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Minimally invasive decompression alone versus fusion surgery for acute lumbar disk herniation combined incomplete cauda equina syndrome

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ABSTRACT

Study design: Retrospective single center study.
Background: Cauda equine syndrome (CES), which caused by acute lumbar disc herniation (LDH), often requires urgent surgical treatment. Currently, there is no standard defining the type of surgery, and approaches to the treatment of patients are based on the experience of the surgeon.
Purpose: to compare the clinical efficacy of minimally invasive decompression alone (Decompression alone group) and transforaminal lumbar interbody fusion (Fusion group) in the treatment of the incomplete CES, caused by acute LDH.
Patients and methods: 89 patients with acute incomplete CES associated with LDH either underwent decompression alone and fusion surgery from January 2005 to January 2020 in single-center, and data were collected and retrospectively analyzed. The patients were divided into 2 groups according to the operation technics: the Decompression alone group (n = 46) and the Fusion group (n = 43). The perioperative clinical data (neurological deficit, control of the urinary bladder sphincter, ODI scale, SF-36) was used to assess the efficacy of the respective surgical methods before operation and with a minimum follow-up 24 months.
Results: Verified statistical significance more bleeding, longer surgery time and hospital stay, in the Fusion group than in the Decompression alone group. The postoperative clinical data dramatic improved after Decompression alone and Fusion surgery. At early postoperative period registered better clinical outcomes according to ODI, SF-36 after Decompression alone surgery, but at minimum follow-up 24 months verified better in the Fusion group. The number of revision interventions in the Decompression alone group was 28.3% (n = 13), in Fusion group – 9.3% (n = 4) (p = 0.02).
Conclusions: The prevalence of acute incomplete CES due to LDH in our series was registered in 1.02% of patients (124 of 12087). In the Fusion group, in the long-term period, there were better clinical outcomes and fewer revision surgical interventions compared with Decompression alone.

Abbreviations: CES –, Cauda equina syndrome; LDH –, lumbar disc herniation; MI –, minimally invasive; MRI –, Magnetic Resonance Imaging; ODI –, Oswestry Disability Index; PTELD –, Percutaneous Transforaminal Endoscopic Lumbar Discectomy; TLIF –, transforaminal lumbar interbody fusion; VAS –, visual analogue scale.

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1. Introduction

Cauda equina syndrome (CES), manifested by impaired sensitivity in the anogenital region, changes in the control of the sphincters of the bladder and anus, weakness of the feet and sexual dysfunction, may result from lumbar disc herniation (LDH), spinal stenosis, spinal tumors, trauma, and inflammatory diseases of the spine [1,2]. Of all the causes of CES, LDH is the most frequent and accounts for about 45%, while LDH is accompanied by the formation of CES only in 1–6% of cases [3]. Depending on the severity of clinical presentation it is customary to subdivide CES into 3 types: (1) CES suspected, characterized by the presence of back pain, bilateral radiculopathy, absence of pelvic dysfunction, and no anesthesia in the anogenital region; (2) CES Incomplete, which differs from the first category by the presence of a partial zone of perineal anesthesia, decreased anal sphincter tone, dysfunction of the bladder while maintaining the ability to retain a voluntary control over urination; (3) CES retention, in which patients lose control of urination and defecation and are fully anesthetized in the anogenital area [1]. At the same time, the clinical picture may be both a consequence of the gradual progression of metabolic disorders in the nervous tissue and the result of simultaneous pronounced compression of the cauda equina roots [4].

Acute compression of neural structures leads to a critical violation of cerebrospinal fluid circulation, deterioration of venous outflow, development of pronounced intraneural edema and ischemia [5]. A delay in the operation for a period of more than 48 h is accompanied by irreversible changes in the nervous tissue with the formation of a gross neurological deficit and disability of patients [6].

Thus, the development of CES is an absolute indication for emergency surgical intervention, among which decompression surgeries are the "gold standard" [7]. However, at present there is no consensus on the preferred type and nature of surgery for acute CES and approaches to patient treatment are largely based on the experience of a spinal surgeon [8]. In addition, the variety of clinical variants of CES (suspected, complete, incomplete) and the presence of preoperative anatomical changes in the lumbar segments (decrease in the height of the interbody space, significant volume of disc material extrusion, segmental instability, stenosis of the spinal canal) stimulate the development of optimal therapeutic tactics aimed at personalized use of surgical techniques in this category of patients.

