TREATMENT OF GUNSHOT WOUNDS OF THE SPINE USING FULL-ENDOSCOPIC SURGERY

Analysis of a small clinical series

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Objective. To assess the effectiveness of the treatment of gunshot wounds of the spine using percutaneous full-endoscopic technique.
Material and Methods. Three patients with gunshot shrapnel wounds of the spine were treated using percutaneous full endoscopy.
Results. The patients underwent a removal of foreign bodies (metal fragments) at the cervical, thoracic and lumbosacral levels of the spine using percutaneous full endoscopic surgery. The operations were carried out without complications, with minimal additional trauma to soft tissues and the spinal motion segment. In all three cases, there was a positive dynamics in the form of regression of the pain syndrome. There were no infectious complications.
Conclusion. The successful use of percutaneous full endoscopy in the surgical treatment of blind shrapnel wounds of the spine is shown. The results indicate the expediency of further research and development of this area to address the issue of introducing the technique into the routine practice of treating gunshot wounds both in peacetime in neurosurgical hospitals and centers of spinal neurosurgery, and in wartime at the stages of specialized care.

Key Words: gunshot wound of the spine, percutaneous full-endoscopic surgery.
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To date, the study of the problems of combat pathology has not lost its relevance. In 2014–2020, the total number of irretrievable losses in armed conflicts exceeded 800,000 people [1].

The first reports of spinal injuries sustained as a result of military actions can be found in historical records dating back to the 5th century BC. The ancient Greeks wrote about the injuries to the cervical spine experienced during the battle, and the Egyptians tried to come up with a treatment for spine fractures and dislocations [2]. Nonetheless, prior to the use of firearms, the majority of the wounded with these injuries died on the battlefield. Despite a proportionally higher number of instances, there is an increase in survivability due to the advancement of weaponry and better aid for this group of wounded [3]. Spinal injuries occurred in 0.17–2.0 and 0.3–1.5 % of all wounds during the First and the Second World Wars, respectively [4], and in 1 % of all combat injuries during the wars in Korea (1950–1953) and Vietnam (1965–1973) [5, 6]. This number rose to roughly 6 % during the US airborne warfare in Panama (1989) [7]. In both the armed conflict in the North Caucasus (1994–2002) and the war in Afghanistan (1979–89), isolated gunshot wounds to the spine accounted for 4.7–5.1 % of cases [8, 9]. During the Operation Iraqi Freedom studies (2003–2004), 7.4 % of all combat injuries were spinal injuries.

Currently, military tactics continue to develop. There is an increase in unconventional techniques of warfare, including the intensive use of self-made explosive devices, land mines, and suicide attackers [10, 11]. This approach, combined with advancements in personnel protective clothing (army combat helmet, armor vest) and in transportation methods, has resulted in an increase in survival and, as a result, an increase in the number of wounded, including those with spinal cord injury.

In addition to combat gunshot wounds, the problem of peacetime gunshot wounds persists, with the majority of victims being people under the age of 45 [12]. Civilian gunshot wounds to spinal cord account for 13–17 % of all cases [13–18]. Many injured people with gunshot wounds to the spine need surgical intervention. The degree of injury is determined by a number of factors, including the presence of a spinal cord bruise and vascular disruption, as well as the distance, caliber, and trajectory of a bullet [19]. According to some studies, the degree of a neurological disorder is determined by the location of the lesion. Thus, lesions of the cervical spine cause severe neurological disorders in 70 % of cases [20], whereas injuries to the lumbosacral spine cause severe neurological disorders in 30 % of cases only [21].

The degree of neurologic impairment formed after injury is the most important factor in the prognosis of neurological disorders [22].

Functional recovery is typically worse in patients with neurological impairment caused by a gunshot wound than

in patients with other types of spinal cord injury [23]. The patient's follow-up period to determine functional status is questionable in the literature and varies from 2 weeks to 6 months [23].

