A comparison of direct lateral and transforaminal lumbar interbody fusions – clinical and radiological outcomes

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In our study, we compared the clinical and radiological results of operation treatment DLIF and TLIF in patients with degenerative disc disease of the lumbar spine

Key words: DLIF – direct lateral interbody fusion , TLIF – transforaminal interbody fusion, spinal motion segment instability, intraoperative computer tomography, navigation system

Porovnanie operačnej liečby bočnej a transforaminálnej medzitelovej fúzie v driekovej chrbtici – klinické a rádiologické výsledky

V našej štúdii sme porovnávali klinické a rádiologické výsledky operačnej liečby metódou DLIF a TLIF u pacientov s degeneratívnym postihnutím driekovej chrbtice.

Kľúčové slová: DLIF – priama laterálna medzitelová fúzia, TLIF – transforaminálna lumbálna medzitelová fúzia, instabilita segmentu chrbtice, perioperačná počítačová tomografia, navigačný systém

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Study design

In conditions of population average life expectancy increase among developed countries, improvement of diagnostic methods has led to an increase in number of patients with degenerative spinal diseases who are in need the hi-tech surgical treatment. In response to an increase in number of patients with spinal degenerative diseases, new, mostly minimally invasive, surgical technologies are introduced into clinical practice. The effectiveness of surgical treatment, first of all, depends on the correct choice of intervention and the quality of its implementation.

Objectives

To carry out a comparative analysis of the outcomes of surgical treatment of patients with vertebral motion segment instability of the lumbar spine treated with transforaminal lumbar interbody (TLIF) and direct lateral interbody fusion (DLIF).

Materials and methods

The 209 patients were followed up after surgery for lumbar vertebral motion segment instability. Our multicenter trial included patients from different institution's spinal departments: Spinal neurosurgery dept. of the FSAI "NRPCN named after academician NN Burdenko" (Moscow, Russia), Spinal neurosurgery dept. of the Clinical hospital №1 "Volynskaya" of the Presidential Property Management Department of the Russian Federation (Moscow, Russia), Spinal neurosurgery dept. of the District hospital „Traumatology Center" (Surgut, Russia) and в neurosurgery dept. of the Central military hospital (Ruzomberok, Slovakia). This fact, in turn, allowed us to enlarge our selection of patients, compare treatment results and objectify the obtained data. During the research we made a profile in a portal version of the Russian vertebrological register, which was developed in FSAI "NRPCN named after academician NN Burdenko" (Moscow, Russia), and allowed to insert both Russian and foreign colleague's patient data. This provided development of international cooperation and analysis of surgical treatment results of degenerative lumbar spine diseases in different countries.

This is a prospective study with a control group. Long-term outcomes (up to 2 years) were studied in 134 patients. All patients were divided into two groups: the first group of patients (98 patients) underwent traditional transforaminal lumbar interbody fusion (TLIF) and transpedicular stabilization of the vertebral segments. Patients from group II (36 patients) were treated with direct lateral interbody fusion (DLIF) in combination with transpedicular stabilization of vertebral segments.

The main criteria for inclusion/exclusion in the study are presented in Table 1.

Table 1. Main inclusion/exclusion criteria

Inclusion criteria	Exclusion criteria
Affected segment located between L2-L5 vertebra	Severe concomitant pathology
Age between 20 to 75 years	Age < 20 years, > 75 years
Lower back pain with or without root compression syndromes and neurogenic claudication after orthopedic provocation tests	Spinal canal stenosis, estimated large amount of posterior vertebral support column resection
Duration of symptoms before surgery and absence of results from conservative treatment after 6-8 weeks	Previous spinal fusion at lumbosacral level
Signs of moderate segmental instability (shift of vertebrae from 4 to 10 mm) on functional spondylograms	II-IV degree spondylolisthesis (Meyerding cassification) with or without spondylosis
Instability with possible combinations of I degree spondylolytic spondylolisthesis, degenerative spondylolisthesis and spinal canal stenosis	Diseases impacting the development of degenerative lumbar spine changes (congenital spinal canal stenosis, previous trauma and spinal tumors, inflammatory lumbar spine diseases, etc)
Lesion of one or two lumbar vertebral motion segment causing clinical manifestations	Multisegmental spinal canal lesion (more than two segments)

