ECRONICON OPEN ACCESS

EC NEUROLOGY
Research Article

Ultrasonography in the Diagnosis of Gunshot Injuries of the Neurovascular Bundle of the Extremities

Rizvan Ya Abdullaiev[1]*, Elena I Grechanyk[2], Faina I Kulikova[3], Alexander N Khvisiuk[1], Natalia A Cherednichenko[3] and Alexandra V Kogut[1]

[1]Kharkiv Medical Academy of Postgraduate Education, Ukraine

[2]National Military Medical Clinical Center of Ukraine, Ukraine

[3]Dnepropetrovsk Medical Academy, Ukraine

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

Received: July 31, 2018; **Published:** October 26, 2018

Abstract

Introduction: In all military operations, injuries of the limbs predominate, which account for about half of all injuries. The presence of a close relationship between the large arterial, venous, bone and nervous structures of the limbs leads to the fact that often the vessels and nerves are traumatized in combination. Such injuries are the main factor determining the long-term functional morbidity in patients receiving gunshot wounds to the extremities, despite the successful treatment of vascular and orthopedic injuries.

Aim: Evaluate the possibilities of complex ultrasound in the diagnosis of damage to the neurovascular bundle of extremities with gunshot wounds.

Material and Methods: An analysis of the results of complex ultrasonography in the diagnosis of the 63 vessels and 51 nerves damages of the extremities in 183 patients (The total number of injuries is 234). All patients received gunshot wounds to the extremities. Their age varied within the limits of 23 - 54 years, on the average 31,4 ± 12,9 years. Ultrasonography (USG) was conducted on a Philips HD 11XE device using a convection transducer in the frequency range 2-5 MHz; MRI - General Electric, Signa HDI, 1.5T.

Results: Gunshot injuries of the lower extremities at the level of the lower limb (179 cases, 76.5 ± 2.8%) were recorded significantly more often (P < 0.001) than at the level of the upper limbs (55 cases, 23.5 ± 2.8%). The greatest number of injuries occurred on the shin (64 cases, 27,4 ± 2,9%), then the thigh (54 cases, 23,1 ± 2,7%) and feet (23 cases, 9,8 ± 1,9%), respectively. At the femoral level, the nerves were significantly more often damaged (31,4 ± 6,5% vs 14,3 ± 4,4%, P < 0,05) and at the level of the shin - the vessels (20,6 ± 5,1% vs 7,8 ± 3,8%, P < 0,05). Isolated arterial damage was recorded in 13 (20,6 ± 5,1%) cases, veins - in 19 (30,2 ± 5,8%) cases, combined - in 31 (49,2 ± 6,3%) cases (P < 0,05 and P < 0,001), respectively.

Among all types of vascular disorders, thrombosis was most often recorded (41 cases, 65.1 ± 6.0%). Venous thromboses were observed more often than arterial thromboses. Injury to the intima of the artery leads to thrombosis for a period of time that causes partial or complete occlusion of the vessel. Pseudoaneurysms were observed more often than true aneurysms.

The peripheral nerves of the lower limbs were damaged much more often than of the upper limbs (68,6 ± 6,5% vs 31,4 ± 6,5%; P < 0,001). Among all the nerves of the limbs, the sciatic nerve was much more often damaged.

The diagnostic value of ultrasonography and MRI was compared in 39 patients undergoing surgical treatment. Ultrasound detected lesions more frequently than MRI: sensitivity 93,9% vs 88,2%; specificity 83,3% vs 60%. Ultrasound was accurate in more cases than MRI 92,3% vs 84,6%. The difference between them was not statistically significant.

Conclusion: Ultrasonography with dopplerography can be used as the main method for diagnosing gunshot injuries of the main vessels and peripheral nerves of the extremities. In the diagnosis of traumatic injuries of peripheral nerves, ultrasound has the advantage over MRI - in sensitivity, specificity and accuracy (93,9% vs 88,2%; 83,3% vs 60%; 92,3% vs 84,6%).

