Ultrasonic Tissue Characterization of Damage of the Lower Extremities in Gunshot Wounds

Rizvan Ya Abdullaiev1*, Elena I Grechanyk2, Faina I Kulikova3, Natalia A Cherednichenko3, Yuri A Demin1 and Maxim A Golyanischev1

1Kharkiv Medical Academy of Postgraduate Education, Ukraine
2National Military Medical Clinical Center of Ukraine, Ukraine
3Dnepropetrovsk Medical Academy, Ukraine

*Corresponding Author: Rizvan Ya Abdullaiev, Department of Ultrasound Diagnostics, Kharkov Medical Academy of Postgraduate Education, Ukraine.

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Abstract
Background: During the antiterrorist operation (ATO) in the east of Ukraine gunshot extremities injuries level was estimated as 58%. Damage to soft tissues always accompanies battle injuries of the limbs. Ultrasound allows in the patient with multi-trauma provide immediate bedside diagnosis and assessment of a range of injuries and guide management.

Objective: Evaluate the possibilities of complex ultrasonography in the diagnosis of soft tissue injuries of extremities with gunshot wounds.

Material and Methods: An analysis of the results of complex ultrasonography in the diagnosis of the nature of soft tissue injuries of the extremities in 132 patients. All patients received gunshot wounds to the extremities. Their age varied within the limits of 19 - 56 years, on the average 30.8 ± 13.7 years. The following types of gunshot injuries were studied: ballistic wounds, shell fragment wounds, mines and explosive wounds.

Results: The total number of gunshot injuries with a single localization was 103 (58.5 ± 3.7%), with multiple localization - 73 (41.5 ± 3.7%) (P < 0.01). Single gunshot shin injuries (23.3 ± 3.2%) occurred significantly (P < 0.05) more often than multiple (13.1 ± 2.5%). Ballistic injuries were in 43 (24.4%) cases; gunshot shell fragment injuries - 113 (64.2%); mines and explosives injuries - 20 (11.4%) cases respectively.

The nerves damage was observed in 21 (11.9 ± 2.4%) cases, the vessels - in 24 (13.6 ± 2.6%) cases and the other soft tissues - in 131 (74.5 ± 3.3%) cases (P < 0.001), respectively. By the type of tissue damage, 17 patients had soft tissue injuries with hematomas. Damage to great vessels was diagnosed in 13 (7.4 ± 2.0%) cases, 7 of them was damages to main artery; 6 was damages to veins.

Conclusions: Ultrasonography can be used not only as a screening, but also as the main method for diagnosing gunshot injuries to soft tissues of extremities, in particular the main vessels and peripheral nerves.

Keywords: Gunshot Wounds; Soft Tissue of the Extremities; Ultrasound Diagnostics
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Introduction

Literary evidence suggests that more people die from gunshot wounds than from road accidents or sports injuries. In 2003, according to statistics, 30,136 people were fatally wounded by firearms, representing 18.4% of all trauma deaths [1].

According to the etiology of the trauma, gunshot wounds can be gunshot with bullets, gunshot shard and mine explosives [2].

Gunshot wounds received in the armed conflict zone in the east of Ukraine during anti-terrorist operation (ATO) account for the following: head (13.2%), neck (4.5%), spine (2.6%), chest (8%), abdominal (3%), pelvis (6.5%), burns (4%), extremities (58%) [3].

Gunshot wounds of soft tissues are accompanied by damage to the skin, muscles, nerves, arterial, venous and lymph vessels [4,5].

The extent of tissue/organ damage depends on a wide variety of factors. The extent of surgery appropriate for limb wounds agreed on at the Inter-Allied Surgical Conference in 1917 included excision of the skin margin, generous extension of the wound, exploration through all layers, and excision of damaged muscle [6].

Ultrasonography (US) makes it possible to assess in an emergency cases the nature of a gunshot wound to a extremity [7]. US is commonly used to assess the soft tissue of the extremities. The most obvious advantages over MR imaging are superior soft-tissue resolution, low cost, portability, lack of magnetic susceptibility artifact, and the ability to image patients who cannot undergo MR imaging. Additional benefits are the capability of real-time and dynamic imaging, and the ability to scan an entire extremity quickly without the need for a patient to lie motionless for long periods of time, as with MR imaging. Any abnormal findings can be easily compared against the contralateral side [8]. Ultrasound evaluation allows evaluation of nerve damage and contributes to early diagnosis and treatment of surgical nerve damage [9].

Objective

Evaluate the possibilities of complex ultrasonography in the diagnosis of soft tissue injuries of extremities with gunshot wounds.

