illustrated view of a specific successful clinical case of the use of a color duplex system to assess the functional status of the implanted soft tissue flaps in this patient.

Only moderate hypertrophy was observed in this patient 10 months after surgery.

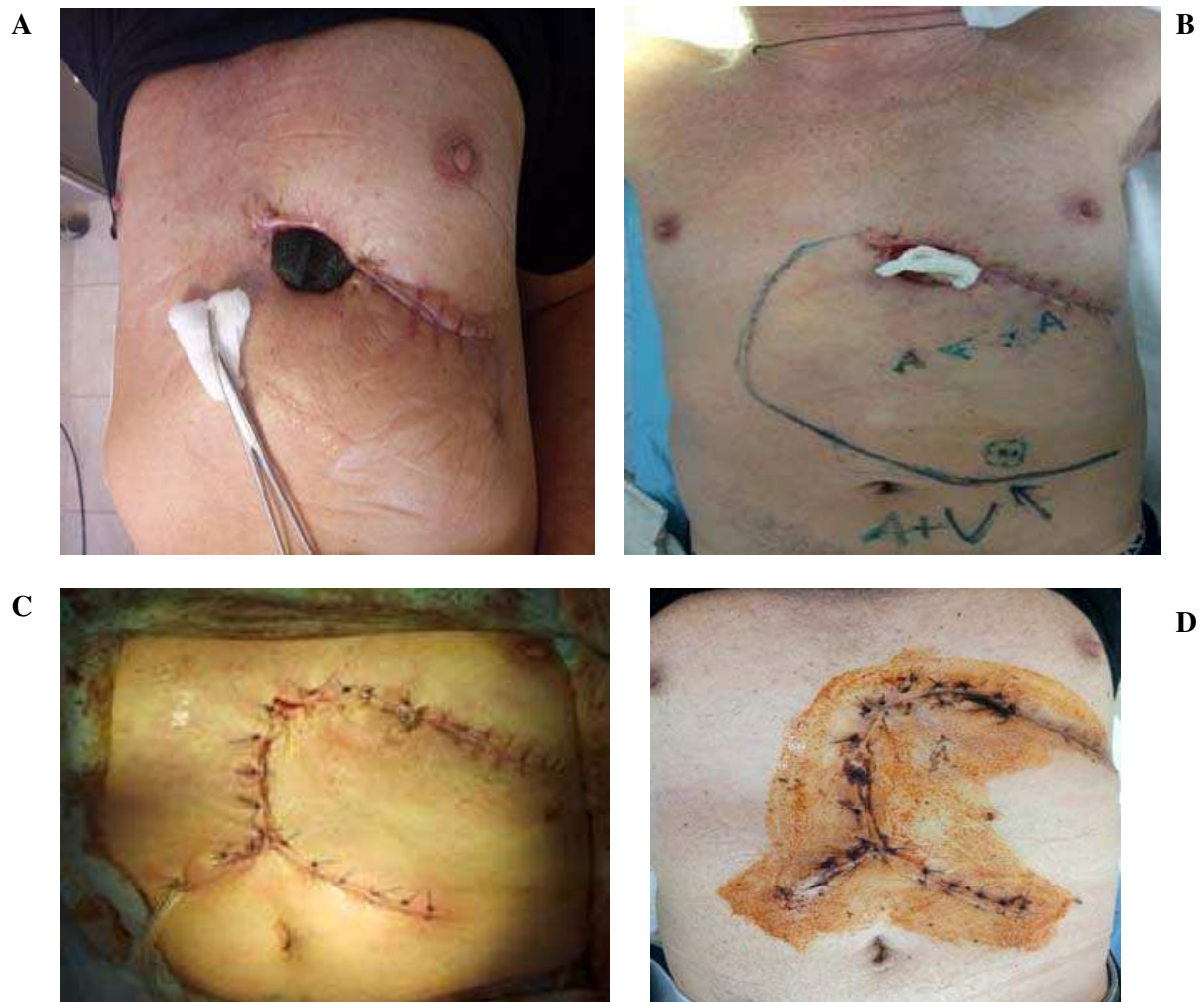


Fig. 3. Patient's S. successful treatment using color duplex sonography. Diagnosis: Gunshot, blind, non-penetrating shrapnel wound of the chest left side frontal surface. Gunshot osteomyelitis of the 6th rib along the parasternal line with a soft tissue defect. **A:** The 30th day from the moment of injury. The local status of the wound after the admission to the SRMMCC Surgical Infection Department. **B:** CCDS of the frontal abdominal wall soft tissues to identify the perforating vessels and the measure the size of the donor flap. **C:** The 1st day after the operation. The state of the wound. The sutures are adapted, the postoperative wound heals without signs of inflammation by primary intention over the whole area. **D:** The 10th day after the operation. The wound is dry and clean. The sutures are adapted. The wound healed by primary intention.

Hence, we proposed and implemented tactics of individual surgical treatment of soft tissues gunshot wounds with various technological support of intra- and postoperative periods in accordance with the multimodal approach to the reconstruction of the gunshot defects of soft tissues, which allowed to improve the definition of medical and evacuation purposes of the wounded with combat surgical trauma.