Keywords: *Gunshot Wounds; The Neurovascular Bundle of the Extremities; Ultrasound Diagnostics*

Introduction

In all military operations, injuries of the limbs predominate, which account for about half of all injuries. The presence of a close relationship between the large arterial, venous, bone and nervous structures of the limbs leads to the fact that often the vessels and nerves are traumatized in combination. Such injuries are the main factor determining the long-term functional morbidity in patients receiving gunshot wounds to the extremities, despite the successful treatment of vascular and orthopedic injuries [1-3].

During the anti-terrorist operation (ATO) in the east of Ukraine, gunshot lesions of nerve trunks in 35-37% were combined with wounds of the vessels of the extremities [4]. Most vascular traumas in military conflicts occur from fragments from ballistic weaponry such as artillery, rockets, grenades, and bombs. The development of high velocity weapons (such as artillery) cause massive tissue destruction [5,6].

Vascular injuries can be divided into following groups: Spasm, Thrombosis, Contusion/Intimal flap, Laceration/Transection, A-V (arteriovenous) fistula, Aneurysm and Pseudoaneurysm, Arterial emboli [7]. Patients with penetrating extremity vascular injury and hard clinical signs should undergo immediate surgery. If the arterial injury needs to be localized, on-table arteriogram in the operating room or in a hybrid suite is performed. Computed tomographic angiography can also be used if patient's condition permits to evaluate extremity vascular injury [8].

Penetrating injuries of the upper and lower limbs can cause a wide variety of complex injuries depending on the penetrating energy transferred to the tissue. Severe injuries occur more often in a military setting and are accompanied by combined damage to soft tissues, bones, vessels and nerves of the limbs are common [9].

In the upper extremity, penetrating trauma mechanism is most common (73%) and the majority of patients (78%) suffer concomitant upper extremity injuries with soft tissue and nerve injuries being most prevalent [10]. The most common anatomic location of penetrating trauma is the superficial femoral artery followed by the popliteal and common femoral arteries. Penetrating mechanism of injury is about 80% in the common and the superficial femoral arteries. The mechanism of popliteal artery injury is penetrating in 39 - 51% of patients, and gunshot injuries dominate. Few penetrating injuries (7%) present with severe concomitant trauma compared to blunt popliteal injury (74%) which is associated with higher amputation rates [11,12].

Electrophysiological methods remain the most common for diagnosing the pathology of the peripheral nervous system, but unlike them, USG makes it possible to evaluate anatomical changes in nerve trunks (rupture, cicatricial degeneration) [13,14].

Early diagnosis and treatment is crucial for saving the patient 's limb and life.

Ultrasonography (US) makes it possible to assess in an emergency cases the nature of a gunshot wound to a extremity. 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 [15].

Objective of the Study

Evaluate the possibilities of complex ultrasound in the diagnosis of damage to the neurovascular bundle of extremities with gunshot wounds.

Material and Methods

An analysis of the results of complex ultrasonography in the diagnosis of the nature of vessels and nerves injuries of the extremities in 183 patients (The total number of injuries is 234) with various types of gunshot wounds was performed. The total number of damaged vessels was 63, nerves - 51. 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 23 - 54 years, on the average 31,4 ± 12,9 years. Gunshot wounds were ballistic, fragmentation and mine explosive. The nature of injuries of 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. The ultrasound and MRI results with diagnoses of nerves damage determined by the surgical were compared.

Ultrasonography (USG) was conducted on a Philips HD 11XE device using a convection transducer in the frequency range 2-5 MHz; MRI - General Electric, Signa HDI, 1.5T.

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 SO (USA).

Results

Among the injured 183 patients from gunshot wounds, the total number of injuries was 234. As shown in table 1, gunshot injuries of the lower extremities at the level of the lower limb (179 cases, 76.5 ± 2.8%) were recorded significantly more often ($P < 0.001$) than at the level of the upper limbs (55 cases, 23.5 ± 2.8%). The greatest number of injuries occurred on the shin (64 cases, 27,4 ± 2,9%), then the thigh (54 cases, 23,1 ± 2,7%) and feet (23 cases, 9,8 ± 1,9%), respectively.

