ANTERIOR DECOMPRESSION AND STABILIZATION SURGERY FOR COMPLICATED THORACIC AND THORACOLUMBAR SPINAL INJURIES*

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Objective. To study the possibility of application of anterior decompression and stabilization operations in patients with complicated thoracic and thoracolumbar spine and spinal cord injury without prior posterior intervention.
Material and Methods. Anterior decompression and stabilization operations in the thoracic and thoracolumbar spine were performed in 82 patients. Transpleural approach was used in 26 patients, transpleural transdiaphragmatic approach — in 46, and retroperitoneal subdiaphragmatic approach — in 10 patients. Decompression of the spinal cord was accomplished by subtotal resection of damaged vertebral bodies. The defect after the fractured vertebral body had been removed was filled with a porous NiTi implant in 41 cases, with a reinforced NiTi implant in 27 patients, and with the unique expandable NiTi implant — in 14 patients. The Vantage fixation plate added in all cases allowed manipulation of vertebrae along all axes in all directions.
Results. A good regression of neurological symptoms was obtained in 28.0 % of patients, and satisfactory — in 48.9 %. Neurological deficit remained unchanged in 23.0 % of operated patients. No technique-related complications were registered. Reinforcement of porous implant with a titanium rod significantly increased the interbody fusion solidity.
Conclusion. Anterior decompression and stabilization surgery for thoracic and thoracolumbar spine and spinal cord injury provides complete decompression of the spinal cord, one-stage reduction, reclination of the spine and correction of its axis, and complete interbody fusion with porous titanium-nickel implants in combination with the Vantage fixation plate.
Key Words: anterior decompression and stabilization surgery, vertebral fractures, porous titanium-nickel implant.

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Frequency of thoracic and thoracolumbar spine injuries (4–5 % of all injuries, 80 % of all spine injuries), mostly in patients in working age, and the absencфe of common treatment tactics determines the urgency of treating this type of injuries. About 58.4 % of all injuries are the injuries in the thoracolumbar spine (T11–L2), 30–70 % of them cause spinal cord compression [1, 6, 8, 10, 15, 19].

In patients with traumatic spinal cord compression, there are three tasks to be performed: early decompression of spinal cord, full correction of the traumatic spine deformity, and strong primary stabilization of the injured functional spinal units (FSU) [4, 5, 8, 10]. Since traumatic spinal cord compression is anterior in most cases, decompression preferably should be performed using anterior operative approaches: transpleural, transpleural transhiatal, extraperitoneal or hypochondriac. Meanwhile, correction of the spinal axis and safe stabilization using ventral approaches is a more difficult procedure compared to transpedicular fixation (TPF) of vertebrae. On the other hand, when using a posterior approach in the acute period of injury it is almost impossible to relocate the osteal fragments localized in front of the spinal cord to the vertebral canal. TPF is regarded as temporal stabilization of the injured FSU that should be supplemented with interbody fusion [1, 3–5, 10, 12, 14, 17]. Over the past years two-stage surgeries have become commonly used [1, 2, 4, 8–10, 16]. At the first stage, laminectomy and TPF are performed. TPF allows one both to robustly stabilize an injured FSU, to perform spine reposition and reclination, and to correct its axis. In most cases severity of paralyzed patient's condition impedes performing of the additional ventral stabilization or decompression and stabilization surgery under single anesthesia. The second stage often cannot be performed for as long as several weeks due to complications, such as pneumonia, urological infection, pressure sore, etc. One should take into account that long-lasting compression of the caudal spine causes irreversible ischemic changes. Late brain decompression can be useless. Furthermore, the reposition attempts during transpedicular manipulations generally fail to prevent anterior compression of the spinal cord by osteal fragments of vertebral bodies that had deeply intruded into the spinal canal.

All this facts spurred us to find a way for safe interbody fusion after radical ventral decompression of the spinal cord and its vessels.

The objective was to study the possibility of using anterior decompression and stabilization operations in patients with complicated injuries of the thoracic or thoracolumbar spine and spinal cord without any prior posterior intervention.