Objective — to evaluate the results of surgical treatment and the effectiveness of functional recovery of patients with acute incomplete cauda equina syndrome after isolated microsurgical decompression and minimally invasive transforaminal interbody fusion.

2. Materials and methods

Patients data

A retrospective study of the patients operated at the center Neurosurgery Irkutsk Railway Clinical Hospital in the period from January 2005–2020 was conducted. A total of 12087 interventions were performed in patients with degenerative diseases of the lumbar spine. The medical records and long-term results of treatment of patients who underwent MI Decompression alone and Fusion interventions for acute incomplete CES, caused by LDH were analyzed. A total of 89 patients who met the inclusion criteria and were available for analysis in the long-term postoperative period (minimum 24 months follow-up) were included in the study. Each patient gave voluntary consent to be included in the study. The study was approved by the Ethics Committee of Irkutsk State Medical Universuty – (Protocol No.2, dated April 19, 2020). The analysis of the clinical material was carried out in

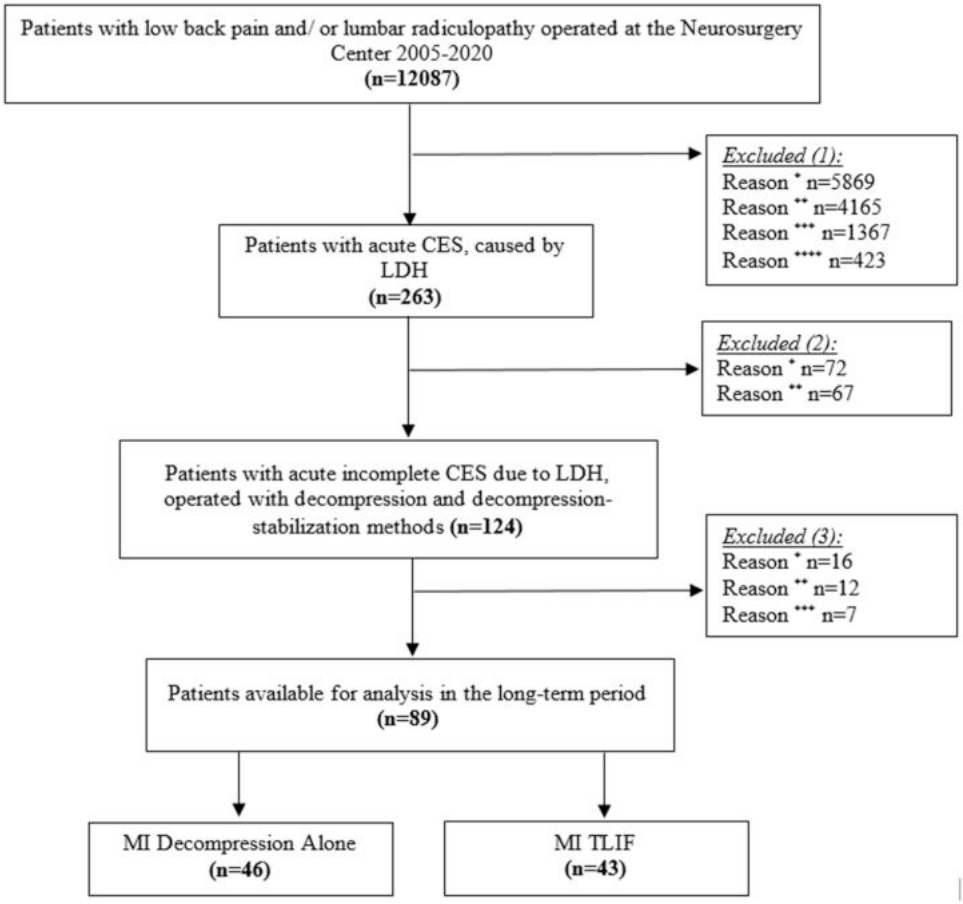

Fig. 1. Patients' study flowchart. CES: Cauda equina syndrome; LDH: Lumbar disc herniation; FSU – functional spine unit; MI – minimally invasive; TLIF – transforaminal lumbar interbody fusion *Exclude reason (1):* Reason * - Spinal stenosis without CES; Reason * * - LDH without CES; Reason * ** - Spinal deformity without CES; Reason * ** * - chronic CES due to spinal stenosis *Exclude reason (2):* Reason * - complete CES; Reason * * - revision decompression and stabilization intervention *Exclude reason (3):* Reason * - loss of follow-up; Reason * * - refusal to participate in the study; Reason * ** - death unrelated to the operation (in these cases, there were no postoperative complications).

accordance with the principles of the Declaration of Helsinki. The study design with reasons for exclusion is shown in Fig. 1.