Percutaneous endoscopic spine surgery is now one of the most widely used techniques in the field of spinal surgery. The safest and most technically convenient way to remove foreign bodies is the transforaminal technique [24]. Tumors and infections of the spine have entered the field of surgical indications for percutaneous endoscopic surgery as surgical skills and technical equipment have improved [25–28].

Full-endoscopic surgery is also spreading rapidly into the treatment of patients with central nervous system gunshot wounds [29]. Several cases of this surgical technique being used in the treatment of patients with gunshot wounds to the spine have been published in recent years [30–36]. This article describes three clinical cases in which patients with gunshot blind shrapnel wounds of the spine were successfully treated with percutaneous endoscopy at the cervical, thoracic, and lumbosacral spine.

The objective is to assess the effectiveness of the treatment of gunshot wounds of the spine using a percutaneous full-endoscopic technique.

Material and Methods

Three patients with gunshot shrapnel wounds of the spine were supervised by the authors. The study complies with the standards of the bioethical committee, which is part of the institution where the study was conducted, as well as the "Rules of Clinical Practice in the Russian Federation" approved by the Order of the Ministry of Health of Russia No. 266 as of June 19, 2003. All individuals who took part in the observation provided informed voluntary consent.

All patients in the front-line stages of medical evacuation received primary surgical wound care, antitetanus toxoid injection and antibiotic prophylaxis with broad-spectrum drugs. Patients had CT scans of the respective spine regions performed as soon as they were admitted to the hospital. Percutaneous monoportal full endoscopy under continuous irrigation with 0.9% sodium chloride solution was chosen as the treatment technique in the presented cases.

Clinical case 1. A 50-year-old male patient A. was admitted to the hospital in two days after a gunshot blind shrapnel wound to the cervical spine. There was a moderate motor deficit in the cervical spine due to pain. A 0.5 × 0.3 cm wound on the right side of the back of the neck was with no signs of inflammation. No neurological disorders were discovered. CT and CT angiography of the cervical spine were performed. A foreign body (metal fragment) of 5 × 6 mm in size was found in the space between vertebral arches of the C1 and C2 vertebrae to the right, close to the dura mater and the upper third of the neck's venous plexuses, without any symptoms of injury to the right vertebral artery (Fig. 1).

The decision was made to perform surgery to remove the fragment from the intralaminar space endoscopically. The procedure was performed on the third day of hospital stay.

Course of the surgery. A linear incision of the skin and soft tissues was made paramedially on the right, in the projection of the spinous processes of the C1–C2 vertebrae, while the patient was lying in prone position and under general multicomponent anesthesia. There were placed tube dilators and an endoscopic port. The Ilessys endoscope (Joimax, Germany) was inserted into the port. The yellow ligament was removed endoscopically, and the edge of the dural sac and the right C2 root were identified. A metal fragment could be seen up from the root. The fragment was fixed with forceps and removed along with the working tube without any technical difficulties (Fig. 2).

The pain syndrome disappeared entirely after surgery. The patient was verticalized two hours after the procedure and transferred to a rehabilitation ward on the second day.

Clinical case 2. A male patient B., 21 years old. From the medical records provided, it is known that he received an explosive shrapnel wound to the left half of the chest. Chest CT revealed an organized hemothorax in the left pleural cavity, a foreign body (metal fragment) paravertebral to the left at the level of the T6 vertebra. At the previous stage, thoracoscopy, surgical revision of the pleural cavity, anterolateral thoracotomy, adhesiolysis, removal of an encapsulated hematoma and resection of the head of the seventh rib on the left were performed on the third day after the injury. According to the discharge summary and the presented CT, the metal fragment migrated to the right neural foramen during the removal attempt (Figs. 3–4). There is no detailed information, and it was not possible to detail the stages and features.

The postoperative period was favorable. The patient was transferred to the neurosurgical unit on the sixth day following the injury. After the examination, it was decided to remove the foreign body using a percutaneous endoscopic technique. The procedure was carried out on the second day after the transfer.