Material and Methods

Over the period of 2007–2011, anterior decompression and stabilization surgeries were performed in 82 patients (68 males and 14 females) aged 19–56.

Thirty-five (42.7%) patients were operated on in the acute period of injury; among them, 4 – during the first 8 h after injury, 31 – during the first 3 days. Half of patients (41 individuals) were operated on in the period between 3 days and 1 month after injury, 6 – 1–2 months after the injury.

In accordance with the objective of the present study, the patients operated on in transition and late periods of traumatic disease of the spinal cord were excluded from the study. We also excluded patients with uncomplicated spine injury; patients operated on using osteotransvesectomy through a lateral approach; patients who underwent a two-stage intervention (posterior decompression and stabilization surgery with TPF followed by ventral decompression-stabilization or stabilization surgery).

Because of spinal stress, compression of the spinal cord was distinguished from the concussion during the first 2–3 weeks after the injury mainly by the instrumental examination data and by detecting of the obstruction of the cerebrospinal fluid tract. Light period in the disease progression was detected only in 3 patients with C-type spinal cord dysfunction and in 14 patients with D-type spinal cord injuries, indicating gradual compression of the spinal cord without severe concussion and spinal shock.

Spondylograms and CT data were used to determine the degree of shifting of bone fragments into the spinal canal, vertebrae instability, the angle of the kyphotic deformity, and particular type of the injury according to the International Classification of Fractures based on the pathomorphological criteria and injury mechanism [18].

Injuries of a single vertebra were found in 55 (67.0 %) cases, two vertebrae – in 19 (23.1 %), three vertebrae – in 8 (9.7 %), multilevel injuries of two non-adjacent vertebrae – in 6 (7.3 %) cases. Meanwhile, only one patient among them had compression of the spinal cord and required decompression at both levels. Thoracolumbar spine fractures (T12 and L1) were detected in 51 patients (62.2 %).

68.3 % of patients had either complete burst fractures with relocation of the vertebral fragments to the spinal canal (type A3.3) or bending (posterior) distraction injury with compression-splintered fracture of the vertebral body and breaking of the posterior support structures (type B2.3). Type C1.3 and C2.2 rotation–distraction injuries were detected only in 17.1 % cases. Compression cuneiform (A1.2) and compression splintered (A2.3) fractures caused no compression of the spinal cord (Table).

Stenosis was measured as of the ratio between the critical area of the spinal canal and the normal anteroposterior size of the canal in the adjacent FSU. The mean size of the traumatic stenosis was 58.1 % at the spinal cord compression level. The average local kyphotic angle in the injured FSUs was 15.2°. In all cases, the spinal cord and its vessels were compressed mainly in the anterior part with one or several fragments of the fractured vertebral bodies and with participation of the cuneiform deformity of the anterior wall of the spinal canal. The arches of the upper vertebrae were involved in spinal stenosis in 16 patients with fracture-dislocations of vertebrae (type B distraction injuries and type C distraction-rotation injuries) when the anterior compression of the spinal cord dominated.

The ASIA/ISCSCI scale was used to assess the neurological status in patients with spinal injuries. This unified scale allowed one to quantitatively estimate

Table

Distribution of patients according to localization and type of spine injury, n

Localization	Type of spine injury [18]								The total number of injuries
	A1.2*	A2.3*	A3.1*	A3.3	B2.3	B3.2	C1.3	C2.2	
T5	5	3	1	–	1	–	–	–	10
T7	–	–	4	1	3	1	–	–	11
T8	7	2	–	–	1	2	–	–	5
T10	1	3	3	–	3	–	–	–	8
T11	–	–	3	7	2	1	2	2	17
T12	–	–	4	8	11	4	3	1	27
L1	–	–	1	6	10	4	4	–	24
L2	–	4	5	–	3	–	1	1	14
Total	13	9	21	22	34	12	10	4	109**

Localization of spinal cord compression is shown in bold;

*injury of the adjacent and remote vertebrae with respect to the site of spinal cord compression in patients with multiple and remote injuries;

**including 35 injuries in 27 patients with multiple fractures.

the functional status of the spinal cord and severity of the neurologic disorders, which is valuable in unbiased assessment of the spinal deficit and in estimation of the treatment outcomes in each individual. Meanwhile, this scale is cumbersome for analyzing the treatment results in a group of patients; therefore, the conventional classification of the spinal cord was used for total estimation the dysfunction.

