DECISION-MAKING AND TECHNICAL CHOICE IN INSTRUMENTAL FIXATION FOR NEUROLOGICALLY UNCOMPLICATED ISOLATED BURST FRACTURES OF THE THORACIC AND LUMBAR VERTEBRAE

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Objective. To substantiate the principles of context-based optimal decision-making and technical choice in instrumental fixation of the spine in trauma patients with neurologically uncomplicated isolated burst fractures of the thoracic and lumbar vertebrae.
Material and Methods. A comparative retrospective analysis of treatment outcomes of 206 trauma patients was performed. Patients of Group 1 (n = 17) underwent anterior spinal fusion with anterior instrumental fixation through isolated open anterior approach, those of Group 2 (n = 80) — open pedicle screw fixation, of Group 3 (n = 70) — posterior mini-invasive percutaneous pedicle screw fixation, of Group 4 (n = 20) — open pedicle screw fixation with the extended laminectomy and reconstruction of the anterior column, and of Group 5 (n = 19) — open pedicle screw fixation and anterior fusion through an open approach. Non-parametric statistical methods were used.
Results. Open or minimally invasive posterior instrumental fixation of the spine with instrumentation systems including 6 screws for incomplete burst fractures and 8–10 screws for complete burst fractures should be considered the best operative option in the immediate post-traumatic period (up to 7 days) both from the point of view of convenience and safety of the patient and from the standpoint of maximally effective use of any hospital resources. The use of open anterior approaches for the reconstruction of the anterior spinal column can be justified only when the time from injury exceeds 7 days, as a part of combined procedure, primarily in combination with minimally invasive posterior pedicle screw fixation.
Conclusion. To date, decision-making and technical choice in instrumental fixation for neurologically uncomplicated isolated burst fractures of the thoracic and lumbar vertebrae should be context-based. The decision-making algorithm should be built on the basis of the experience of the operating surgeon, the time from injury, the trauma patient's state of health, as well as the administrative and logistical context of provision of the specialized medical care.
Key Words: spine and spinal cord injury, A3–A4 spine fractures, spine surgery, instrumental fixation of the spine, anterior spinal fusion, trauma center.
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Nowadays, as there is no certainty regarding which treatment option (conservative or surgical) is preferable, application of instrumented spinal fixation techniques should be considered justified for patients with burst fractures of the thoracic and lumbar vertebrae (types A3 and A4 according to the AO fracture classification) [1, 2]. However, the problem of adequate choice of the operative measures still needs to be solved.

Nevertheless, the core of the problem does not mean only the differences between the three key variants of surgical treatment (isolated anterior, isolated posterior, and combined instrumented fixation) currently used to reconstruct the normal anatomy and functional state of the traumatized spinal cord. Indeed, they all, with the use of additional options (extended posterior approaches or minimally invasive surgical techniques), can provide for achieving more or less similar favorable anatomical and functional outcomes in the long run [3, 4]. That is why, according to the realities of modern life, adequacy of any surgical treatment means its correspondence, on one side, to the important parameters of the patient's state in each particular case, and, on the other side, to the conditions of specialized medical care delivered to the patient [5].

The objective of the study was to substantiate the principles of situation-based optimal decision-making and technical choice in instrumented spinal fixation in trauma patients with neurologically uncomplicated isolated burst fractures of the thoracic and lum-

bar vertebrae by performing comparative analysis of the treatment outcomes.

Material and Methods

The study was carried out at two large Russian centers of spine surgery, first-level trauma centers: St. Petersburg Research Institute of Emergency Medicine n.a. I.I. Dzhanelidze (St. Petersburg, Russia), where there has been the City Center of Urgent Spine Surgery since 2010, and A.A. Vishnevsky 3rd Central Military Clinical Hospital (Moscow Region, Novy settlement). The clinical data necessary for the current work were collected at these centers in 2014–2016 and 2008–2016, respectively. During these periods, the total number of indoor patients with type A3 or A4 isolated uncomplicated fractures of any thoracic or lumbar vertebrae was 582; 467 (80.2 %) of them were operated on.