Location of injuries to the lower extremities		**Total number of injured (n = 234)**
Lower limb n=179 76,5 ± 2,8% P < 0,001	Hip Joint	11 (4,7 ± 1,4%)
	Thigh	54 (23,1 ± 2,7%)
	Knee-joint	15 (6,4 ± 1,6%)
	Shin	64 (27,4 ± 2,9%)
	Ankle joint	12 (5,1 ± 1,4%)
	Foot	23 (9,8 ± 1,9%)
Upper limb n=55 23,5 ± 2,8%	Shoulder joint	11 (4,7 ± 1,4%)
	Shoulder	14 (6,0 ± 1,5%)
	Elbow joint	9 (3,8 ± 1,2%)
	Forearm	15 (6,4 ± 1,6%)
	Hand	6 (2,6 ± 1,0%)

Table 1: *Damage to tissue, vessels and nerves of the lower extremities according to the level of these anatomic location with gunshot wounds.*

Table 2 presents data on damage to blood vessels and peripheral nerves at each anatomical level of the lower and upper extremities. It can be seen from the table that at the femoral level, the nerves were significantly more often damaged (31,4 ± 6,5% vs 14,3 ± 4,4%, P < 0,05) and at the level of the shin - the vessels (20,6 ± 5,1% vs 7,8 ± 3,8%, P < 0,05).

Location of injuries to the lower extremities	**Total number of injured vessels**	**Total number of injured nerves**
	n = 63	**n = 51**
Hip Joint	2 (3,2 ± 2,2%)	2 (3,9 ± 2,7%)
Thigh	9 (14,3 ± 4,4%)	16 (31,4 ± 6,5%) P < 0,05
Knee-joint	9 (14,3 ± 4,4%)	7 (13,7 ± 4,8%)
Shin	13 (20,6 ± 5,1%) P < 0,05	4 (7,8 ± 3,8%)
Ankle joint	4 (6,3 ± 3,1%)	3 (5,9 ± 3,3%)
Foot	4 (6,3 ± 3,1%)	3 (5,9 ± 3,3%)
Shoulder joint	3 (4,8 ± 2,7%)	2 (3,9 ± 2,7%)
Shoulder	6 (9,5 ± 3,7%)	5 (9,8 ± 4,2%)
Elbow joint	2 (3,2 ± 2,2%)	3 (5,9 ± 3,3%)
Forearm	9 (14,3 ± 4,4%)	5 (9,8 ± 4,2%)
Hand	2 (3,2 ± 2,2%)	1 (2,0 ± 2,0%)

Table 2: *Damage to tissue, vessels and nerves of the lower extremities according to the level of these anatomic location with gunshot wounds.*

Isolated arterial damage was recorded in 13 (20,6 ± 5,1%) cases, veins - in 19 (30,2 ± 5,8%) cases, combined - in 31 (49,2 ± 6,3%) cases (P < 0,05 and P < 0,001), respectively (Table 3).

The following types of vascular disorders were identified as a result of gunshot wounds of the extremities (Table 4): spasm, thrombosis, intimal flap, transaction, arteriovenous fistula, aneurysm, pseudoaneurysm and arterial emboli. Among all types of vascular disorders, thrombosis was most often recorded (41 cases, 65.1 ± 6.0%). Venous thromboses were observed more often than arterial thromboses.

Injury to the intima of the artery leads to thrombosis for a period of time that causes partial or complete occlusion of the vessel (Figures 1-4). Pseudoaneurysms were observed more often than true aneurysms. A true aneurysm contains all layers of vessel wall (intima, media and adventitia) and may be rarely produced by trauma (Figure 5).

Arteries	Veins	Arteries + Veins
n = 13	n = 19	n = 31
20,6 ± 5,1%	30,2 ± 5,8%	49,2 ± 6,3% P < 0,05 P < 0,001

Table 3: *The injuries distribution of vessels of extremities with gunshot wounds.*

Type of vascular injury	Total number of Vessels injuries (n = 63)
Spasm	6 (9,5 ± 3,7%)
Thrombosis	41 (65,1 ± 6,0%) P < 0,001
Intimal flap	4 (6,3 ± 3,1%)
Transection	2 (3,2 ± 2,2%)
Aneurysm	1 (1,6 ± 1,6%)
Pseudoaneurysm	4 (6,3 ± 3,1%)
Arterial emboli	3 (4,8 ± 2,7%)
Arteriovenous fistula	2 (3,2 ± 2,2%)