65 patients (79.3 %) had type A injuries (a total loss of the spinal cord function); 3 patients (3.6 %) had type C injuries (preserved motional functions below the injury level and strength less than 3 points in most control groups of muscles); 14 patients (17.1%) had type C injuries (partial disorder of reflex activity of the spinal cord, preserved motional functions below the injury level, and strength more than 3 points in most control groups of muscles).

Severity and dynamics of the neurological deficit, time since injury, type of the spine traumatic deformity, localization and severity of the spinal canal deformity, and instability of the injured FSUs were taken into account when planning surgery.

Contraindications for the surgery were traumatic or hemorrhagic collapse with hemodynamic instability, accompanied visceral injuries, severe cerebrocranial injury with consciousness alterations (score of less than 9 according to the Glasgow Coma Scale), suspected intracranial hematoma, severe accompanying diseases, fat embolism, pulmonary artery thromboembolism, and pneumonia. Attempts were made to eliminate these contraindications at the Neuroresuscitation Department in order to perform decompression and stabilization surgery as soon as possible.

Thirty-one and four patients out of 35 individuals hospitalized in the acute period of traumatic injury of the spinal cord had compensated and decompensated traumatic shock, respectively. Accompanying fractures of other bones and cerebrocranial injuries requiring no surgical treatment were found in 49 cases (59.8 %).

Ventral decompression and stabilization surgeries were performed without prior posterior intervention. In 1 case, decompression and stabilization surgeries were performed at two non-adjacent levels: at the burst fracture of T7 and at the type B2.3 fracture-distraction of T10 vertebra.

Transpleural approach was used in 26 patients, transpleural transdiaphragmatic – in 46, and retroperitoneal subdiaphragmatic approach – in 10 patients. Decompression of the spinal cord was accomplished by subtotal resection of the damaged vertebral bodies. The accessible portion of the vertebral body was resected as widely as possible after excision of the discs adjacent to the fractured vertebra and scraping of their fragments. At the resected discs level, the spinal canal was opened and the resulting foramina were widened towards the sides and the bone fragments of the fractured vertebral body. In the acute traumatic period, bone fragments are movable, so the deeply intruded fragments should be removed under visual control. One should bear in mind the risk of shifting and rotating of these structures during the removal, which may additionally injure the spinal cord and its vessels. Flexibility of the vertebrae in the damaged FSU should be taken into account. The dural sac was not opened, since it is difficult to seal it subsequently and there was a risk of uncontrollable liquorrhea.

After the fractured vertebral body had been removed, the spinal defect was filled with the precisely modeled porous NiTi implant in 41 cases, with the reinforced NiTi implant in 27 patients, and with the unique expandable NiTi implant – in 14 patients. A combination of the fixation plate with different NiTi implants demonstrated that these implants were upgraded from a porous cylinder towards the rod-reinforced and expandable implant. The use of reinforced NiTi-implants caused no loss of correction in the spine segments operated on.

In all cases, a Vantage fixation plate was used. This plate is not attached to the vertebrae; instead, its clamps are fixed to the adjacent vertebrae with bicortical screws. The modular distraction system tightly connected to the clamps allows one to perform distraction or construction, as well as to manipulate vertebrae along any axes and in any directions. We consider this to be the main advantage of the Vantage system when used for this localization of acute spine and spinal cord injuries. The Vantage system was used for reposition and reclination, as well as to provide additional fixation of the spine segment operated on. After correction of the spinal axis with fixation system, the interbody space was extended to install one of three types of NiTi implants (Fig. 1): a precisely modeled porous cylinder, an implant reinforced with a titanium rod or an expandable implant. The vertebrae were subsequently proportionally aligned to compress the interbody implant and the plate was finally fixed to the vertebral bodies maintaining the spinal axis. Therefore, safe fixation of the operated segment was achieved by combining the fixation plate and interbody fusion with NiTi implants.