The main surgical treatment option was posterior instrumented fixation: 386 cases (82.6 %). The following methods were used for this type of surgeries: transpedicular systems (287 cases), laminar ones being used rather rarely (76 cases), and hybrid ones, even more rarely (23 cases). Transpedicular fixation (TPF) was performed through the conventional open approach in 199 cases (42.6 %) and using the minimally invasive percutaneous technique in 88 cases (18.8 %). In 11.8 % of patients (n = 55), the posterior approaches were expanded due to laminectomy, facet joint resection, transversectomy, and costotransversectomy to perform manipulations for anterior column reconstruction. In this case, prosthetic repair of the anterior column involving the interbody bone block formation in the injury site (anterior support and spinal fusion) was conducted in 5.1% of patients (n = 24). The surgeries pathogenetically and biomechanically justified for this type of trauma were carried out through the anterior approach only in 4.1 % of patients (n = 19) and using the combined method (anterior + posterior approaches) in 13.3 % of patients (n = 62). In the latter case, the interventions through the posterior approach were performed by minimally invasive percutaneous TPF in 39 (8.4 %) cases or by the similar open procedure in 23 (4.9 %) cases.

The problem related to choosing the optimal approach and technique of the surgical spine stabilization in patients with uncomplicated burst fractures of the thoracic and lumbar vertebrae includes the following three important aspects, which can be solved by obtaining and comparing the treatment outcomes for the relevant groups of trauma patients.

1. Choosing the type of surgical intervention. The adequate evidence basis can be obtained by comparative assessment of the treatment outcomes of anterior spinal fusion involving anterior instrumented fixation, which are performed through the isolated open anterior approaches, and the treatment outcomes of open TPF using the systems including six screws for incomplete burst fractures (type A3) and 8–10 screws for complete burst fractures (type A4), without additional resection of bone elements of the posterior column (laminectomy, facet joint resection, transversectomy or costotransversectomy).

2. Choosing the method for ventral column reconstruction (anterior fusion), when reconstructing the proper shape of the damaged vertebral body by means of posterior instrumented fixation of the spine (through ligamentotaxis) is either infeasible or inefficient. This problem can be solved by comparing the treatment outcomes for the patients operated on through the extended open posterior approaches with additional resection of bone elements of the posterior column (facet joint resection, transversectomy or costotransversectomy), and using the so-called combined approaches, when the conventional open anterior approach had been performed for anterior column reconstruction in addition to the posterior open approach within a surgical intervention.

3. Choosing the technique of posterior instrumented spinal fixation as the most common variant of surgical treatment. For this purpose, treatment outcomes in patients who had been subjected to the conventional open TPF using the systems including 6–10 screws were compared with those in patients who underwent minimally invasive percutaneous TPF using the similar system, while achieving a satisfactory level of anterior column reconstruction exclusively by ligamentotaxis, without resecting the bone elements of the posterior column.

The clinical trials were based on the treatment outcomes for 206 patients 18–60 years old, both males and females, with types A3 and A4 fractures, who had the normal status of bone tissue and no neurologic impairments at baseline. The follow-up period was 24 months after the surgery. The data set was divided into five groups homogeneous in terms of age, sex, and fracture localization, depending on which type of surgical intervention aimed at spine stabilization and the approach had been used: Group 1 – anterior spine fusion and fixation; Group 2 – open TPF; Group 3 – percutaneous TPF; Group 4 – open TPF with extended laminectomy; Group 5 – combined intervention (Table 1).

The patients were examined on admission, during their stay at hospital, and after discharge according to the commonly used contemporary diagnostic schemes, which mandatorily involved two-dimensional plain radiography of the spine and helical computed tomography of the damaged section.

The patients' performance status was determined when planning the spine stabilization surgery using the American Society of Anesthesiologists (ASA) classification system. Pain intensity was assessed using the Numeric Rating Scale (NRS). The Russian-language adaptation of the Oswestry questionnaire (Oswestry Disability Index, ODI), version 2.1a, was used to assess the patients' quality of life [6]. The treatment outcomes were assessed using the modified MacNab scale.

Statistical data analysis was performed using Microsoft Excel and Statistica for Windows 6.0 software packages. The median and quartiles were used to characterize the distributions of quantitative variables. A comparative analysis of frequency estimates of the treatment outcomes within each selected pair of

groups was carried out using the Pearson's chi-squared test, χ^2 test with the Yates' continuity correction, one- and two-tailed Fisher's exact tests; quantitative variables were analyzed using the Mann–Whitney U test. The differences were considered statistically significant at $p < 0.05$.