Table 4: *Type of vascular injury of extremities with gunshot wounds.*

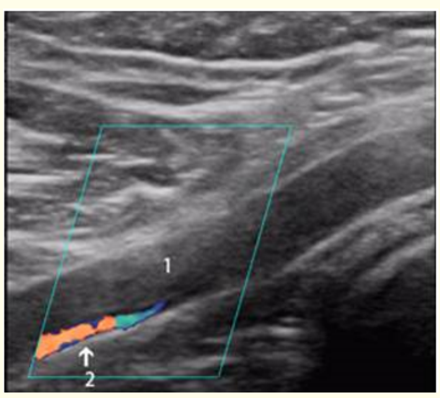

Figure 1: *Gunshot wound of the femoro-popliteal segment. Thrombosis of the popliteal vein. With color Doppler, there is no blood flow in the lumen of the vessel.*

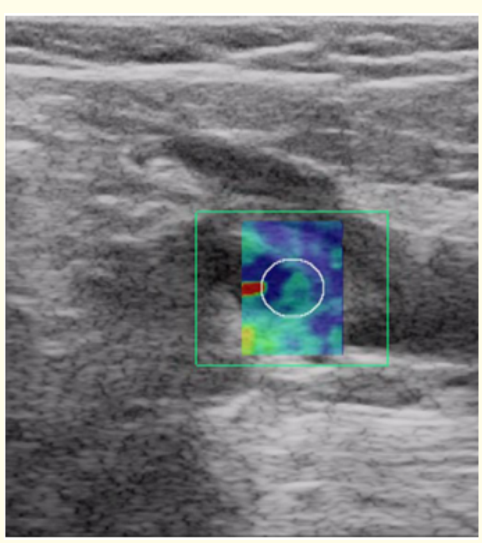

Figure 2: *Gunshot fragmentation wound of the thigh. Thrombosis of deep femoral vein. Elastography demonstrates high density of thrombotic mass.*

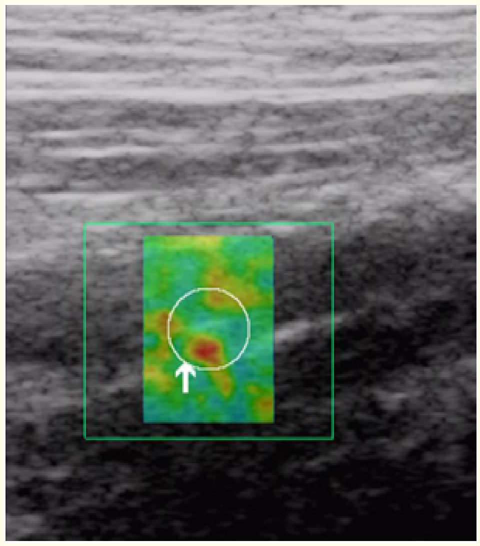

Figure 3: *Gunshot fragmentation wound of the thigh. Thrombosis of deep femoral artery. Elastography demonstrates high density of thrombotic mass.*