Material and Methods

An analysis of the results of complex ultrasonography in the diagnosis of the nature of soft tissue injuries of the extremities in 132 patients (The total number of injuries is 176) with various types of gunshot wounds was performed. In 103 patients one lesion localization was registered, in 29 several. All patients were participated in the armed conflict during antiterrorist operation in the Eastern Ukraine. They received gunshot wounds to the extremities. Their age varied within the limits of 19 - 56 years, on the average 30.8 ± 13.7 years. The following types of gunshot injuries were studied: ballistic wounds, shell fragment wounds, mines and explosive wounds. The most frequent localization of gunshot injuries of soft tissues were: shin, thigh, foot, shoulder and forearm. The nature of injuries of muscles, peripheral nerves, arterial and venous vessels was studied. We used Gray-scale ultrasonography, Doppler ultrasonography to study anatomical integrity, acuity of contours, structure, and condition of surrounding tissues. We analyzed anatomical channel condition and topographic zones, hematomas of surrounding tissues, foreign bodies (shells, bullets, metal fragments). The results of ultrasonography and MRI were compared.

The frequency of occurrence of various types of injures were determined using the methods of variation statistics for the computer program “Statgraphics” version 3.0 (USA) and “Microsoft Excel” version 5.0 (USA).

Results

The total number of injuries, considering multiple and combined, totaled to 176 in 132 patients (Table 1).
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In 103 patients, gunshot damage had one localization, and in 29 patients - multiple localizations. The total number of gunshot injuries with a single localization was 103 (58.5 ± 3.7%), with multiple localization - 73 (41.5 ± 3.7%) (P < 0.01). The total number of single gunshot injuries of the shin was 23.3 ± 3.2%, multiple - 13.1 ± 2.5% (P < 0.05). For the hip, these parameters were 19.9 ± 3.0% and 12.5 ± 2.5%; for the foot - 5.1 ± 1.7% and 8.0 ± 2.0%; for the shoulder - 4.0 ± 1.5% and 4.5 ± 1.7%; for the forearm - 6.2 ± 1.8% and 3.4 ± 1.4% respectively.

Distribution of injuries depending on the nature of gunshot wounds is presented in table 2. Ballistic wounds were in 43 (32.6%) patients (43 injuries, 24.4 ± 3.2%); gunshot shell fragment wounds in 78 (59.1%) patients (113 injuries, 64.2 ± 3.6%); mines and explosives wounds in 11 (8.3%) patients (20 injuries, 11.4 ± 2.4%).

Distribution of injuries depending on the nature of tissue structure is presented in table 3. The nerves damage was observed in 21 (11.9 ± 2.4%) cases, the vessels - in 24 (13.6 ± 2.6%) cases and the other soft tissues - in 131 (74.5 ± 3.3%) cases (P < 0.001), respectively. By the type of tissue damage, 17 patients had soft tissue injuries with hematomas. Metallic foreign bodies appear hyperechoic on ultrasound with acoustic shadow or comet tail artifact. Comet tail artifacts are characteristic bands of increased echogenicity deep to the object due to reverberation (Figure 1 and 2).

Table 1: Patient distribution depending on the number of wounds and their localizations in the lower extremities.

<table>
<thead>
<tr>
<th>Location of injuries to the lower extremities</th>
<th>The patients with one injuries locations</th>
<th>The patients with multiple injuries locations</th>
<th>Total number of patients and injuries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shin</td>
<td>n = 103</td>
<td>n = 29</td>
<td>n = 132</td>
</tr>
<tr>
<td></td>
<td>41 (23.3 ± 3.2%)</td>
<td>23 (13.1 ± 2.5%)</td>
<td>64 (36.4 ± 3.6%)</td>
</tr>
<tr>
<td>Thigh</td>
<td>35 (19.9 ± 3.0%)</td>
<td>22 (12.5 ± 2.5%)</td>
<td>57 (32.4 ± 3.5%)</td>
</tr>
<tr>
<td>Foot</td>
<td>9 (5.1 ± 1.7%)</td>
<td>14 (8.0 ± 2.0%)</td>
<td>23 (13.1 ± 2.5%)</td>
</tr>
<tr>
<td>Shoulder</td>
<td>7 (4.0 ± 1.5%)</td>
<td>8 (4.5 ± 1.7%)</td>
<td>15 (8.5 ± 2.1%)</td>
</tr>
<tr>
<td>Forearm</td>
<td>11 (6.2 ± 1.8%)</td>
<td>6 (3.4 ± 1.4%)</td>
<td>17 (9.6 ± 2.2%)</td>
</tr>
<tr>
<td>The total number of injuries (n/%)</td>
<td>103 (58.5 ± 3.7%)</td>
<td>73 (41.5 ± 3.7%)</td>
<td>176 (100.0%)</td>
</tr>
</tbody>
</table>

Table 2: Patient distribution depending on the nature of gunshot wounds.

<table>
<thead>
<tr>
<th>The localization of structure injuries</th>
<th>Ballistic wounds</th>
<th>Gunshot shell fragment wounds</th>
<th>Mines and explosives wounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>The number of patients</td>
<td>n = 43</td>
<td>n = 78</td>
<td>n = 11</td>
</tr>
<tr>
<td>The number of injuries</td>
<td>43 (24.4 ± 3.2%)</td>
<td>113 (64.2 ± 3.6%)</td>
<td>20 (11.4 ± 2.4%)</td>
</tr>
</tbody>
</table>

Table 3: The injuries distribution depending on the nature of tissue structure.