The results of decompression and stabilization surgery in one patient are shown in Fig. 2 for illustration.

NiTi implants have been used in spine surgery at our institute for 15 years. They are durable, corrosion resistant, and can be easily modeled during a surgery. Prior to installation, they can be impregnated with an antibiotic solution to prevent possible infectious complications. The osteoid tissue has been proved to grow into the implant pores, and the implant integrates well in the organism. After 4.5 months, the filling degree of pores is 60 %. 1.5 years after the porous NiTi implant had been installed, organic tissues fill 100 % of pores; calcium and phosphorus content in the pores is close to that in human bones [7]. Integration of the bone and the porous implant matches the tasks of using the porous constructs to replace the defects and fuse the vertebral bodies. After 3 months, the implant can be separated from the bone.

To increase the implant strength we suggested reinforcing with a titanium rod.

The length of the reinforcing rod (5 mm in diameter) was chosen so that the rod ends should protruded at both

sides as spikes after screwing the proper number of porous cylinders 20–24 mm in diameter. Long implants used to replace 2–3 or more vertebral bodies can be chosen from porous cylinders of different diameter (Fig. 3).

The endplates of the adjacent vertebrae were perforated in places where they come in contact with end spikes of the implant. The porous reinforced implant was tightly wedged between the bodies of the upper and lower vertebrae in cases when flexibility of FSU increased or vertebral bodies were moved apart by the Vantage system. In this case, the end spikes of the implant go into the vertebral bodies, while the corresponding surfaces of porous cylinders seat at the endplates of the adjacent vertebrae. Preservation of the endplates prevents implant intrusion into the adjacent vertebral bodies and loss of the correction in postoperative period.