Inclusion criteria

- acute incomplete CES, caused by LDH;
- monosegmental lesion and / or the need for a single-level surgical intervention;
- primary decompression or decompression and stabilization intervention in the lumbar spine.

Exclusion criteria

- CES suspected, caused by LDH;
- CES retention, caused by LDH;
- LDH without CES;
- chronic CES due to spinal stenosis;
- polysegmental lesion and / or the need for multilevel surgical intervention;
- preoperative data on the presence of lumbar deformity, segmental instability at the operated level;
- performing revision isolated decompression or decompression and stabilization intervention;
- refusal to participate in the study.

Surgical technique

All surgical interventions were performed by one operating team. Surgical approach and decompression of neural structures were performed according to generally accepted standards using an OPMI Pentero® 900 operating microscope (Carl Zeiss Meditec AG, Germany; OPMI Neuro NC4 ("Carl Zeiss Meditec AG", Germany), power equipment (("Aesculap", Germany; "Anspach Effort", USA), intraoperative fluoroscopy ("Philips", Netherlands; "Siemens", Germany), and specialized instrumentation.

Two study groups were identified: in the Group I (Decompression alone group, n = 46), MI isolated microsurgical decompression was performed from the intermuscular approach with medial unilateral facetectomy, partial laminectomy, bilateral decompression and removal of the LDH extrusion; in the Group II (Fusion group, n = 43), paraspinal approach, bilateral decompression from a unilateral transforaminal approach and reconstruction of the spinal canal using the "Over the Top" technique (lumbar decompression involve a unilateral approach and moving the operative corridor to the contralateral side of the neural elements by passing above of the dural sac) [9], discectomy and interbody fusion using MI-TLIF technology with percutaneous bilateral transpedicular fixation were used.

In the postoperative period, under the supervision of a neurologist and urologist, all patients underwent early comprehensive rehabilitation, which included drug therapy (vascular drugs, non-steroidal anti-inflammatory drugs, B vitamins, muscle relaxants in conventional dosages), physiotherapy (laser-magnetic therapy of the lower extremities, electrical stimulation of the bladder and intestines) and exercise therapy.

Study outcomes

Clinical evaluations were performed preoperatively, at discharge and at 39 (31;47) months in the Decompression alone group and 38 (32;48) months in the Fusion group (p = 0.62).

(1) according to the results of the analysis of medical records and the database of instrumental examination methods before surgery and at discharge, analyzed:

- general data about patients: gender, age, level of surgery, time from the onset of symptoms to surgery, time from hospitalization to surgery, intra-surgical and early postoperative complications;.

- clinical data before surgery and at discharge: motor weakness (weakness was assessed using the Medical Research Council (MRC) grading scale of 0–5. A power of root less than grade 3 was considered to be a significant weakness, and improvement of greater than grade 3 was considered to be a recovery. Motor recovery rate was assessed: № patients with motor recovery (MRC > grade 3) / № patients with preoperative motor weakness X 100% [4]), sensory disorders, control of the bladder sphincter;.

- preoperative and at discharge parameters of the functional state according to the ODI scale, quality of life according to the SF-36 questionnaire.

(2) in the long-term postoperative period by phone call, patients were invited for clinical and radiological examination:

- postoperative clinical data: motor weakness and motor recovery rate, sensory disorders, the ability to control the bladder sphincter, functional state according to the ODI scale, quality of life according to the SF-36 questionnaire;
- according to the medical documentation presented by patients at the follow-up examination, postoperative complications were studied, which served as the reasons for readmissions and revision surgery.

Statistical analysis

Statistical processing of the study results study was carried out on a personal computer using the Statistica 8.0 program. The character of the distribution of signs was evaluated by the Shapiro — Wilk, Kolmogorov — Smirnov and Lilliefors tests for normality. Considering the presence of statistically significant differences according to these tests ($p < 0.05$), the distribution was considered to be different from normal. In this regard, the criteria of nonparametric statistics were used to assess the significance of the differences in the samples. The obtained results are presented by the median, the values of the 1st and 3rd quartiles — Me (Q_{25}; Q_{75}). For a comparative analysis of the obtained values, the Mann — Whitney U—test and the Wilcoxon criterion, the χ^2 criterion for binomial signs were used. The differences were considered significant at the level of $p < 0.05$.