All patient data was imputed into the patient profile with vertebral-motive segments instability. The profile was based at portal version of the Russian vertebrological register (http://www.spineregistry.ru/), which included patient's main characteristics and clinical signs. Patient's average age in both groups was 59±11,9 years. 55 (41%) males and 79 (59%) females were enrolled. According to the main characteristics there were no differences between male and female groups. Analysis of patient distribution based on level of surgical intervention showed no significant differences between two groups either. Traditionally the most often affected vertebral levels were L3-L4 and L4-L5.

When determining the indications for surgical treatment, standard criteria were used: symptom duration before surgery and absence of conservative treatment effect (6-8 weeks). Before surgery, all patients underwent a standard examination, including neurologic examination, functional spondylograms, CT and MRI of the lumbosacral spine.

We used standard time points for monitoring patient condition: before surgery, at discharge, at 3 months, 6 months, 9 months, 1 and 2 years after surgery. For dynamic observation, the following scales were used in the study:

- Visual analogue scale (VAS),
- Oswestry disability index (ODI),
- Goal Attainment Scale (GAS).

Surgical treatment outcome of patients with vertebral motion segment instability of the lumbar spine at long-term follow-up (12 and 24 months) was formulated in accordance with the modified criteria of Kawabata et al. (1973):

- I class (good outcome) – absence of complaints, pathological symptoms and normal results on objective examination, significant improvement, absence of disabling dysfunction (minor sensitive disorders and grade 4/5 paresis with improvement to at least one degree);
- Class II (poor outcome) – lack of positive dynamics (persistent complaints, severe neurologic deficit and atrophy) or worsening.

Outcome evaluation using modified criteria of Kawabata et al. allows for evaluation of neurologic symptoms and disease severity.

The international „gold standard“ for surgical treatment of vertebral motion segment instability of the lumbar spine is 360-degree stabilization of the vertebral segment, including interbody and transpedicular fusion with installation of various implants. Undoubtedly, the location of these devices in the spine diCTates the basic requirements for operating equipment, primarily the presence of intraoperative neuroimaging, like intraoperative fluoroscopy, being the most common and often used device.

At FSAI "NRPCN named after academician NN Burdenko", to improve patient's safety and quality of surgical care, for intraoperative visualization, cone-beam computed tomography and navigation system are used.

In the first patient group, interbody fusion was performed using the transforaminal access. Before surgery, in patient's prone position under endotracheal anesthesia, a 2D intraoperative CT scan is performed to determine the surgical intervention site. Next, surgical access to the spine is performed (a parasagittal skin incision 3-4 cm in length for the Wiltse approach). After surgical access is completed, a navigation frame is inserted into the iliac crest and a CT scan is performed in the 3D scan mode.

The next stage is the transforaminal placement of the interbody implant. First, a trial cage is inserted in the interbody space and the cage size is determined using the navigation system. Since the fusion is performed using navigated instruments, additional fluoroscopic control is not required. Next, under the control of a microscope, the cage is inserted into the interbody space and its position is controlled by navigation system (Figure 1).

After completing interbody spondylodesis, a 3D scan is performed to control the cage position and accuracy of the subsequent installation of transpedicular screws.