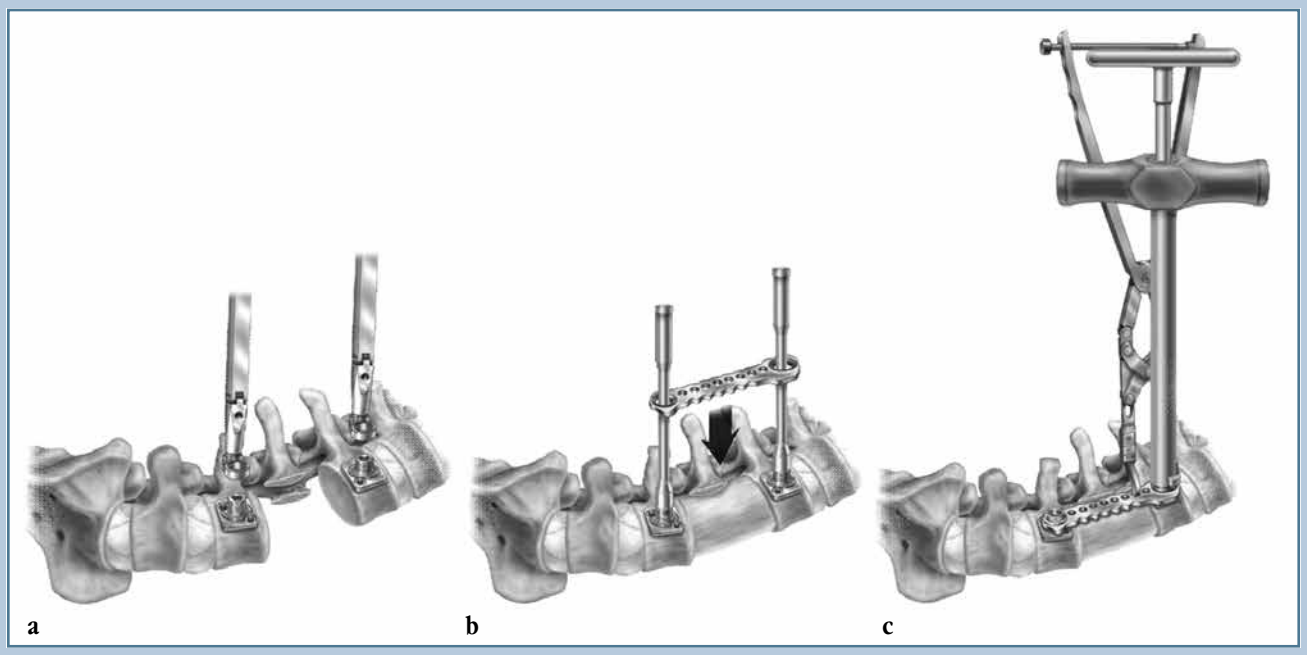

Fig. 1
Individual stages of interbody fusion using Vantage fixation plates: **a** – clamps are fixed to the adjacent vertebrae after the damaged vertebral body had been removed; **b** – installation of an implant into the defect after reclination and reposition; **c** – installation of a fixation plate in the compressed position of the implant

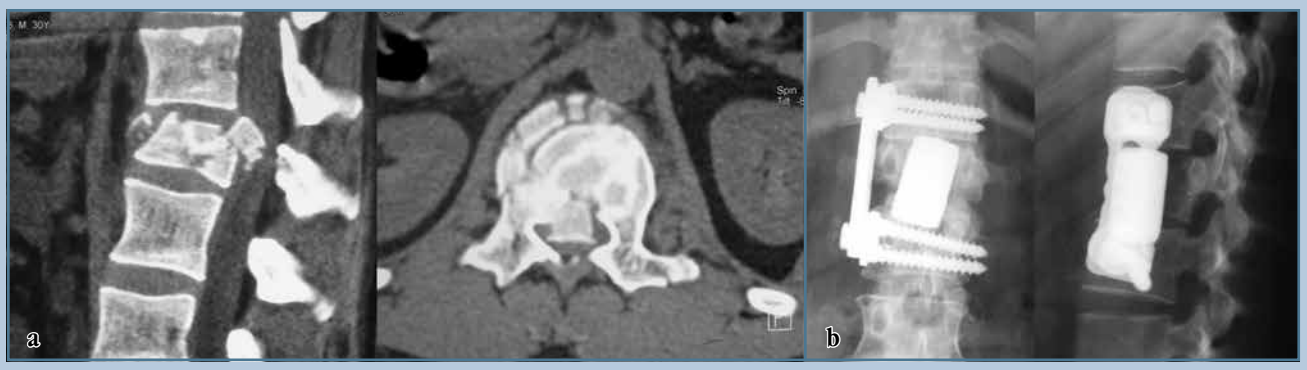

Fig. 2
An illustration of using a porous implant together with a Vantage fixation system after the ventral decompression of the spinal cord: **a** – type A3.3 injury of the L1 vertebra with severe deformity of the spinal canal and compression of the spinal cord; **b** – porous NiTi implant replacing the resected vertebral body and the Vantage" fixation plate can be seen

The third type of implant is a jacking fixation device, which was suggested by an analogy with the reinforced implant. Supporting porous cylinders with end spikes (to be intruded into the holes in the adjacent vertebral bodies) localize at the implant sides. Spikes have sleeves with the counter thread. Supporting surfaces are moved apart by rotation of the connected rod (Fig. 4).

This fixation device allowed one to gradually move apart the adjacent vertebrae and to fix them in the position of slight hypercorrection of the spinal axis, while additional screwing of the fixation plate increased fusion safety.

Therefore, the NiTi implants have evolved towards the increased fixation safety and preventing of kyphosis of the operated FSU in the postoperative period.

Results

Dynamics of the neurological deficit, correction maintenance, and stability of fixation of the FSUs were estimated according to deformation of the spinal canal walls, local kyphosis, deficit of the vertical size of the implant, and the distance between the adjacent vertebrae.