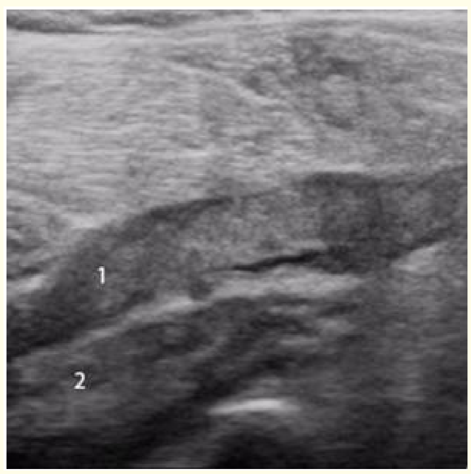

Figure 4: *Gunshot fragmentation wound of the thigh. Arterio-venous thrombosis.*

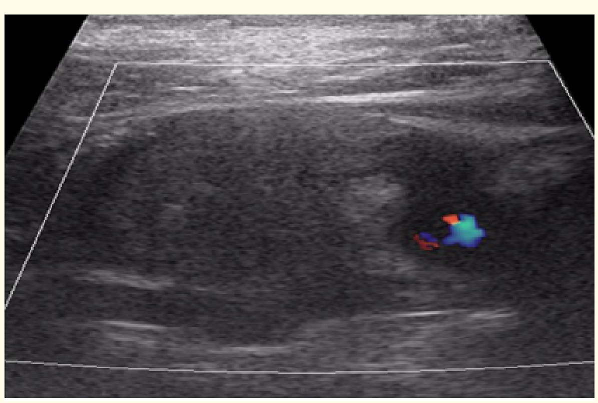

Figure 5: *Shoulder injury. Pseudoaneurysm of the brachial artery.*

Nerve damage is shown in table 5. As can be seen from the table, the peripheral nerves of the lower limbs were damaged much more often than of the upper limbs (68,6 ± 6,5% vs 31,4 ± 6,5%; P < 0,001). Among all the nerves of the limbs, the sciatic nerve was much more often damaged (Table 6).

Damaged nerves n = 51		The number of damaged nerves
Lower limb n=35 68,6 ± 6,5% P < 0,01	Sciatic nerve	16 (31,4 ± 6,5%)
	Femoral nerve	3 (5,9 ± 3,3%)
	Tibial nerve	7 (13,7 ± 4,8%)
	Sural nerve	6 (11,8 ± 4,5%)
	Common peroneal nerves (CPNs)	3 (5,9 ± 3,3%)

Table 5: *The frequency of damage to the nerves of the extremities with gunshot wounds.*

Damaged nerves n=51		The number of damaged nerves
Lower limb n = 35 68,6 ± 6,5% P < 0,01	Sciatic nerve	16 (31,4 ± 6,5%)
	Femoral nerve	3 (5,9 ± 3,3%)
	Tibial nerve	7 (13,7 ± 4,8%)
	Sural nerve	6 (11,8 ± 4,5%)
	Common peroneal nerves (CPNs)	3 (5,9 ± 3,3%)
	Medial plantar nerve	1 (2,0 ± 2,0%)
Upper limb n = 16 31,4 ± 6,5%	Axillary nerve	2 (3,9 ± 2,7%)
	Median nerve	5 (9,8 ± 4,2%)
	Radial nerve	4 (7,8 ± 3,8%)
	Ulnar nerve	4 (7,8 ± 3,8%)

Table 6: *The frequency of damage to the nerves of the extremities with gunshot wounds.*

The main signs of traumatic damage of the peripheral nerves were disorders of the fibrillar structure, heterogeneity and thickness changes, decrease in echogenicity, locally recorded fuzzy contours (Figure 6).

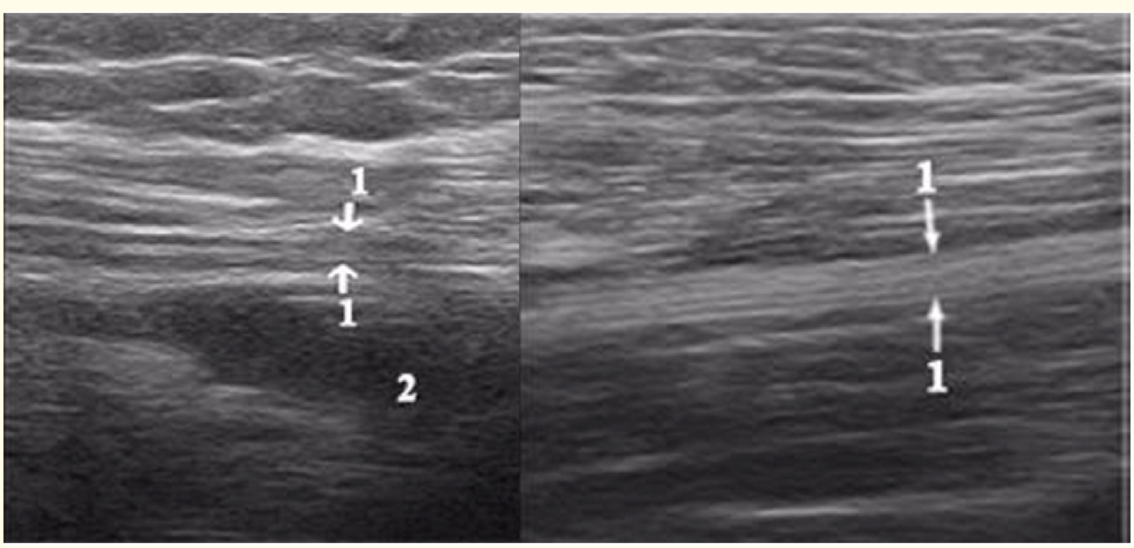

Figure 6: *Injury of the posterior surface of the left thigh. Longitudinal scan of the thigh.*

1 - Partial traumatic injury of the sciatic nerve; 2 - Wound channel. On the right side of the echogram is the unchanged sciatic nerve of the contralateral side.