Results

Surgical interventions carried out through the isolated open conventional and extended posterior approaches were characterized by significantly lower values of all studied parameters compared to those in patients operated on through the anterior approaches. A similar situation was observed for isolated minimally invasive and open surgeries involving posterior instrumented spine fixation without laminectomy (Table 2).

An analysis of the frequency and structure of postoperative complications revealed that there were no significant differences between the three pairs being compared (Table 3). Fractures and migrations of metal constructs were detected in two patients in Group 2 and in one patient in Group 3 during the period of 14–17 months after the surgery. This was an indication for their immediate surgical removal, but no refixation was required. More than half of the patients operated on through the anterior approaches had specific approach-related complications: neuropathy of truncal nerves (intercostal nerves, the subcostal nerve, and the iliohypogastric nerve) and acute pleurisy.

When assessing the pain syndrome according to the NRS in the postoperative period, the patients were asked to take into consideration only the situations when they were experiencing more or less persistent pain at relative rest; pain intensity was supposed to be assessed before taking analgesics (Table 4). The highest frequency of pain, its intensity and duration were typical of trauma patients operated on through the anterior approaches. Significant differences with respect to similar interventions carried out through isolated posterior approaches were revealed. Minimally invasive techniques of isolated posterior fixation in this case differ from the conventional open interventions only in the short-term (up to 3 months) postoperative period.

Quality of life during the short-term postoperative period was statistically significantly higher in trauma patients who had undergone the intervention through the posterior approaches only. These differences persisted within at least six months after the surgery. Quality of life in patients who had undergone open and percutaneous TPF differed significantly: percutaneous TPF was associated with a better quality of life during the postoperative period of less than six months. Later, this indicator was nearly the same for all groups (Table 5).

Radiographic evaluation of the spine condition 24 months after the surgery showed that frequency of consolidation of fractured vertebral fragments or bone block formation after the spinal fusion was approximately 90% for each study group. Pseudoarthrosis after the anterior spinal fusion through the anterior approach was detected in two (11.8 %) patients in Group 1 and two (10.5 %) patients in Group 5. For the extended posterior approach, it was detected in two (10.0 %) patients in Group 4. Incomplete consolidation (the state involving >2 mm diastasis between the fragments forming the marginal rims of the damaged vertebrae) after the surgeries involving isolated posterior instrumented fixation (Groups 2 and 3) was detected in seven (8.8 %) and six (8.6 %) patients, respectively. The differences between the three pairs of groups in terms of osseous coalescence parameters were statistically nonsignificant (Groups 1 and 2: $p = 0.4929$; Groups 2 and 3: $p = 0.8010$; Groups 4 and 5: $p = 0.6778$). Nevertheless, despite this fact, five patients in Group 2 and three patients in Group 3 needed subsequent revisional interventions for incomplete consolidation of vertebral fracture fragments more than 24 months after the primary surgeries.

In all cases, the performed surgical interventions provided sufficient levels of intraoperative correction of the existing post-traumatic spine deformities. Twenty-four months later, the critical loss of Cobb angle correction for kyphosis ⩾10°) was detected in one (5.9 %) patient, 14 (17.5 %) patients, 13 (18.6 %) patients, one (5.0 %) patient, and two (10.5 %) patients in study groups 1, 2, 3, 4, and 5, respectively. Moreover, the significant frequency of correction loss was because the short (four-screw) TPF systems had been used. The differences in this parameter between the all comparison pairs were statistically nonsignificant (Groups 1 and 2: $p = 0.2086$; Groups 2 and 3: $p = 0.8647$; Groups 4 and 5: $p = 0.4802$).

Comprehensive assessment of treatment outcomes using the modified MacNab scale 24 months after the surgery showed that the patients with excellent results more or less predominated in nearly all groups, with an exception of Group 4, where the situation was quite the opposite. No significant differences were revealed for all three comparison pairs (Table 6).

Discussion

In our opinion, the following aspects can be selected among the most important circumstances that are potentially able to determine the decision-making regarding the choice of the algorithm and the scope of surgical treatment for the analyzed category of trauma patients. These aspects are arranged in descending order according to the influence they have on decision-making.