Course of the surgery. The patient was in the prone position on the surgical table under general multicomponent anesthesia. The injection point of the needle shield in the projection T6–T7 on the right was marked out. At the injection site, a 1 cm-long linear soft tissue incision was made. A Jamshidi needle was inserted, through which a Kirchner needle was inserted into the neural foramen in the projection of a foreign body at T6–T7 level on the right through the triangle of safety, bypassing the upper articular process. Dilators were installed on the needle. Along dilators a ring bone cutter was installed. A fragment of the facet joint and the rib head were resected with a cutter, after that the dilator tube was passed through the intervertebral foramen. A tube was installed through which the Tessys endoscope (Joimax, Germany) was inserted. A metal fragment was visualized with the help of the endoscope, fixed with forceps, clipped and removed together with the endoscope port (Fig. 5).

The patient was verticalized two hours later and transferred to rehabilitation treatment on the second day.

Clinical case 3. A male patient V., 22 years old, was taken to a neurosurgical in-patient facility a day after being injured. On admission, he complained of lumbar spine pain with irradiation along the outer surface of the left hip that worsened when he moved his left leg. A blunt-edged wound with a round shape measuring 2 × 1 cm was found in the area of the wing of the left ilium, with no signs of inflammation. Severe focal deficit wasn't found when assessing the neurological status. It was not possible to evaluate the volume of movements and strength of the muscles in the left leg due to the pronounced pain syndrome. A CT scan of the lumbosacral spine revealed a buttonhole fracture of the left iliac bone wing, bone fragments along the wound canal, and a foreign body (metal fragment) in the area of the L5–S1 left intervertebral foramen (Fig. 6).

A decision was made on the percutaneous endoscopic transforaminal removal of the fragment from the left neural foramen at the level of the L5–S1 vertebrae.

Course of the surgery. The patient was in a prone position under general multicomponent anesthesia, and the injection point of the needle shield in the projection of the L5–S1 vertebrae was marked under X-ray control. A 1-cm long soft tissue incision was made in the projection of the injection point. A Jamshidi needle was inserted, through which a Kirchner needle was inserted into the neural foramen in the projection of a foreign body L5–S1 on the left through the triangle of safety, bypassing the upper facet joint. Dilators were installed on the needle, along which a ring bone cutter was inserted. A dilator tube was passed through the intervertebral foramen after a fragment of the facet joint was resected with a cutter. A tube was installed through which the Tessys endoscope (Joimax, Germany) was inserted. A metal fragment was visualized by means of the endoscope, fixed with forceps, and removed together with the endoscope port (Fig. 7).

In the first case, the chosen trajectory corresponded to the shortest distance from the body's surface to the fragment;