The diagnostic value of ultrasonography and MRI was compared in 39 patients undergoing surgical treatment (Table 7). Ultrasound detected lesions more frequently than MRI: sensitivity 93,9% vs 88,2%; specificity 83,3% vs 60%. Ultrasound was accurate in more cases than MRI 92,3% vs 84,6%. The difference between them was not statistically significant.

Diagnostic results	The presence of damage to the peripheral nerves of the limbs (n = 39)	
	USG	MRI
True positive	31	30
True negative	5	3
False positive	1	2
False negative	2	4
Parameters of diagnostic value, %		
Sensitivity	93,9	88,2
Specificity	83,3	60,0
Accuracy	92,3	84,6

Table 7: *Comparison of ultrasound and MRI results with diagnoses determined by the surgical.*

Discussion

Injuries to peripheral vessels have a potential to cause morbidity and mortality if they are not recognized and treated promptly [16]. By results of researches Baram A., *et al.* (2015) in the diagnosis of military trauma, the sensitivity of Doppler ultrasound reaches 95 - 97% [17]. The incidence of brachial artery damage was 31.9%, while others reported injuries to the femoral and popliteal arteries as the most common vascular injury of the limbs [18,19].

High-resolution ultrasonography may provide an economical and accurate imaging modality with utility in diagnosis and management of peripheral nerve lesions. Further research is required to assess the role of ultrasonography in evaluation of peripheral nerve pathology [20].

When there are no hard signs of vascular injury and the patient is stable, imaging methods can aid in the localization and diagnosis of trauma-related vascular lesions. While angiography still remains the gold standard for the assessment of traumatic vascular injuries of the limbs and neck, other less invasive imaging modalities have gained popularity in the recent years and are routinely used. Point-of-care ultrasound and Color flow duplex Doppler ultrasound are widely available, noninvasive, sensible and specific techniques that can be used bedside, as a first approach for a prompt diagnosis and follow-up of trauma-related vascular injuries, and for an integrated management of trauma patients [21].

To assess the peripheral nerves of the lower extremity, ultrasonography (USA) has numerous advantages over magnetic resonance imaging (MRI). The most obvious of them are: excellent soft tissue resolution, low cost, lack of magnetic the artifact of susceptibility and the ability to research patients who cannot undergo an MRI. Studies of Zaidman CM., *et al.* (2013) show that in the differential diagnosis of mononeuropathy and brachial plexopathies ultrasound is more sensitive than MRI (93% vs 67%), has equivalent specificity (86%), and better identifies multifocal lesions than MRI. In sonographically accessible regions ultrasound is the preferred initial imaging modality for anatomic evaluation of suspected peripheral nervous system lesions [22].

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 compared the possibilities of ultrasound and MRI in the diagnosis of gunshot injuries of peripheral nerves in 39 patients who underwent surgical treatment. Ultrasound detected lesions more frequently than MRI: sensitivity 93,9% vs 88,2%; specificity 83,3% vs 60%. Ultrasound was accurate in more cases than MRI 92,3% vs 84,6%. The difference between them was not statistically significant.

Conclusion

Ultrasonography with dopplerography can be used as the main method for diagnosing gunshot injuries of the main vessels and peripheral nerves of the extremities. In the diagnosis of traumatic injuries of peripheral nerves, ultrasound has the advantage over MRI - in sensitivity, specificity and accuracy (93,9% vs 88,2%; 83,3% vs 60%; 92,3% vs 84,6%).