Surgeon's hands-on experience. The pathogenetically justified method for surgical treatment of trauma patients with type A spinal fractures is to perform an intervention exclusively on the damaged anterior spinal column through the anterior approach that corresponds to trauma localization, thus leaving the anatomical structures of the posterior column intact [7, 8]. Various types of posterior instrumented fixation of the spine are other options of surgical intervention in such situations. In most cases, they are based on the phenomenon of ligamentotaxis that ensures shape reconstruction of the fractured vertebral body without any interventions to the anterior

Table 1

Statistical analysis of the homogeneity of groups of patients with uncomplicated isolated burst fractures of the thoracic and lumbar spine

Parameters for comparison	Group 1 (n = 17)	Group 2 (n = 80)	Group 3 (n = 70)	Group 4 (n = 20)	Group 5 (n = 19)
Age, years					
Min/max	19/51	18/60	28/60	24/47	26/49
Median (25th/75th percentile)	34 (27/42)	37 (30/42)	38 (33/43)	34.5 (31/41.5)	39 (34/43)
p value	Groups 1 and 2: p = 0.5405; Groups 2 and 3: p = 0.1387; Groups 4 and 5: p = 0.2493				
Sex, n (%)					
Male	12 (70.6)	43 (53.7)	48 (68.6)	12 (60.0)	11 (57.9)
Female	5 (29.4)	37 (46.3)	22 (31.4)	8 (40.0)	8 (42.1)
p value	Groups 1 and 2: p = 0.3159; Groups 2 and 3: p = 0.0638; Groups 4 and 5: p = 0.8477				
Fracture localization, n (%)					
Thoracic spine	8 (47.1)	42 (52.5)	29 (41.4)	12 (60.0)	9 (47.4)
Lumbar spine	9 (52.9)	38 (47.5)	41 (58.6)	8 (40.0)	10 (52.6)
p value	Groups 1 and 2: p = 0.8883; Groups 2 and 3: p = 0.1755; Groups 4 and 5: p = 0.6386				

Table 2

Comparative analysis of the parameters of inpatient treatment of patients in the study groups

Parameters for comparison	Group 1 (n = 17)	Group 2 (n = 80)	Group 3 (n = 70)	Group 4 (n = 20)	Group 5 (n = 19)
Post-injury period*, days					
Min/max	3/9	1/7	1/3	6/12	8/15
Median (quartiles)	6 (4/7)	3 (2/4)	2 (2/3)	9.5 (8.5/10.5)	11 (9/12)
Postoperative length of stay, days					
Min/max	8/18	7/15	3/7	9/20	10/22
Median (quartiles)	10 (9/11)	8 (7/9)	4 (3/5)	11 (10/12.5)	14 (12/15)
p value	Groups 1 and 2: p = 0.0001; Groups 2 and 3: p = 0.0001; Groups 4 and 5: p = 0. 0015				
Operative time, min					
Min/max	140/235	80/130	65/130	190/305	315/405
Median (quartiles)	190 (175/205)	100 (85/105)	90 (75/100)	250 (215/272.5)	350 (330/380)
p value	Groups 1 and 2: p = 0.0001; Groups 2 and 3: p = 0.0007; Groups 4 and 5: p = 0.0001				
Blood loss (intraoperative and drainage-associated), ml					
Min/max	610/1050	420/690	30/110	760/1480	1090/1920
Median (quartiles)	820 (750/910)	510 (470/570)	70 (60/80)	920 (860/1070)	1590 (1480/1780)
p value	Groups 1 and 2: p = 0.0001; Groups 2 and 3: p = 0.0001; Groups 4 and 5: p = 0.0001				
Patients requiring transfusion of blood components, n (%)	11 (64.7)	13 (16.3)	0 (0.0)	17 (85.0)	19 (100.0)
p value	Groups 1 and 2: p = 0.0001; Groups 2 and 3: p = 0.0002; Groups 4 and 5: p = 0.2308				
Postoperative stay in the intensive care unit, n (%)	12 (70.6)	9 (11.3)	0 (0.0)	13 (65.0)	19 (100.0)
p value	Groups 1 and 2: p = 0.0001; Groups 2 and 3: p = 0.0036; Groups 4 and 5: p = 0.0083				

* Comparative analysis makes no practical sense.