At hospital discharge or one month after surgery, the neurological symptoms improved (increased by two points) in 23 patients (28.0 %): 12 patients moved from group C to group E and 11 – from group A to group C.

A reasonable regression of neurological symptoms was observed in 36 patients (43.9 %): 12 patients moved from the group A to the group B and 11 – from the group D to the group E.

The neurological deficit was not changed in 19 patients (23.0%). Symptoms aggravated in 4 patients (4.9 %). Two of them with the syndrome of C type partial ductance damage moved to group B. One patient moved from group D to group B and the other one, to group C. Neither spinal canal deformation nor compression of the spinal cord were observed in these patients during the control examination. The aggravation of the symptoms was transient in the patient who moved to group C. Two of three patients who had moved to group B after the recovery treatment moved back to group C 2 and 4 months after surgery. The third patient stayed in group B. These complications can be attributed to an extremely strong impact during the implant installation, by rough manipulation of the damaged structures aiming to correct the spinal axis, and by the possible injury of the spinal cord when the vertebral fragments were being removed.

In 14 of 41 patients who had undergone interbody fusion using a porous (non-reinforced) implant, the kyphotic deformity of the operated spine segments increased by 2.6 ± 1.9 %. This deformity was not found in 27 patients with reinforced implants. In 2 patients with the type B3.2 fracture-dislocation of the T12 vertebra, the jacking stabilization device detached and the upper screws damaged the bone, causing kyphosis in the operated spine segments. The patients were reoperated. The jacking device was properly fixed and larger fixation plates were installed.

Long-term treatment results (over 1 year) were studied in 46 patients during rehabilitation hospitalization and in 19 patients using questionnaires. In the first group, the neurological deficit was more severe and the patients experienced health problems. In the second group, treatment yielded better results. Thus, the efficacy of treatment in all these patients can be estimated only roughly. Therefore, the general clinical and X-ray criteria were used for complex assessment of the treatment results [1, 4, 8, 10, 18].

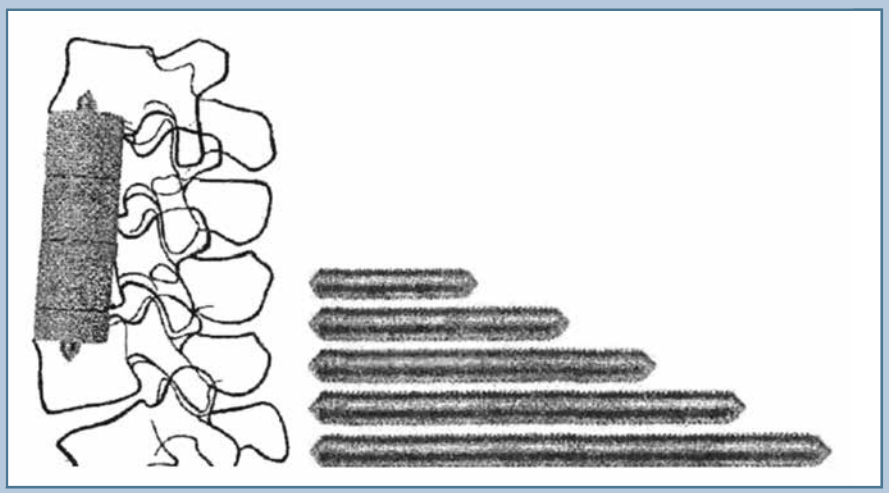

Fig. 3
The general view of the construct installed into the spine and reinforcing rods of different length to which porous cylinders are attached

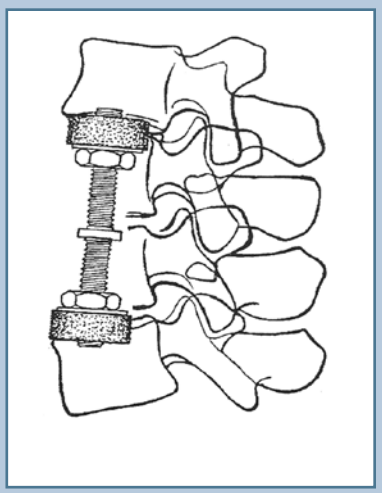

Fig. 4
Scheme of the jacking device immobilizing the operated spine segment

Stabilization of the injured spine section, recovery of the supporting ability and fusion of the operated FSUs, lack of spinal canal stenosis, lack of the pain syndrome, normalization of the neurological status or significant regression of neurological disorders (patient's conditions improved by two points according to the Frankel scale) were considered as good treatment results.