Conflict of Interest

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

Bibliography

1. Dicpinigaitis PA., *et al*. "Gunshot Wounds to the Extremities". *Bulletin of the NYU Hospital for Joint Diseases* 64.3 (2006): 139-155.
2. Chandler H., *et al*. "Severe Extremity injuries sustained by the UK military in the Iraq and Afghanistan conflicts: 2003-2014". *Injury* 48.7 (2017): 1439-1443.
3. Fox N., *et al*. "Eastern Association for the Surgery of Trauma (November). "Evaluation and management of penetrating lower extremity arterial trauma: an Eastern Association for the Surgery of Trauma practice management guideline". *The Journal of Trauma and Acute Care Surgery* 73 (2012): S315-S320.
4. Grechanyk OI., *et al*. "Ukrainian experience in hybrid war the challenge to update algorithms for personalized care and early prevention of different military injuries". *EPMA Journal* 7.1 (2016): A30.
5. Ahanger AG., *et al*. "Missile vascular injuries: 19-year experience". *Ulus Travma Acil Cerrahi Derg* 16.2 (2010): 135-138.
6. Lateef WM., *et al*. "Vascular Injuries Caused by Tear Gas Shells: Surgical Challenge and Outcome". *Iranian Journal of Medical Sciences* 36.1 (2011): 14-17.
7. Wani ML., *et al*. "Vascular Injuries: Trends in Management". *Trauma Monthly* 17.2 (2012): 266-269.
8. Wahlgren CM and Riddez C. "Penetrating Vascular Trauma of the Upper and Lower Limbs". *Current Trauma Reports* 2.1 (2016): 11-20.
9. Kruger A., *et al*. "Penetrating arterial trauma to the limbs; outcome of a modified protocol". *World Journal of Emergency Surgery* 8 (2013): 51.
10. Franz RW., *et al*. "A five-year review of management of upper-extremity arterial injuries at an urban level I trauma center". *Annals of Vascular Surgery* 26.5 (2012): 655-664.
11. Lang NW., *et al*. "Characteristics and clinical outcome in patients after popliteal artery injury". *Journal of Vascular Surgery* 61.6 (2015): 1495-1500.
12. Sciarretta JD., *et al*. "Management of traumatic popliteal vascular injuries in a level I trauma center: a 6-year experience". *International Journal of Surgery* 18 (2015): 136-141.
13. VM Schreiber., *et al*. "The timing of definitive fixation for major fractures in polytrauma - a matched-pair comparison between a US and European level I centres: analysis of current fracture management practice in polytrauma". *Injury* 42.7 (2011): 650-654.
14. E Adigüzel., *et al*. "Peripheral nerve injuries: Long term follow-up results of rehabilitation". *Journal of Back and Musculoskeletal Rehabilitation* 29.2 (2016): 367-371.
15. Yablon CM., *et al*. "US of the Peripheral Nerves of the Lower Extremity: A Landmark Approach". *RadioGraphics* 36.2 (2016): 464-478.
16. Shalabi R., *et al*. "Vascular Injuries of the Upper Extremity". *Journal Vascular Brasileiro* 5.4 (2006): 271-276.
17. Baram A., *et al*. "Vascular Trauma Registry Analysis in Sulaimani Province of Southern Kurdistan". *Surgical Science* 6.8 (2015): 369-375.
18. Oliver JC., *et al*. "Temporary Vascular Shunting in Vascular Trauma: A 10-Year Review from a Civilian Trauma Centre". *The South African Journal of Surgery* 51.1 (2013): 6-10.
19. Wani ML., *et al*. "Evaluating Peripheral Vascular Injuries: Is Color Doppler Enough for Diagnosis?" *International Cardiovascular Research Journal* 8.1 (2014): 15-17.

20. Lee FC., *et al*. "High-resolution ultrasonography in the diagnosis and intraoperative management of peripheral nerve lesions". *Journal of Neurosurgery* 114.1 (2011): 206-211.

21. Montorfano MA., *et al*. "Point-of-care ultrasound and Doppler ultrasound evaluation of vascular injuries in penetrating and blunt trauma". *Critical Ultrasound Journal* 9.1 (2017): 5.

22. Zaidman CM., *et al*. "Detection of peripheral nerve pathology: comparison of ultrasound and MRI". *Neurology* 80.18 (2013): 1634-1640.

Volume 10 Issue 11 November 2018