column of the spine, but they can also be combined. However, even posterior fixation of the spine (transpedicular, laminar or hybrid one) is inevitably accompanied by an additional intraoperative injury to the posterior support complex [9, 10]. If any manipulations for surgical reconstruction of the damaged ventral column through the posterior approach (prosthetic repair involving formation of one- or two-segment interbody bone block within the injury site using a ver-

Table 3
Comparative analysis of postoperative complications, n (%)*

Complication types	Group 1 (n = 17)	Group 2 (n = 80)	Group 3 (n = 70)	Group (n = 20)	Group 5 (n = 19)
Local infectious and necrotic complications (the total number)	3 (17.6)	6 (7.5)	1 (1.4)	2 (10.0)	3 (15.8)
p value	Groups 1 and 2: p = 0.1906; Groups 2 and 3: p = 0.1221; Groups 4 and 5: p = 0.6614				
including marginal wound necrosis	2 (11.8)	2 (2.5)	0 (0.0)	0 (0.0)	2 (10.5)
including superficial wound abscess	1 (5.9)	3 (3.8)	1 (1.4)	1 (5.0)	1 (5.3)
p value	Groups 1 and 2: p = 0.1430; Groups 2 and 3: p = 0.2156; Groups 4 and 5: p = 0.3416				
including deep wound infections	0 (0.0)	1 (1.3)	0 (0.0)	1 (5.0)	0 (0.0)
p value	Groups 1 and 2: p = 1.0; Groups 2 and 3: p = 1.0; Groups 4 and 5: p = 1.0				
Fracture/migration of metal constructs	0 (0.0)	2 (2.5)	1 (1.4)	0 (0.0)	0 (0.0)
p value	Groups 1 and 2: p = 1.0; Groups 2 and 3: p = 1.0				
Neuropathy of truncal nerves	10 (58.8)	0 (0.0)	0 (0.0)	0 (0.0)	10 (52.6)
Acute pleurisy	1 (5.9)	0 (0.0)	0 (0.0)	0 (0.0)	2 (10.5)
General complications (the total number)	2 (11.8)	5 (6.3)	0 (0.0)	2 (10.0)	2 (10.5)
p value	Groups 1 and 2: p = 0.6023; Groups 2 and 3: p = 0.0611; Groups 4 and 5: p = 1.0				
including lobular segmental pneumonia	1 (5.9)	3 (3.8)	0 (0.0)	1 (5.0)	1 (5.3)
p value	Groups 1 and 2: p = 0.5435; Groups 2 and 3: p = 0.2483; Groups 4 and 5: p = 1.0				
including thrombembolism of small pulmonary arteries	1 (5.9)	2 (2.5)	0 (0.0)	1 (5.0)	1 (5.3)
p value	Groups 1 and 2: p = 0.4428; Groups 2 and 3: p = 0.4989; Groups 4 and 5: p = 1.0				

* The number of cases developed for each complication and its frequency in the given study group.

tebral body replacement implant) are needed, the degree of additional injury increases because of extended laminectomy involving facet joint resection, transversectomy in the lumbar spine, or costotransversectomy involving tractotomy of the spinal root in the thoracic spine [11].

Anterior approaches to the thoracic and lumbar spine and the methods for its anterior instrumented fixation are characterized by significant complexity, as well as high risk of traumatization during surgical interventions [12, 13]. In this connection, it is quite reasonable to assume that the choice of a surgical approach and, consequently, the method of instrumented spine fixation for the discussed fracture type depends largely not only on objective factors (e.g. institutional environment, as well as technical facilities available for surgical treatment), but mostly on such an internal reason as surgeon's hands-on experience. In order to determine the possible influence of this factor, we interviewed 46 neurosurgeons, trauma surgeons, and orthopedic surgeons who operate patients with spine traumas at medical institutions (varying in terms of their level and jurisdiction) in St. Petersburg, Moscow, and some other large cities of Russia. The surgeons were interviewed during personal contacts throughout daily activities, as well as during the relevant industry-specific research and practical events. The results of the interview revealed that each surgeon has mastered the technique of performing open thoracic and lumbar spine surgeries through the posterior approach involving TPF. As far as the minimally invasive methods including those with percutaneous TPF were concerned, only 18 respondents (39.1 %) were able to perform them. The interventions through the open anterior approaches could be carried out by six (13.0 %) respondents only.