Transpedicular stabilization was performed using minimally invasive technology without additional muscle detachment or with percutaneous technique. On the side of the installed interbody cage, placement of transpedicular screws was made through the same access under the control of the navigation system. On the opposite side, a simi-

Figure 1. Transforaminal placement of interbody implant: A – placement of the cage in the interbody space with the help of navigated tools, B – intraoperative control of cage position and size using the navigation system

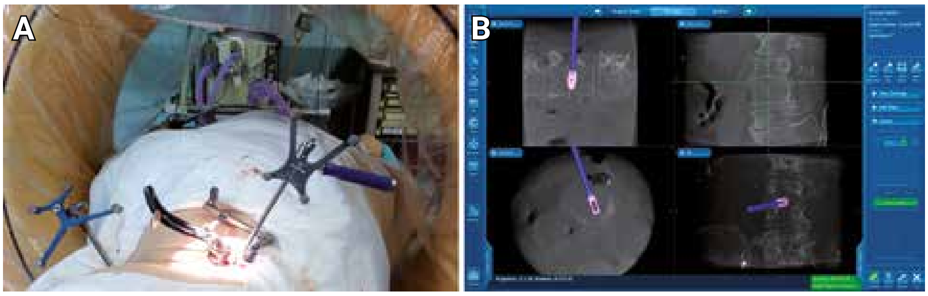


Figure 2. Patient positioning on the operating table when performing a direct lateral interbody fusion

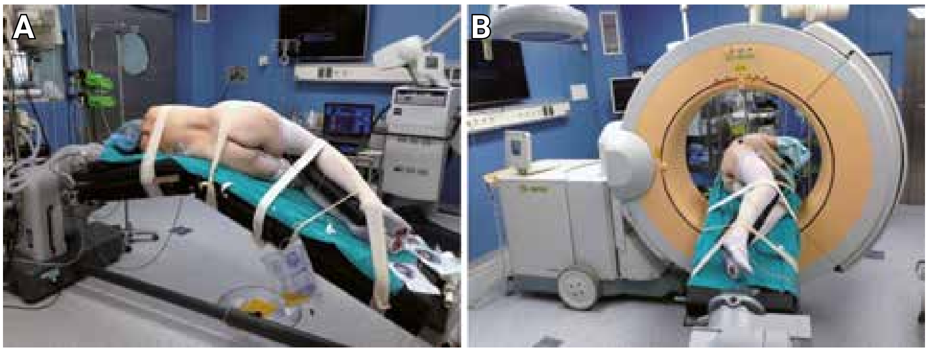
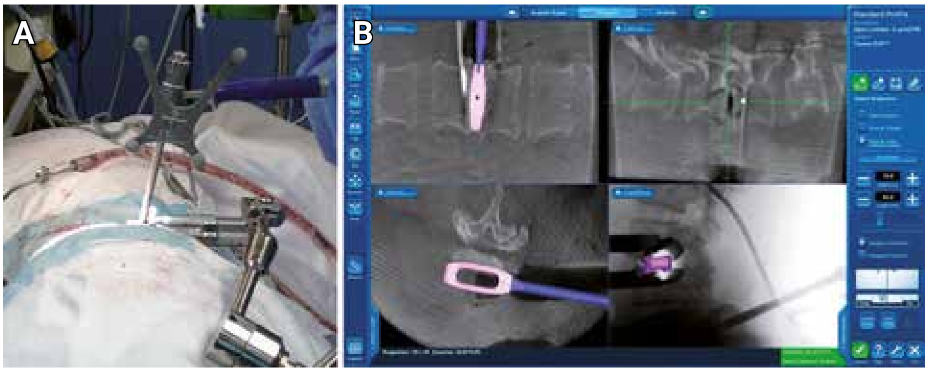


Figure 3. Placement of interbody implant using DLIF method: A – cage placement; B – intraoperative control of cage size and position using the navigation system



lar paravertebral incision of the skin, subcutaneous fat and aponeurosis was performed and screw insertion points were determined. After the transpedicular screw stabilization stage is complete, a iCT scan with 3D reconstruction is performed.

In the second patient group, surgical access to the anterior and middle columns of the spine was performed through the iliac muscle. Direct lateral interbody fusion is performed in patient lateral position; the permissible levels for implantation are L1-L5 vertebrae. This limitation is due to the presence of a costal arch in the cranial direction, and in the caudal one – the ilium wing. The choice of the side for the interbody cage installation is usually determined by the preference of the operating surgeon.