Stabilization of the injured spine section, recovery of the supporting ability and fusion of the operated FSUs, lack of spinal canal stenosis, lack of the pain syndrome, lack of changes in the neurological status or regression of neurological disorders (patient's conditions improved by one point according to the Frankel scale) were considered as satisfactory treatment results.

Development of instability in the operated FSUs, lack of the supporting ability of the spine, presence of the deformity of the spinal canal and/or local kyphosis over 25°, persistence or aggravation of the neurological status were considered as unsatisfactory treatment results.

No aggravation of the neurological symptoms was observed in the late period of the traumatic disease of the spine.

Good results were observed in 18 patients (27.7 %), satisfactory – in 21 (32.3 %), unsatisfactory – in 26 (40.0 %). Unsatisfactory treatment results were attributed to severe damage of the spinal cord, when compression of the spinal cord was accompanied by a severe concussion. These patients had type A spinal cord injuries.

Orthopedic evaluation of the patient's condition was more reasonable when the neurological status mainly depended on the severity of the spinal cord injury.

No deformities of the spinal canal walls were found. A bone-metal block was detected in all the examined patients. In 4 of 29 patients operated on using porous NiTi implants and in 2 of 8 patients operated on using the extendable reinforced implants, the kyphotic deformity increased over 1 year. No significant loss of correction of the operated spine segments was found in all 27 patients operated on using reinforced NiTi implants.

The Vantage system ensured safety of the primary fusion; the porous NiTi implant formed a durable osteo-metallic block.

Discussion

This study was not aimed at providing comparative characterization of the anterior and posterior decompression stabilization operations. Its objective was to study the possibility of using anterior decompression and stabilization operations in patients with complicated injuries of the thoracic and thoracolumbar spine and spinal cord without prior transpedicular fixation.

Over the past years, it has been thought that emergency decompression stabilization operations should be performed only through a posterior approach (laminectomy and stabilization with transpedicular, interlaminar, or other systems) in the cases of severe complicated injuries of the spine and the spinal cord in patients with unstable functioning of vital organs and systems in the acute period of traumatic disease of the spinal cord. The use of TPF in some cases eliminates critical stenosis of the spinal canal by the ligamentotaxis effect when the posterior longitudinal ligament is intact [3, 10–13, 16]. This excludes the need for additional anterior interbody fusion with anterior decompression of the dural sac, reduces the surgical traumaticity and risks. Meanwhile, such reconstruction of the spinal canal is almost infeasible if the spinal cord is severely damaged by vertebral body fragments deeply intruded in the canal. Most of transpedicular spinal systems that are currently widely used in clinical practice are limited because of their reposition potential. They can ensure only controllable segmental distraction or compression of the posterior osteoligamental column. Rare exceptions are several systems (e.g., Sintez, Signus, Aesculap) that ensure the repositioning effect on the implant screws in various directions [10].

The second stage of surgical treatment is total ventral decompression of the spinal cord by removing the damaged vertebral body and replacing it with a transplant, implant or other fixation devices. The second stage should be performed when a patient is not in the critical condition, post-traumatic homeostasis disorders are normalized, general and local complications are absent, and when there are indications for further surgical treatment. Refusal to perform ventral stabilization causes TPF inconsistency due to the chronic overload of the constructs, fatigue fractures of screws, damage to the bone structures, and their migration. This can cause palindromia, development of the post-traumatic deformities of the spine and the spinal canal [1, 2, 4, 5].