Type of a medical institution and the features of its organizational management. Specialized medical care for patients with spine and spinal cord injuries can be rendered under fundamentally different institutional environments. They are characterized by two aspects. The first aspect means the specialty profile of the medical institution: whether it is a multidisciplinary in-patient emergency hospital (a municipal or interdistrict hospital, a research institute of emergency medicine, or a military hospital), or a specialized medical institution (a research institute or a center of traumatology and orthopedics/neurosurgery) [14, 15]. The second aspect arises out of the first one and means that, contrary to the specialized medical institutions, multidisciplinary in-patient emergency hospitals are characterized by an enormous time-constant patient flow, which is extremely heterogeneous in terms of pathology of patients both being admitted and hospitalized. Moreover, the latter factor obviously determines the peculiar features of utilization of the hospital bed capacity, as well as the financial, material, technical and human resources in general, and those of the vertebrological service in particular. These two aspects are associated with an important factor for the medical institution: the possibility to have specialists who have mastered the maximally wide range of surgical inter-

ventions to the spine and can perform them when it is necessary.

The technological facilities of the vertebrological service in a medical institution. When analyzing the potential impact of this factor on treatment choice, it should be nowadays considered indisputable that the possibility of easily using the adequate surgical techniques by the vertebrological service of a medical institution is an essential condition for reaching high clinical outcomes [5, 15]. It is starkly obvious that for the multidisciplinary emergency care hospitals (which deal with the major part of managing patients with acute spine and spinal cord injuries in Russia), it should be optimal to use the relatively technically simple, easily reproducible, less traumatic, and, at the same time, sufficiently effective and adequate techniques offered by modern surgical vertebrology. In the context of patients with uncomplicated burst fractures of the thoracic and lumbar vertebrae, the

Table 4

Comparative analysis of pain dynamics assessed using the Numeric Rating Scale (NRS) during the postoperative period, n (%)

Duration of postoperative follow-up	Group 1 (n = 17)	Group 2 (n = 80)	Group 3 (n = 70)	Group 4 (n = 20)	Group 5 (n = 19)
At discharge					
Pain syndrome, total	12 (70.6)	23 (28.8)	4 (5.7)	5 (25.0)	14 (73.7)
p value*	Groups 1 and 2: p = 0.0028; Groups 2 and 3: p = 0.0006; Group 4 and 5: p = 0.0065				
Mild pain (score 1–3)	9 (52.9)	15 (18.8)	3 (4.3)	3 (15.0)	10 (52.6)
Moderate pain (score 4–6)	3 (17.7)	8 (10.0)	1 (1.4)	2 (10.0)	4 (21.1)
p value**	Groups 1 and 2: p = 0.2962; Groups 2 and 3: p = 0.0273; Groups 4 and 5: p = 0.3053				
One month postoperatively					
Pain syndrome, total	10 (58.8)	11 (13.8)	3 (4.3)	3 (15.0)	11 (57.9)
p value*	Groups 1 and 2: p = 0.0002; Groups 2 and 3: p = 0.0415; Groups 4 and 5: p = 0.0064				
Mild pain (score 1–3)	7 (41.2)	8 (10.0)	3 (4.3)	2 (10.0)	7 (36.8)
Moderate pain (score 4–6)	3 (17.6)	3 (3.8)	0 (0.0)	1 (5.0)	4 (21.1)
p**	Groups 1 and 2: p = 0.0647; Groups 2 and 3: p = 0.1490; Groups 4 and 5: p = 0.1548				
Three months postoperatively					
Pain syndrome, total	8 (47.1)	3 (3.8)	1 (1.4)	2 (10.0)	9 (47.4)
p value*	Groups 1 and 2: p = 0.0001; Groups 2 and 3: p = 0.3619; Groups 4 and 5: p = 0.0116				
Mild pain (score 1–3)	6 (35.3)	2 (2.5)	1 (1.4)	2 (10.0)	7 (36.8)
Moderate pain (score 4–6)	2 (11.8)	1 (1.3)	0 (0.0)	0 (0.0)	2 (10.6)
p**	Groups 1 and 2: p = 0.0784; Groups 2 and 3: p = 0.5333; Groups 4 and 5: p = 0.2561				
Six months postoperatively					
Mild pain (1–3 points)	4 (23.5)	1 (1.3)	0 (0.0)	1 (5.0)	4 (21.1)
p value*	Groups 1 and 2: p = 0.0031; Groups 2 and 3: p = 0.5333; Groups 4 and 5: p = 0.1548				

* The results of comparative analysis for the percentage of patients having pain of any intensity.