We did not register any episode of complications in 34 patients with gunshot wounds of soft tissues during intra- and postoperative period of treatment using the technique of vessels ultrasound duplex examination.

The analysis of the results of the method of the ultrasound duplex examination of vessels of this contingent of patients convincingly shows its high reproducibility, ease of use under operating conditions and postoperative supervision, as well as its effectiveness in the case of complex application at the third level of specialized care.

Despite the high rates of successful reconstructive plastic surgery using free flaps (95–99 %), the problem of non-functioning or thrombosis of anastomoses [9, 12] still exists, and although free

microvascular flaps are regularly used in reconstructive surgery, our knowledge of perioperative changes in blood flow in the free skin and muscle flaps remains limited.

Moreover, the effect of the free flap on blood flow parameters in the recipient vessel is also insufficiently studied. Until recently, few methods of studying intraoperative blood flow in free skin and muscle flaps were available [4, 13]. But with the advent of Doppler ultrasound, the situation has changed radically.

Our results are comparable with the clinical data [7], in which the quantitative parameters of blood flow of perforating vessels were presented. It was shown that the blood velocity in the perforating artery is higher than the one detected in the main vascular bed [8, 12]. Some effects of increased blood flow velocity in these microvessels and the subordinate zone of cutaneous flap microcirculation have also been studied [8], although standard control values have not yet been established. Our results allow us to propose further measurement values of the diameter, PSV, EDV and RI as the representative parameters of size and hemodynamics, which can be used for initial assessment [10, 11]. However, larger prospective studies are needed to establish generally accepted reference values for controlled CCDS selection of appropriate microvessels.

By adequately adjusting the device mode, the standard color coding mode that we used simplifies the detection and evaluation of perforating microvessels in the deep fascia and makes quantitative measurements possible. The use of PD mode increases the sensitivity by 3-5 times compared to CF mode [15] and reflects the intensity and speed of the blood flow with a significant increase. However, the differentiation of the artery and the vein in this situation is impossible, and the signals of the extravascular flow around the detected perforators are usually superimposed, which prevents a realistic assessment of the diameter of the vessel, despite the fact that it increases the sensitivity of the device for microvessel detection.

However, our study regimen is likely to lead to further overestimation of hemodynamic parameters of microvessels that are too small, which may not be suitable for the supply of large angiosomes. This finding has also been described in the context of microvascular mapping in the modeling of free flaps [10]. Due to the specific settings of the low-flow detection device, the PD mode has lost its past advantage concerning the visualization of microvessels, as the CF mode now works more reliably in this regard.

Actually, regarding the analysis of our previous data [5, 6], the introduction of the developed differentiated surgical tactics of medical care for the wounded with a multimodal approach to the reconstruction of soft tissue gunshot defects helped to reduce the proportion of traumatic disease complications by 41.1 % ($p < 0.01$), the share of postoperative complications (twice, from 48.6 % to 21.3 %, $p < 0.01$), purulent-destructive – from 21.5 % to 14.3 % ($p < 0.05$) and thromboembolic complications – from 2.3 % to 0.9 % ($p < 0.01$), as well as a significant reduction in the duration of inpatient treatment by 9.3 ± 2.5 bed-days ($p < 0.05$). Our data show that the introduction of differentiated surgical tactics of medical care to this group of patients allowed to reduce mortality from 12.1 % to 8.6 % ($p < 0.05$), which allowed to recommend its introduction in health care facilities. At the same time, the results of treatment and rehabilitation of servicemen got significantly improved by reducing the number of wounded who were discharged from the Armed Forces of Ukraine due to health issues (57.4 % to 31.3 %) and increased the proportion of the wounded who were returned to the military. parts (from 42.6 % to 68.7 %; $p < 0.05$).

Conclusions

1. The tactics of individual surgical treatment of gunshot wounds of soft tissues with various technological support of intra- and postoperative periods according to the multimodal approach to reconstruction of gunshot defects of soft tissues was offered and implemented, which allowed to improve the definition of medical and evacuation appointment of the wounded with combat surgical trauma.

2. In all treated patients with gunshot wounds of soft tissues, in the intra- and postoperative period of treatment of which the technique of ultrasound duplex examination of vessels was used, no episode of complications was registered.

3. The results of the method of ultrasound duplex examination of vessels of this group of patients convincingly demonstrated its high reproducibility, ease of use under operating conditions and postoperative supervision, as well as its effectiveness in the case of comprehensive use at the third level of specialized medical care for the wounded.

4. The introduction of the developed differentiated surgical tactics of medical care for the wounded with a multimodal approach to the reconstruction of soft tissue defects helped to reduce the proportion of complications of traumatic illness, the proportion of postoperative complications, purulent-destructive and thromboembolic changes.

5. The obtained data show that the introduction of differentiated surgical tactics of medical care to this contingent of patients allowed to reduce mortality from 12.1% to 8.6% ($p < 0.05$), which allowed to recommend its introduction in health care facilities.

Prospects for further researches include a comprehensive laboratory and clinical investigation of reconstructive-restorative tactics of treatment efficacy in patients with soft tissues gunshot wounds with the greatest emphasis on early diagnosis and effective restorative therapy.

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