Development of polyorgan insufficiency in paralyzed patients after posterior decompression and stabilization surgeries impedes the main stage of the treatment (full-fledged anterior spinal cord decompression). The therapeutic window can be missed, and irreversible ischemic disorders can develop in the spinal cord compressed for a long time. There have been a number of attempts at using the low-invasion surgical treatment for the combined (anterior and posterior) fusion under a single anesthesia by reducing the surgery duration and traumaticity [6, 11, 14, 16]. When the spinal cord is severely compressed in anterior part, the urge to reduce the impact on the soft tissues and reduce the incision lengths is of lesser importance than to create the optimal conditions for the full-fledged decompression and revision of the spinal cord. It seems likely that anterior decompression and stabilization surgery should be accompanied by low-invasive TPF to perform combined fusion under a single anesthesia.

To perform circular stabilization of the FSUs and the full decompression of the spinal cord, which is often frontally compressed, additional anterior approach is often required after using the posterior approach for temporal transpedicular, interlaminar or other types of fixation. Posterior approach can be extended in lateral direction to remove rib heads, articular processes, and vertebral bodies [3]; however it is feasible only in the late period of injury

when the spinal cord is atrophied and not swollen.

Anterior decompression and stabilization surgeries through a single approach allow one to resect the damaged vertebral bodies, to perform anterior decompression of the spinal cord and its processes by reconstructing the ventral parts of the spinal canal, to fix the spinal axis and to perform a long-term fixation of the spine. The use of posterior approach is not needed in this case, reducing the number of treatment stages, load on a weakened patient, and surgical traumaticity. It is widely believed among neuro-surgeons that anterior decompression and stabilization surgeries are more traumatic than the posterior ones, but this opinion is hyperbolized. Our experience suggests that patients sustained well the anterior decompression and stabilization surgeries even in the acute period of the traumatic disease. The attempts at using of the posterior approach to resect the compressing substrates localized in front of the spinal cord may severely damage the spinal cord.

Ventral stabilization of the injured FSUs is less safe compared to TPF. Meanwhile, TPF without interbody fusion is considered to be temporal by most vertebrologists. It often becomes inconsistent because of fractures of the fixation screws, damage to the bone structures and increase in spine deformity.

The use of an additional ventral approach under the same anesthesia is dangerous because of critical health condition and homeostasis disorder in paralyzed patients. It is undesirable to divide the surgical treatment into two stages, since anterior compression of the spinal cord should be eliminated as soon as possible. Irreversible ischemic disorders in the spinal cord can develop during several hours. It is important to use the therapeutic window when the spinal cord and its major vessels are compressed.

The use of anterior stabilization of the spinal cord allows one to solve a number of problems during a single approach: to resect the damaged vertebral bodies, to perform anterior decompression of the spinal cord and its processes, to embole fracture-dislocations, to reconstruct the ventral parts of the spinal canal, and to perform stable fixation of the spine. Constructional features of the Vantage fixation plates allow one to fix the deformity of the spinal canal and to stabilize the damaged FSUs together with interbody implants either in patients with type B3 burst fractures or with fracture-dislocations. The posterior approach is not needed in this case, which reduces the number of treatment stages, surgery duration and traumaticity.

Thus, anterior decompressive and stabilizing surgeries are adequate approach to treat the patients with injury of the thoracic and thoracolumbar spine and the spinal cord, especially in the burst fractures.

Conclusions

1. In patients with acute injury of the thoracic and thoracolumbar spine and the spinal cord, ventral decompression and stabilization surgeries provide full decompression of the spinal cord, simultaneous reposition, reclination, correction of the spinal axis, stabilization of the damaged spine segments without prior posterior TPF.

2. A safe method of the interbody fusion is to use porous NiTi implant in combination with the Vantage fixation system, which allows one to fully recline and repose the vertebrae, to correct the spinal axis, and to perform durable stabilization.

3. A major improvement of the porous NiTi implants is reinforcement with a titanium rod, which increases the implant hardness, making it more universal.

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