Nevertheless, it is technically easier to perform the operation on the side of the most „open“ interbody space. With degenerative scoliotic deformity – from the convexity of the arc, where the interbody space is higher and the distance between the iliac crest and the ribs is longer. Correction will be the same when accessed from either side, but it is technically easier to enter from the convex side. This is assessed at the stage of surgical planning using preoperative spondylograms and intraoperatively, after positioning the patient on the operating table and using fluoroscopic control (using intra-operative CT scanning in 2D scanning mode or fluoroscopy) (Figure 2).

When passing the cage through the iliac muscle to the anterior and middle columns of the spine, one should remember the surrounding anatomical structures that could potentially be damaged. First of all, this is the lumbar plexus.

To avoid damage to the branches of the lumbar plexus, primarily the genitofemoral nerve, which is formed from the upper lumbar spinal nerves and located along the anterior surface and in the thickness of the lumbar muscle, intraoperative neuromonitoring (IONM) should be used.

After positioning the patient on the operating table and placing IONM electrodes, we use intraoperative CT in 2D mode or fluoroscopy during the layout stage to mark the entry point to the interbody space, which is determined directly in the projection of the vertebral disk.

After confirming the absence of a signal from the lumbar plexus branches, in a series of twisting movements, dilators from minimum size to maximum are introduced, along which the retractor is lowered. The free end of the retractor is rigidly fixed to the operating table. Then the dilators are removed and a discectomy is performed. After performing the discectomy, the cage is selected using the trial template for the size of the interbody space using the navigation system (Figure 3).

After completing of the interbody spondylodease phase under the control of the navigation system (Spinal neurosurgery dept. of the FSAI "NRPCN named after academician NN Burdenko" (Moscow, Russia) or under fluoroscopic control (Spinal neurosurgery dept. of the Clinical hospital №1 "Volynskaya" of the Presidential Property Management Department of the Russian Federation (Moscow, Russia), Spinal neurosurgery dept. of the District hospital „Traumatology Center“ (Surgut, Russia) and в neurosurgery dept. of the Central military hospital (Ruzhomberok, Slovakia)) percutaneous transpedicular stabilization was performed using standard techniques or transpedicular stabilization using minimally invasive technology (the same way as in patient group I).

Results

For statistical processing "Microsoft Excel“ and „Statistica 8“ were used. The probability $p<0.05$ was considered sufficient to conclude that the differences were reliable; at p>0.05, the difference between the values was regarded as statistically unreliable.

Analysis of main opportunities and advantages of using ICT with navigation system in surgical treatment of degenerative diseases of the spine was conducted. During operations, surgical time was monitored. Duration of the first surgical interventions with the use of iCT and navigation system was higher, which is associated with mastering the system. However, in the learning process, there was a tendency for shortening of surgical time. It is important to note that in cases of using iCT and navigation system during the stabilization phase (interbody and transpedicular), there is no radiation exposure to the operating brigade, since at the time of 3D scanning (duration 13-23 seconds), medical personnel, with the exception of an anesthesiologist, are not present in the operating room, and the subsequent installation of implants is carried out under the control of the navigation system. The accuracy of implant placement was assessed on the basis of post-operative iCT analysis with 3D reconstruction.

During the stabilizing stage of operations, requiring installation of interbody implants and transpedicular screws, including percutaneous techniques, intraoperative computed tomography and navigation system were used to determine the intervention zone, conduct intraoperative control of implant placement accuracy, control of intervertebral disc height restoration and the diameter of the intervertebral foramen. After operation completion, 3D scanning and 3D reconstruction were performed. In our opinion, the use of an intraoperative computed tomography with a navigation system is especially important in cases when surgical treatment is performed in complex anatomical conditions (thin pedicles, scoliosis or posttraumatic deformation of the spine), and the use of two-dimensional images does not provide a full visualization of the operation zone. In addition, the use of iCT and navigation system is useful for neurosurgeons in clinics where fusion surgeries and percutaneous techniques are rare or are just being mastered.