3. Results

Out of a total of 12087 patients with degenerative diseases of the lumbar spine that were screened according to the inclusion criteria, the results of surgical treatment of 89 respondents with acute incomplete CES caused by LHD were studied. Data on the study groups, taking into account the type and nature of the surgical intervention, are presented in Table 1. Of all the hospitalized patients, middle-aged male patients prevailed, most often surgical interventions were performed at the L4-L5 and L5-S1 levels (over 65%). Comparative intergroup analysis did not reveal statistically significant differences in sex, age, degree of physical status according to ASA and the fact of smoking. The median time between the onset of symptoms and hospitalization was 23 h for Decompression alone group I and 21 h for Fusion group (p > 0.05). The median time between hospitalization and surgery in Decompression alone group was 7 h, in Fusion group - 6 h (p > 0.05).

An intergroup comparison of intraoperative parameters and the specificity of the course of the postoperative period in the studied patients showed statistically lower parameters in Decompression alone group compared with Fusion group: the duration of surgery - 60 (45;75) minutes and 130 (105;155) minutes, respectively (p = 0.01), the volume of blood loss 45 (30;70) ml and 100 (50;150) ml, respectively (p = 0.03), the duration of inpatient treatment 3 (2;5) days and 6 (5;9) days, respectively (p = 0.04). In all cases (n = 89), the next day after the surgery, patients became more active and rehabilitation activities began with the use of physiotherapy and physical therapy under the supervision of a neurologist and urologist.

Table 1
General and clinical data of the studied patients.

Criterion		Decompression alone ($n = 46$)	Fusion ($n = 43$)	p
age, yrs, Me (Q_{25}; Q_{75})		35 (28;47)	32 (25;43)	0.31
Sex	Males, n (%)	25 (54.3)	23 (53.5)	0.55
	Females, n (%)	21 (45.7)	20 (46.5)	
Lumbar disc herniation level	L1-L2, n (%)	3 (6.5)	2 (4.7)	0.22
	L2-L3, n (%)	4 (8.7)	1 (2.3)	
	L3-L4, n (%)	5 (10.9)	3 (6.9)	
	L4-L5, n (%)	15 (32.6)	16 (37.3)	
	L5-L6, n (%)	2 (4.4)	3 (6.9)	
	L5-S1, n (%)	17 (36.9)	18 (41.9)	
ASA score, n (%)	I	8 (17.4)	7 (16.3)	0.83
	II	24 (52.1)	19 (44.2)	
	III	12 (26.1)	14 (32.6)	
	IV	2 (4.4)	3 (6.9)	
Smoking, n, %		21 (45.6)	19 (44.2)	0.29
Time from initation of symptoms to admission, hours, Me (Q_{25}; Q_{75})		23 (9;34)	21 (6;31)	0.66
Time from admission to surgery, hours, Me (Q_{25}; Q_{75})		7 (3;12)	6 (3;11)	0.79

Evaluation of clinical data before surgery, in the early and in the long-term postoperative period is shown in Table 2. Comparative intergroup analysis did not reveal statistically significant differences in all preoperative parameters ($p > 0.05$).

At discharge, a statistically significant improvement in neurological symptoms was registered in both study groups ($p < 0.05$); comparative analysis did not reveal significant intergroup differences ($p > 0.05$). In the early postoperative period, statistically significantly better clinical parameters according to ODI and SF-36 were noted in patients Decompression alone group.

In the long-term postoperative period, an intra-group analysis revealed a significant recovery of motor and sensory functions, as well as control of the bladder sphincter compared with both preoperative neurological symptoms and discharge time ($p < 0.05$). We registered a high frequency of motor recovery rate after both types of surgical interventions, comparable both at discharge ($p > 0.05$) and in the long-term postoperative period ($p > 0.05$).

At the same time, statistically significantly better indicators of functional state according to ODI and quality of life according to SF-36 were registered in the Fusion group ($p < 0.05$).

The perioperative surgical complications identified during the study are shown in Table 3. The analysis revealed a comparable level of perioperative surgical complications ($p > 0.05$). At the same time, there was a greater number of symptomatic complications associated with the progression of degenerative and biomechanical changes in the operated segment (segmental instability, reherniation, disk collapse) and which are an indication for revision fusion surgery in Decompression alone group.

Table 3
Comparative analysis of perioperative complications and causes of reoperations in patients of the study groups.