Damage to great vessels was diagnosed in 13 (7.4 ± 2.0%) cases, 7 of them was damages to main artery (shoulder - 1, radial - 1, ulnar - 1, femoral - 1, tibial - 3, popliteal - 1); 6 was damages to veins (great saphenous vein thrombosis - 2; superficial femoral vein thrombosis - 2; sural vein thrombosis - 1, popliteal vein thrombosis - 1). Concussion of great vessels causes thrombosis of vein segments. All forms of blood vessels traumas and compression result in thrombosis with full or partial blocking (Figure 3-6).
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Figure 3: Torn mine-explosive wound of soft tissues of the proximal part of the thigh.

Figure 4: The same case. Ultrasonogram of flotation thrombus in deep femoral vein (arrow).

In 21 (11.9 ± 2.4%) cases experienced damage to nerves: radial - 4, sciatic - 9, peroneal - 3, tibial - 2, ulnar - 2, axillary - 1. The main ultrasound signs of damage to the peripheral nerves were a local disturbance of the nerve architectonics with its disintegration, partial or total absence of the image in the projection of the wound channel (Figure 7 and 8).

**Figure 5:** Shell fragment shoulder injuries. Thrombosis of brachial artery (arrows). Modified Doppler blood flow in the brachial artery.

**Figure 6:** Normal Doppler spectrum of blood flow on the opposite brachial artery. Arrows show anechoic lumen of the brachial artery.

Distribution of injuries depending on the nature of wound channel is presented in table 4. The extent of tissue/organ damage depends on a wide variety of factors including the bullet’s or gunshot shell fragment diameter, as well as its shape, velocity and weight [10]. Wounds are generally classified as low velocity (less than 609.6 m/s) or high velocity (more than 609.6 m/s). Those with higher velocity may be expected, on this basis, to dissipate more energy into surrounding tissue as they are slow and cause more tissue damage. However, more important than velocity is the efficiency of energy transfer, which is dependent on the physical characteristics of the projectile, as well as the kinetic energy, stability, entrance profile and path traveled through the body, and the biological characteristics of the tissues injured [11]. By nature of wound channel blunt wounds were in 106 patients (60.2 ± 3.7%); penetrating wounds in 61 patients (34.7 ± 3.6%); gutter wounds in 9 patients (5.1 ± 1.7%). The contours of shell fragment wounds are often irregular in shape (Figure 9).
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**Discussion**

Fragment wounds occupy the leading place among all types of gunshot wounds of the limbs. It is known that gunshot wounds, as a rule, are accompanied by damage to all structures of soft tissues - muscles, nerves, blood and lymphatic vessels. Early diagnosis of the nature of damage to the structures of the soft tissues of the limbs is important for the choice of treatment tactics. Only a visual assessment of the area of the wound does not allow the identification of deep-lying lesions. Among the methods of early diagnosis, ultrasonography is the most appropriate and informative. Ultrasonography can be performed at the patient’s bedside, especially in the non-transportable. Previously published works show the possibilities of the method mainly in assessing the size of the hematoma and damage to large vessels [12,13].

In the article Wani ML and others (2012) shows the results of dopplerography in assessing the nature of vascular injury due to blunt trauma in a road traffic accident [14].

Peripheral nerve injuries (PNI) sustained in combat are typically severe and are frequently associated with marked soft tissue damage, anatomic distortion, and retained metallic fragments. These features complicate clinical and electrodiagnostic assessment and may preclude MRI [4,15].

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**Table 4: The injuries distribution depending on the nature of wound channel.**

<table>
<thead>
<tr>
<th>Wound Type</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blunt wounds</td>
<td>106 (60.2 ± 3.7%)</td>
<td>61 (34.7 ± 3.6%)</td>
<td>9 (5.1 ± 1.7%)</td>
</tr>
<tr>
<td>Penetrating wounds</td>
<td>1-2 &lt; 0.001</td>
<td>2-3 &lt; 0.001</td>
<td></td>
</tr>
<tr>
<td>Gutter wounds</td>
<td>1-3 &lt; 0.001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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**Figure 9: Mine-explosive injuries to the lower extremities: penetrating wound channel (arrow). Contours of a wound of irregular shape.**

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In our study in the B-mode, we evaluated the anatomical integrity, the sharpness of the contours, the structure, the state of the surrounding tissues. We analyzed the wound channels in the wounded, the hematomas of surrounding tissues, foreign bodies (shells, bullets, metal fragments), rupture of peripheral nerves. In the regime of color and spectral Doppler, we diagnosed thrombosis of venous and arterial vessels.

**Conclusions**

Ultrasonography can be used not only as a screening, but also as the main method for diagnosing gunshot injuries to soft tissues of extremities, in particular the main vessels and peripheral nerves.

**Conflict of Interest**

The authors declared no potential conflict of interest with respect to the research, authorship, and/or publication of this article.

**Bibliography**


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