In both groups of patients, in the nearest postoperative period (at the time of discharge), there was a significant decrease in lower back pain and leg pain (according to the VAS scale), which persisted in the long-term period. In the early postoperative period, the majority of patients (in group 1 – in 81% of patients, in group 2 – in 95%) showed complete or partial regression of radicular pain the next day after surgery. Evaluation of postoperative pain at 3, 6, 9 months, 1 and 2 years after surgery, showed was a persistent decrease of leg pain in both patient groups. However, in the second group, the intensity of lower back pain and leg pain on VAS scale in the long-term follow-up (more than a year after surgery) was almost two times lower (p<0.05) (Table 2).

In assessing patient disability using the Oswestry disability index before surgery, the following data was obtained: in patients of the 1st group 79.63±3.75, in patients of the 2nd group 73.45±4.2, which indicates a high disability of patients in the preoperative period.

In both patient groups in the nearest postoperative period (at the time of discharge) a significant decrease in patient quality of life was noted: in the first group of patients 33.19±2.4, in the second group 27.89±2.9. In the long-term follow-up period, we obtained a gradual decrease in the index of work incapacity. Differences in evaluation patient quality of life using the Oswestry disability index in both groups of patients were not detected (p<0.05).

In both groups, we analyzed the level of achievement of treatment goals for patients one year after surgery. The best result was noted in the second group of patients, who underwent spinal fusion using DLIF technology. In both groups, the goal of treatment was not achieved in some patients: in the first group – in 11 (11.2%) patients, in the second group – in 2 (5.6%) patients.

When assessing the duration of surgery, it was found that the duration of the first surgical interventions using DLIF technology was higher, which is associated with the mastery a new technique. However, in the course of training within half a year there was a tendency for a decrease in duration of operations. There was no statistically significant difference in the duration of interbody fusion performing TLIF and DLIF.

Analysis of intraoperative blood loss showed statistically significant differences in both groups. In the first group of patients, when interbody fusion was performed with a single cage, the magnitude of intraoperative blood loss was 33 % higher than in the second group. None of the patients undergoing TLIF and DLIF needed to undergo blood transfusion.

The average hospital stay in both groups of patients was 7±4 days, with no statistically significant differences between the subgroups.

X-ray, CT and MRI studies conducted at 3, 6, 12 months, 1 and 2 years after the operation, revealed no cases of implant destruction and insertion into the vertebral bodies. Signs of bone resorption around the interbody cage were noted in the first group of patients in 9 cases, which we regarded as an unformed interbody block. In the second group, there were no such changes.

Thus, the implementation of direct lateral interbody fusion (DLIF) in combination with transpedicular fixation leads to the formation of an interbody block.

When analyzing the results, we found that good outcomes (class I) in the first group (using TLIF technology) were achieved in 79 patients (81%), in the second group (using DLIF technology) in 32 patients (89%).

Surgical complications in both study groups were typical for these types of surgical procedures. No infectious complications, as well as complications associated with the use of implants: their incorrect position and migration were noted.

Damage to the dura mater, which occurred in 1 patient from the first group, was eliminated by careful suturing and hermetic sealing of the dura at the final stage of the surgery.

In the postoperative period neurological deficit was noted in the form of paresis and hypesthesia in the leg resulting from postoperative edema of the spinal cord roots in 12 (12%) patients

Table 2. Dynamic of pain intensity by VAS, M ± SD

Patient group	Follow-up period						
	Before surgery	At discharge	After 3 months	After 6 months	After 9 months	After 1 year	After 2 years
Intensity of lower back pain							
Group I	7.8± 2.19	4.26± 1.17*	3.12± 1.7*	3.05± 1.38*	2.89± 1.68*	2.73± 1.2*	2.6± 1.89*
Group II	8.06± 1.87	3.21± 1.56*	2.78± 1.95*	2.3± 1.19*	1.91± 1.35*	1.76± 1.46*	1.4± 1.51*
Intensity of leg pain							
Group I	5.67± 1.84	2.3 ± 1.8*	2.0± 1.17*	1.6± 1.32*	1.4± 1.1*	1.38± 1.24*	1.26± 1.14*
Group II	6.14± 2.32	1.8± 1.14*	1.47± 0.7*	1.08± 0.6*	0.87± 0.5*	0.81± 0.4*	0.66± 0.41*

**The difference with the preoperative index is reliable; p<0.05*

from the first group and 4 (11%) from the second group. With complex conservative treatment for up to 2 months, there was a partial or complete restoration of lost functions.