Parameter		Decompression alone ($n = 46$)	Fusion ($n = 43$)	p
Surgery complication	Nerve root injury	1	-	0.62
	Dural tear	-	1	
	Tethering and adhesions	1	1	
	Surgical site infection	1	1	
Reoperation	Segmental instability	1	-	0.02
	Reherniation	5	-	
	Adjacent segment degeneration	1	2	
	Disk collapse	3	-	
	Pseudo radicular pain syndrome	2	1	
	Incomplete decompression	1	-	
	Pseudoarthrosis	-	1	

Perioperative MRI data of patients are presented below, depending on the method of surgical treatment: Fig. 2 (clinical case Decompression alone group) - minimally invasive microsurgical decompression alone from the intermuscular approach with medial unilateral facetectomy, partial laminectomy, bilateral decompression and removal of the LDH extrusion, followed by recurrent disc herniation and the results of revision fusion surgery; Fig. 3 (clinical case Fusion group) shows primary fusion surgery with bilateral decompression from a unilateral transforaminal approach and reconstruction of the spinal canal using the "Over the Top" technique, discectomy and interbody fusion using MI-TLIF technology with percutaneous bilateral transpedicular fixation.

4. Discussion

Despite the unanimous opinion that CES is an absolute indication for surgery, there are disagreements between spinal surgeons on the timing of the operation and the choice of its method [10,11]. In addition, in most studies devoted to the results of surgical treatment of CES, it is customary to combine patients into a general cohort without detailing the outcomes between complete and incomplete CES [1,12,13]. Most likely, these reasons are due to the ambiguous results of treatment of patients with acute development of CES, developed as a result of LDH extrusion.

An important prognostic factor that determines the prospects for recovery and full rehabilitation is the initial neurological deficit [5,7]. So, in the patients with suspected CES, all neurological functions are preserved in the long-term period; with incomplete CES, in the vast majority, complete recovery of neurological deficit or significant improvement is recorded; in the case of complete CES, dysfunction of the sphincters of the bladder and anus persists and varies from 20% to 90%

Table 2
Comparative analysis of clinical results in patients of the study groups.

Criterion		Decompression alone (n = 46)			Fusion (n = 43)			P_{M-U} discharge	P_{M-U} last FU
		Before	Discharge	Last FU	Before	Discharge	Last FU		
Motor improvement rate, %		78.3%		86.9%	81.4%		86.1%	0.35	0.76
Sensory deficit, n (%)		46 (100)	24 (52.2)	9 (19.6)	43 (100)	23 (53.5)	7 (16.3)	0.53	0.49
Neurogenic Bladder Dysfunction, n (%)		46 (100)	13 (28.3)	5 (10.9)	43 (100)	11 (25.6)	3 (6.9)	0.48	0.39
Functional state according to ODI score, Me (Q_{25}; Q_{75})		72 (62; 84)	8 (6;10)	13.5 (11;15)	70 (64; 86)	14 (10;18)	8 (6;10)	0.03	0.04
SF-36, score, Me (Q_{25}; Q_{75})	Physical component	27.77 (20.41;36.79)	45.63 (42.38;49.68)	47.29 (46.58;50.12)	29.22 (19.70;34.55)	40.02 (38.18;46.34)	53.14 (51.92;56.38)	0.03	0.04
	Psychological component	31.16 (17.88;40.93)	44.19 (38.26;46.43)	45.18 (42.34;47.11)	34.28 (19.58;40.29)	39.24 (34.1;41.14)	56.69 (51.44;57.98)	0.02	0.01