** The results of comparative analysis for the percentage of patients having moderate pain.

Table 5

Assessment of patients' quality of life after the surgery according to the ODI scale, %

Patient groups	ODI: median (quartiles)			
	3-month follow-up	6-month follow-up	12-month follow-up	24-month follow-up
1 (n = 17)	30 (28/32)	26 (24/26)	8 (6/8)	8 (8/8)
2 (n = 80)	22 (20/24)	16 (16/18)	8 (6/10)	8 (6/10)
3 (n = 70)	22 (20/22)	16 (15.5/18)	8 (6/10)	8 (6/8)
4 (n = 20)	28 (26/32)	22 (20/22)	8 (7/8)	8 (8/10)
5 (n = 19)	32 (30/38)	26 (24/26)	8 (6/8.9)	8 (8/10)
p value for Groups 1 and 2	0.0001	0.0001	0.6937	0.9962
p value between Groups 2 and 3	0.0004	0.0879	0.6324	0.5207
p value between Groups 4 and 5	0.0004	0.0001	0.6940	0.8883

Table 6

The treatment outcomes for the patients 24 months after the surgery assessed using the modified MacNab scale, n (%)

Treatment outcomes	Group 1 (n = 17)	Group 2 (n = 80)	Group 3 (n = 70)	Group 4 (n = 20)	Group 5 (n = 19)
Excellent (patients returned to work)	10 (58.8)	49 (61.3)	40 (57.1)	9 (45.0)	11 (57.9)
Good (patients switched to less demanding work)	7 (41.2)	26 (32.4)	27 (38.6)	11 (55.0)	8 (42.1)
Fair	0 (0.0)	5 (6.3)	3 (4.3)	0 (0.0)	0 (0.0)
p value*	Groups 1 and 2: p = 0.5828; Groups 2 and 3: p = 0.7242				
p value**	Groups 1 and 2: p = 0.8218; Groups 2 and 3: p = 0.4885; Groups 4 and 5: p = 0.6278				

* The results of comparative analysis of the number of trauma patients with fair treatment outcomes performed to assess the overall treatment efficacy.

**The results of comparative analysis of the ratio between the numbers of trauma patients with excellent and good outcomes performed to assess the level of the patients' returning to work.

posterior transpedicular (as well as laminar and hybrid) instrumented spine fixation performed through the conventional open surgical approaches meets all these conditions to the maximum extent. Application of minimally invasive TPF by the vertebrological services at such medical institutions should be considered extremely desirable, because, due to their relatively low traumaticity, they can potentially promote the optimized use of financial, material, technical and human resources, as well as contribute to improvement of the quality of life of trauma patients during treatment.

Hence, the decision-making algorithm and technical choice of surgical treatment for patients with isolated uncomplicated burst fractures of the thoracic and lumbar vertebrae should be built using the following four key factors (Table 7).

Factor I: time from injury. This factor determines whether repositioning through the posterior approach using ligamentotaxis without immediate intervention to the anterior vertebral column is possible. Although the existing publications provide no direct instructions concerning the age of trauma, based on our own clinical experience, we have drawn a conclusion that repositioning is possible within the period of up to 3 days after the trauma, regardless of the used techniques of posterior instrumented fixation. Repositioning is usually possible if the time from injury is 3–7 days; the open posterior approach is optimal for its successful implementation. If the time from injury is more than 7 days, repositioning is most often infeasible.

Factor II: the surgeon's experience. This factor determines whether the surgeons can perform a spine surgery only through the open posterior approaches, through open and minimally invasive posterior approaches, or through any approach.

Factor III: patient's physical status. This factor means whether a patient has or does not have any somatic diseases, which could affect the surgical approach in terms the volume of surgical intervention: favorable (Class I according to the ASA scale) – a surgery of any volume is possible; unfavorable (Classes II–IV according to the ASA scale) – the volume of the surgery should be limited.

Factor IV: type of the medical institution. This factor characterizes the institution and the conditions of specialized medical care for patients with spine pathology: a multidisciplinary emergency medicine hospital or a specialized (traumatological, orthopedic or neurosurgical) hospital.