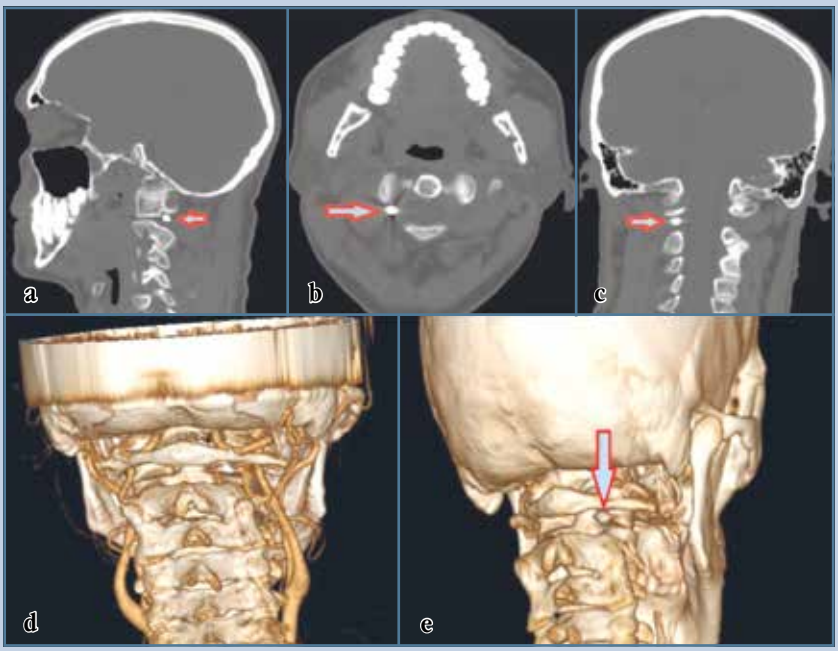

Fig. 1
CT scan of a male patient A., 50 years old: **a** – sagittal CT reconstruction; **b** – axial CT reconstruction; **c** – frontal CT reconstruction; **d** – 3D reconstruction of CT angiography; **e** – 3D reconstruction of a native image; arrows indicate foreign body

Fig. 2
The course of the surgery (the male patient A.): **a** – the position of the wounded man on the surgical table; **b** – appearance of the installed tube dilator; **c** – intraoperative X-ray control; **d** – capture and extraction of a foreign body; **e** – appearance of the removed fragment

in the second and third cases, a transforaminal approach was chosen due to the foreign body's location in the area of the neural foramen. The surgical approach did not match the gunshot wound canal in all three cases. The indications for surgery were root symptoms (patient V.), fragment migration prevention, and late complications. Surgical interventions were performed as planned on the second and third days of hospital stay. Gunshot wounds were treated daily with the imposition of an aseptic dressing; no secondary surgical debridement was required. Gunshot wounds heal by secondary adhesion on the 8th-10th day from the moment of injury.

Results and Discussion

The follow–up for the injured patients at the time of writing: the patient A. – 62 days, the patient B. – 46 days, and the patient V. – 28 days. The patient A. was verticalized two hours after the surgery. On the second day, he was transferred to the ward for rehabilitation. The postoperative wound was healed by primary adhesion. The patient B. was verticalized on the first day. On the second day, he was transferred to rehabilitation treatment. The wound from the thoracotomy healed on the tenth day, and the wound from the endoscopic fragment removal healed on the sixth. The patient B. showed regression of the pain syndrome and radicular symptoms on the second day. There was a minor (2–3 points according to VAS) pain syndrome during palpation in the area of the fracture of the iliac wing. The patient was allowed to get up on the first day. He was transferred to an inpatient rehabilitation facility on the third day after surgery. The postoperative wound healed by primary adhesion on the seventh day after the surgery.

In all cases, the pain syndrome resolved completely after surgery. Patients did not make any additional complaints during the follow-up, and there was no increase in neurological symptoms.

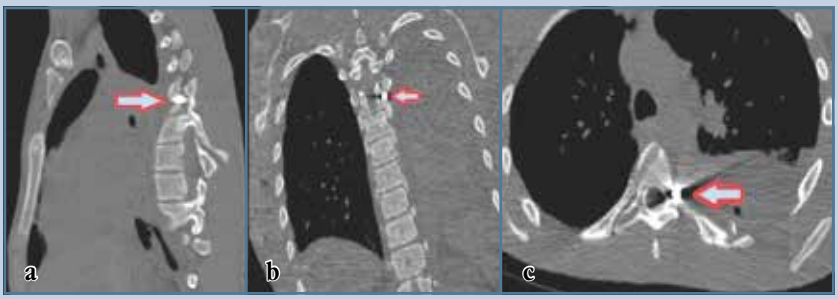

Fig. 3
CT scan of a male patient B., 21 years old, a metal fragment is located in the region of the left foramen: **a** – sagittal plane; **b** – coronal plane; **c** – axial plane

Fig. 4
CT scan of the male patient B., 21 years old, after surgery, a metal fragment migrated into the right foramen: **a** – sagittal CT reconstruction; **b** – frontal CT reconstruction, **c** – axial CT reconstruction

When compared to previous wars, the proportion of gunshot wounds to the spine increased significantly during the period of modern armed conflicts [3, 10]. It is considered that this is due to weapon modifications and change in methods of warfare, as the mine-explosive mechanism is prevalent in modern armed conflicts.