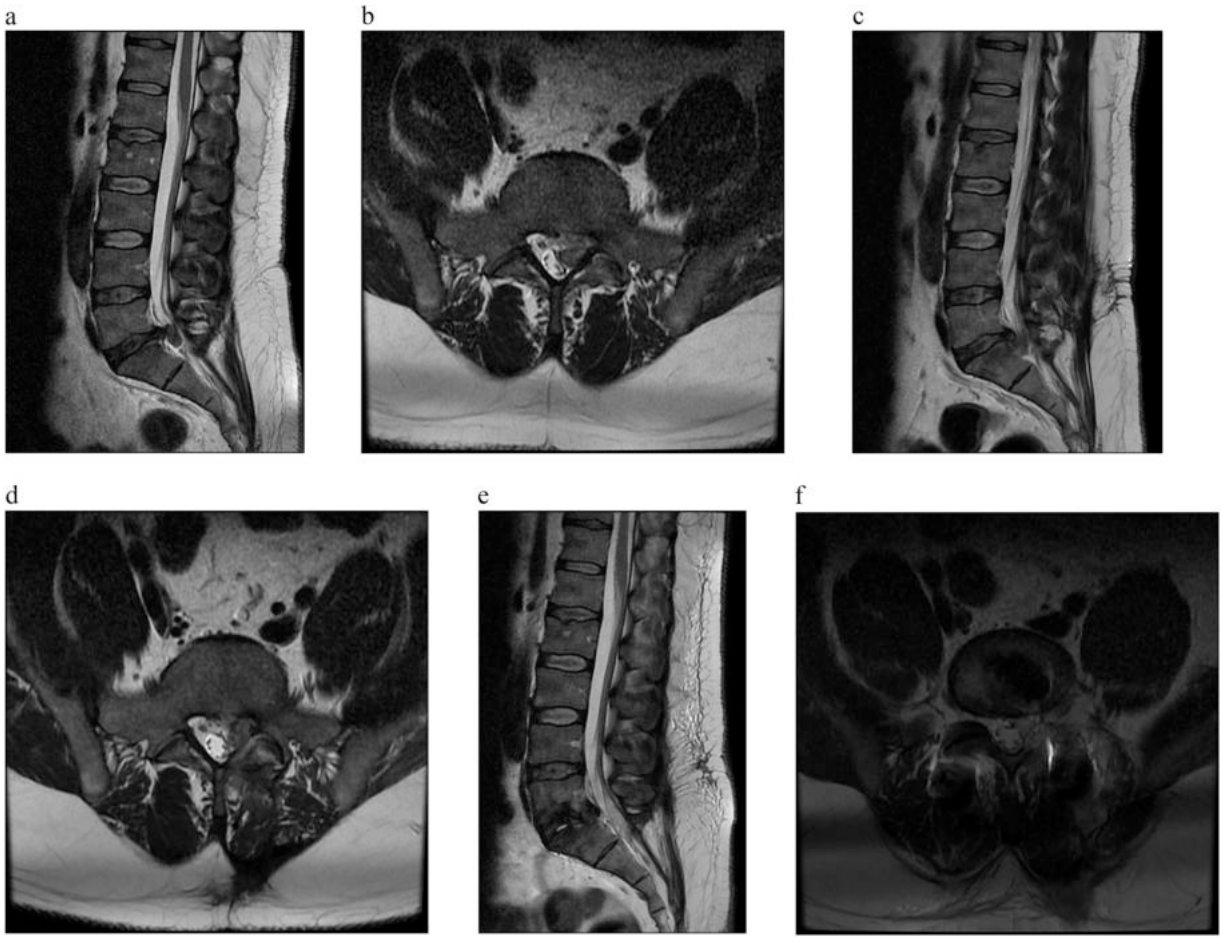

Fig. 2. Perioperative imaging of patient S., 45 y.o.: a – preoperative magnetic resonance imaging (MRI) sagittal projection in T2 mode (extrusion intervertebral disk [IVD] L5-S1 with caudal migration); b – preoperative MRI axial projection in T2 mode left side L5-S1 disc extrusion; c – postoperative MRI sagittal projection in T2 mode after decompression alone – L5-S1 disc reherniation; d – postoperative MRI axial projection in T2 mode after decompression alone – left side L5-S1 disc reherniation; e – postoperative MRI sagittal projection in T2 mode after revision fusion surgery MI-TLIF (no signs of degenerative disease of the adjacent segment); f – postoperative MRI axial projection in T2 mode after revision fusion surgery MI-TLIF.

[3,14,15].

A number of researchers have established a high efficiency of surgical treatment of acute CES caused by LDH with a minimum time from the development of neurological deficit to surgery [16,17]. So, Uçkun O. M. et al. confirmed the importance of performing decompression surgery within the first 24 h in terms of the dynamics of muscle strength recovery and bladder sphincter control [1]. Moreover, in a meta-analysis, Kohles S. et al. [12] noted comparable efficacy of surgical treatment of CES both in the early periods (after 24 and 48 h) and in the long term (more than 48 h). In contrast to the previous study, in a retrospective assessment of a nationwide database of 4066 patients with CES, Thakur J. et al. [13] found that early intervention at CES (up to 48 h) has a higher probability of improving clinical outcomes and reducing perioperative complications. Hogan W. et. al. [18] analyzed the Utilization Project National Inpatient Sample Database from 2000 to 2014 consisting of 20,924 respondents with CES. The authors noted that patients who received decompression of the spinal canal during the first day from the day of admission to the hospital had a significant improvement in the results, a decrease in the number of complications and mortality rates.