Meanwhile, in the context of the problem discussed, the optimal variants of surgical treatment should be not only the interventions that meet the modern principles of surgical vertebrology to the full extent and make it possible to achieve the necessary clinical anatomical outcomes (reconstruction of the physiological shape and balance of the vertebral column), but also the interventions equally meeting the following two groups of requirements according to their clinical and technical characteristics:

1) providing the optimal conditions for the maximally quick, complete and safe recovery of patient's health status, as well as his/her social activity;

2) ensuring the maximally efficient utilization of the labor, territorial, technical, financial, and other resources of a medical institution, as well as of the entire healthcare system for the administrative institution within which and under whose jurisdiction it functions.

Less optimal but still possible variants of surgical treatment (because of more complicated performance, costs, and traumacity for patients) are characterized by lower convenience for the patient: poorer quality of life in the postoperative period in general (as assessed according to the relevant scales) and quality of life assessed using such parameters as how quickly he/she returned to normal social activity and could be engaged in work. Another drawback of the less optimal treatment variants is that the resources of the hospital and the healthcare system in general are utilized less efficiently. Meanwhile, the key conditions determining whether these vari-

ants can be utilized in clinical practice are as follows: first, sufficient experience of the operating surgeons to perform such interventions and, second, delivery of specialized aid at a specialized medical institution (a research institute or a center of traumatology and orthopedics).

Conclusion

Today, decision-making and technical choice in instrumented fixation for neurologically uncomplicated isolated burst fractures of the thoracic and lumbar vertebrae should be situation-based. The decision-making algorithm should be built according to the following parameters: surgeon's experience, the time from injury, patient's health status, as well as the administrative and logistical context of providing specialized medical care.

Open or minimally invasive posterior instrumented spinal fixation using the systems including six screws for incomplete burst fractures (type A3) and up to 8–10 screws for complete burst fractures (type A4) should be considered the best option for surgical intervention in the nearest post-injury period (up to 7 days), both in terms of the convenience and safety for the patient and in terms of the maximally efficient utilization of all resources of the medical institution.

Application of open anterior approaches for ventral column reconstruction in patients study can be reasonable only if the time from injury exceeds 7 days and if combined surgeries are performed (mainly in combination with minimally invasive posterior transpedicular fixation).

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Table 7

Decision-making and technical choice in instrumented fixation for neurologically uncomplicated isolated burst fractures of the thoracic and lumbar vertebrae

Time from injury	Physical status of the patient	Types of in-patient hospitals	Therapeutic approach and technical choice of surgical treatment
Up to 3 days*	Favorable (ASA I)	Multidisciplinary	Open posterior instrumented fixation (without laminectomy). Minimally invasive TPF (without laminectomy
		Specialized	Optimal: open posterior instrumented fixation (without laminectomy); minimally invasive TPF (without laminectomy). Acceptable: anterior spinal fusion with anterior instrumented fixation (the isolated open anterior approach)
	Unfavorable (ASA II–IV)	Multidisciplinary	Optimal: minimally invasive TPF (without laminectomy).
		Specialized	Acceptable: open posterior instrumented fixation (without laminectomy)
From 3 to 7 days*	Favorable (ASA I)	Multidisciplinary	Open posterior instrumented fixation (without laminectomy)
		Specialized	Optimal: open posterior instrumented fixation (without laminectomy). Acceptable: anterior spinal fusion with anterior instrumented fixation (the isolated open anterior approach)
	Unfavorable (ASA II–IV)	Multidisciplinary	Open posterior instrumented fixation (without laminectomy)
		Specialized	
More than 7 days**	Favorable (ASA I)	Multidisciplinary	Posterior instrumented fixation with extended laminectomy
		Specialized	Optimal: posterior instrumented fixation with extended laminectomy. Minimally invasive TPF + anterior spinal fusion through the conventional open approach. Acceptable: open posterior fixation + anterior spinal fusion through the conventional open approach
	Unfavorable (ASA II–IV)	Multidisciplinary	Posterior instrumented fixation with extended laminectomy
		Specialized	

* For the cases of effective reposition through the posterior approach without laminectomy (without intervention to the anterior vertebral column).

** If the injury occurred more than 7 days ago and for fresher traumas in case of ineffective reposition through the posterior approach without laminectomy (without intervention to the anterior vertebral column).

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