Delayed healing of the postoperative wound was noted in 5 (5%) patients from the first group and in 2 (5.6%) patients from the second group. This required additional placement of secondary skin sutures in the early postoperative period the, which were removed after the formation of a scar (10–12 days after surgery).

Discussion

The main task of surgical treatment of patients with vertebral motion segment instability of the lumbar spine is to restore the stability to the vertebral segment and eliminate compression of the nerve structures. The difficulty in choosing the optimal surgical treatment option for these patients is the need to take into account various factors, including the degree of instability, the presence of spondylolisthesis and stenosis, clinical manifestations, methods of neuroimaging, treatment goals, concomitant diseases, patient's age etc. The choice of the most effective and safe method for treating vertebral motion segment instability of the lumbar spine should be performed on the basis of a comprehensive analysis of each therapeutic and tactical situation separately and taking into account the outcome prognosis data.

The most common minimally invasive methods for spinal fusion are the technology of transforaminal lumbar interbody fusion (TLIF) and direct lateral interbody fusion (DLIF) (1, 2), which were used to treat patients in our study.

DLIF technology has established itself as a highly effective technique for correcting sagittal and frontal spinal balances and laterolisthesis (1, 3). The cage, placed using DLIF method, is larger in size, has a larger contact area than other implants and is supported by dense part of the vertebral endplate, thereby creating greater support for the front column while maintaining the middle and posterior columns of the spine. Thus, lateral interbody fusion does not require resection of bone structures and avoids traumatization of nerve structures (4). In this case, indirect decompression is performed without opening the spinal canal, the height of the interbody space and the diameter of the intervertebral foramen are restored (5).

Preservation of the anterior and posterior longitudinal ligaments using DLIF technology plays an important role in preventing anterior and posterior migration of the cage and increasing dynamic stability in connection with ligamentotaxis (6). In our series, there were no complications associated with migration of the interbody implant, which confirms the above hypothesis.

The incidence of complications with DLIF technology varies from 0.7% to 62.7% (7, 8, 9). The most common complications include damage to the branches of the lumbar plexus, which leads to weakness of the hip flexors and sensitivity disorders (10, 11, 12). This necessitates the use of intraoperative neuromonitoring (IONM) in the DLIF procedure to prevent damage to the lumbar plexus roots passing through the lumbar muscle, visual control of which is difficult, and the damage to the roots during traction when installing the cage (10). With the use of IONM, the incidence of complications with direct lateral interbody fusion gradually decreased to 20% (8, 9, 12). In our study, the incidence of complications with DLIF technology was 11 %, which is due to the additional advantage of using an intraoperative computed tomography and a navigation system.

Conclusions

1. The use of direct lateral interbody fusion (DLIF) in combination with transpedicular screw stabilization allowed to restore sagittal balance in 89% of the patients, frontal balance in 85% of patients and to achieve formation of spinal fusion in 9 months after surgery in 89% of the patients studied.
2. Indirect decompression with the technology of direct lateral interbody fusion (DLIF) minimizes the risks of intraoperative damage to dural sack and neural structures.
3. Outcomes of class I according to Kawabata (good) were achieved in 89% of cases using the technology of direct lateral interbody fusion (DLIF) and in 81% of patients who underwent transforaminal lumbar interbody fusion (TLIF) in combination with transpedicular screw fixation.
4. The developed profile of the vertebrological register with the possibility of imputing data in Russian and English languages allows to accumulate information about patients, who were surgically treated with direct lateral interbody fusion (DLIF), within the scope of international cooperation.
5. The use of intraoperative computed tomography and navigation system increases safety and provides high accuracy of implant placement, shortens the duration of the stabilization phase and reduces the amount of radiation load on the operating team and the patient.

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