Thus, the outcome of surgical treatment of patients with CES is influenced by both the initial neurological deficit and the timing of surgery. In the study, both groups showed a statistically significant improvement in the existing clinical manifestations, which is most likely due to (1) the presence of incomplete CES in all patients, which characterizes the potential reversibility of neurological symptoms and (2) the time between the onset of symptoms and the performance of surgery, which did not exceed average 48 h.

Currently, there is no consensus regarding the choice of the method of surgical correction for acute incomplete and complete CES due to LDH. Taking into account the risks of irreversible changes in the spinal roots due to their compression, decompression of neural structures is urgently indicated after the clinical diagnosis of CES [19]. Rigid fixation of the operated segments is necessary in the presence of initial segmental instability or with significant resection of the supporting elements of the spine [20,21].

Isolated decompression of the spinal canal is considered the “gold standard” of surgical treatment for acute CES associated with LDH extrusion [22,23]. At the same time, the ways to improve the long-term outcomes of surgical treatment of patients are aimed at reducing iatrogenic surgical aggression through the use of low-traumatic surgeries, the results of the implementation of which remain contradictory. This is largely due to the comparative analysis of surgical treatment with different surgical techniques without taking into account the presence of a complete or incomplete CES in patients.

Thus, in a study conducted by Yankang L. et al. [24] when comparing the results of surgical outcomes of acute CES with open laminectomy and endoscopic decompression, a comparable efficiency was found in terms of the number of excellent and good results according to JOA 81.8% and 85.7%, respectively, as well as the number of perioperative complications 4.8% (rough scar - adhesive process) and 4.5%

Fig. 3. Perioperative imaging of patient Yu., 50 y.o.: a – preoperative magnetic resonance imaging (MRI) sagittal projection in T2 mode (extrusion intervertebral disk [IVD] L5-S1 with cranial migration).; b – preoperative MRI axial projection in T2 mode: left side and central L5-S1 disc extrusion; c – postoperative MRI sagittal projection in T2 mode after primary fusion surgery MI-TLIF (no signs of degenerative disease of the adjacent segment); d – postoperative MRI axial projection in T2 mode after primary fusion surgery MI-TLIF.

(insufficient decompression), respectively. At the same time, according to Shen L. et al. [25] the use of minimally invasive hemilaminectomy for acute CES of hernial genesis, compared with traditional open laminectomy, allowed to obtain better outcomes on the VAS, ODI, and Frankel scales over a 36-month period with a comparable number of perioperative complications and lower risks of postoperative segmental instability. In a retrospective evaluation of the clinical series presented by Chen C. et al. [10], the results of using PELD (Percutaneous Endoscopic Lumbar Discectomy) technology in 11 patients with LDH complicated by acute CES are described. The authors noted complete recovery in 9 cases and partial recovery in 2 cases 12 months after the surgery. In this regard, it was found that the minimally invasive surgical method provides sufficient decompression during LDH extrusion and satisfactory clinical outcomes in patients with acute CES. Krishnan A. et al. [26] presented the results of surgical treatment of 15 patients with acute and chronic CES using the Percutaneous Transforaminal Endoscopic Lumbar Discectomy (PTELD) technique. According to the authors, on average, 20 months after the intervention, complete restoration of the control over the urinary bladder sphincter, a significant decrease in the level of pain in the back and lower extremities, an improvement in the functional state according to ODI, and the absence of perioperative surgical complications were noted.

The use of decompression-and-stabilizing technologies in the treatment of patients with CES is aimed at preventing revision surgeries associated with the formation of postoperative segmental instability, recurrence of LDH or the development of foraminal stenosis due to a significant decrease in the height of the interbody space [27]. According to Dave B. et al. [4] when comparing isolated decompression (laminectomy and/or discectomy) with O-TLIF in patients with acute and chronic CES, comparable results of long-term pain syndrome in the lumbar spine and lower extremities, the number of perioperative complications, restoration of urologic functions, as well as motor and sensitive neurological deficits were revealed. Our study showed better long-term clinical outcomes and fewer revision operations when using MI-TLIF technology compared to isolated decompression. Low-traumatic decompression-and-stabilizing interventions made it possible to perform full decompression of neural structures, provided early functional recovery and a better clinical outcome due to less damage to paravertebral tissues and a minimum level of perioperative pain syndrome.