In the absence of data on antitetanus measures in the emergency unit, the use of antitetanus toxoid is mandatory for all patients with gunshot wounds after diagnosis [37].

Today, an initial surgical debridement remains a necessary part of the complex treatment of gunshot wounds [38]. Nonetheless, the possibility of using the wound canal as an access point to a foreign body in the future may exclude this stage in some cases. More research is required on this matter.

Such life-threatening septic complications as osteomyelitis, meningitis, and abscesses of the thoracic and abdominal cavities are a serious problem in the treatment of gunshot wounds. In this regard, broad-spectrum antibacterial therapy should be used in all cases of gunshot wounds to the spine. According to the literature [39, 40–43], the duration of antibacterial therapy ranges from 7 to 10 days. A distinct group consists of patients with a combined wound of the abdominal organs. This combination is found in 23.7 % of cases [44, 45]. When compared to the group that received antibiotic therapy for 48–72 hours, the use of broad-spectrum antibiotics in this group for 7–14 days results

Fig. 5
The course of the surgery (the male patient B.): **a** – the position of the wounded man on the surgical table; **b** – appearance of the installed tube dilator; **c** – intraoperative X-ray control; **d** – capture and extraction of a foreign body; **e** – appearance of the removed fragment

Fig. 6
CT scan of a male patient V., 22 years old: **a** – axial CT reconstruction; **b** – sagittal CT reconstruction

in a reduction in infectious complications [46, 47].

The duration, type, and indications for surgical treatment are all still up for debate. Wound liquorrhea, progressive neurologic impairment, and verified compression of vascular and neural structures by bone fragments or a foreign body are absolute indications for surgical treatment.

In rare cases, a gunshot blind penetrating spine wound does not result in neurological impairment [48–50]. Nevertheless, neurological symptoms can appear months or even years after an injury [51]. Delayed deepening of neurological impairment is frequently associated with the migration of a foreign body (bullet or a metal fragment) into the spinal canal [52, 53]. The issue of surgical treatment must be approached individually. To justify their tactics, ideologues of early surgical treatment of blind gunshot wounds to the spine refer to the prevention of new neurological manifestations associated with the migration of a foreign body, late meningitis, reactive fibrosis, and arachnoiditis [20, 54]. Early surgical treatment has also been linked to neurological impairment recovery ranging from partial to complete [53, 55]. In only one study by Young et al. [48] it is reported that removing a foreign body did not result in improvement of neurological impairment. Waters et al. [56] report a significant increase in the risk of infectious complications when conservative treatment is chosen. The removal of a foreign body compressing the spinal root improves clinical outcomes and increases the rate of axon regeneration [54].

We chose the endoscopic technique to remove metal fragments in order to avoid further trauma. The undeniable advantages of this technique over open methods of surgery include minimal tissue injury, a reduction in the duration of surgery and hospitalization, early verticalization, a decrease in the frequency of postoperative epidural fibrosis and infectious complications, and the absence of a disorder of the stability of the spinal motion segment.

A positive trend in the form of pain syndrome regression was observed in all three cases. There were no postoperative complications.

Conclusion

There is currently no agreement on how to treat gunshot wounds to the spine, as well as there is no unified surgical treatment algorithm. The successful use of percutaneous full-endoscopy in the surgical treatment of blind shrapnel wounds of the spine is presented in this study. The results indicate the expediency of further research and development of this area to address the issue of introducing

Fig. 7
The course of the surgery (the male patient V.): **a** – the position of the wounded man on the surgical table; **b** – appearance of the installed tube dilator; **c** – intraoperative X-ray control; **d** – capture and extraction of a foreign body; **e** – appearance of the removed fragment

the technique into the routine practice of treating gunshot wounds both in peacetime in neurosurgical hospitals and centers of spinal neurosurgery, and in wartime at the stages of specialized care.

The study had no sponsors. The authors declare that they have no conflict of interest. The study was approved by the local ethical committees of institutions. All authors contributed significantly to the research and preparation of the article, read and approved the final version before publication.

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