From the medical literature available for analysis, we have not found information on the results of using minimally invasive dorsal decompression-and-stabilizing interventions in patients with acute incomplete CES caused by LDH. That, in our opinion, is, on the one hand, associated with a sufficiently high efficiency of isolated decompression, on the other hand - with the absence of the need to expand

surgical aggression, prolong the duration of surgery and inpatient treatment with an initially unfavorable clinical prognosis, for example, the presence of complete CES or the duration of time between the development of symptoms and surgery for more than 48 h.

Due to the lack of information on the possibilities/ benefits/ limitations of MI-TLIF technology in patients with acute incomplete CES caused by LDH compared to isolated minimally invasive decompression, these two surgical technologies were compared. In the presented clinical series, we eliminated possible known factors affecting the dynamics of neurological manifestations - severe neurological deficit and the time from the development of symptoms to surgery. Thus, we leveled the role of a significant neurological deficit (we excluded patients with acute complete CES) and the time factor (all patients were operated on within 48 h from the onset of symptoms of CES). At the same time, the volume of decompression with both technologies used was comparable: medial unilateral facetectomy and partial laminectomy with bilateral decompression in the Decompression alone group and bilateral decompression from a unilateral transforaminal approach using the "Over the Top" technique in the Fusion group.

A retrospective study revealed lower parameters of the surgery duration, the volume of blood loss and the duration of inpatient treatment, as well as better clinical outcomes at discharge after Decompression alone surgery in patients with acute incomplete CES caused by LDH. At the same time, the advantages of Fusion surgery in the minimum period of postoperative follow-up of 24 months were noted, which was confirmed by statistically significantly better indicators of functional state according to ODI and quality of life according to SF-36. In addition, the number of symptomatic complications associated with the progression of degenerative and biomechanical changes in the operated segment and being an indication for repeated surgical manipulations was registered more in Decompression alone group.

Despite the fact that a comparative analysis of the long-term results of the functional state (motor recovery rate, regression of sensory disorders and neurogenic bladder dysfunction) between the Decompression alone group and the Fusion group showed comparable outcomes. The final assessment of the effectiveness and benefits of the MI-TLIF technology in terms of functional state according to ODI and quality of life according to SF-36 is based on greater patient satisfaction with the primary operation and fewer revision surgeries in the follow-up associated with the progression of degenerative changes in the operated segment. This justifies the economic cost and potential long-term benefit of fusion in patients with acute incomplete CES due to LDH extrusion. Besides, costs of isolated decompression and MI-TLIF operations are refunded our institute by the insurance company.

In our opinion, the use of Fusion surgery is advisable in patients with acute incomplete CES due to LDH extrusion and high likelihood of regression of preoperative neurological deficit in order to conduct rapid effective rehabilitation, as well as to optimize the long-term clinical outcome with a decrease in the risks of revision surgery.

5. Limitations

Limitations of the study, potentially having the ability to influence its results, include: (1) the retrospective type of the study; (2) lack of analysis of results in the intermediate period after surgery; (3) the single-center study and the absence of randomization of patients depending on the chosen surgical technology; (4) examining the results of only acute incomplete CES, caused by LDH; (5) lack of analysis of results with patients operated on with other known decompression and decompression-stabilizing technologies; (6) lack of evaluation of the economic expense of the methods of surgical interventions.

6. Conclusion

The prevalence of acute incomplete CES caused by LDH in the study was 1.02% of patients (124 out of 12087). Despite the rather rare development, CES is a serious complication and is associated with high risks of the formation of persistent disability, even if the surgical intervention is performed timely. In the presented clinical series (n = 89), the persistence of motor deficit in 24 patients (26.9%), sensory disorders in 16 patients (17.9%) and impaired bladder sphincter function in 8 patients (8.9%) were registered in the long-term postoperative period.

Minimally invasive Decompression alone surgery and Fusion surgery are effective in the treatment of patients with acute incomplete CES caused by LDH to restore clinical parameters due to the possibility of rapid full rehabilitation of patients. At discharge, Decompression alone surgery has advantages in terms of the level of functional state and quality of life compared to the Fusion surgery. At the same time, we found better long-term outcomes according to ODI and SF-36 in Fusion group, associated with fewer reasons for revision surgery ($p = 0.02$).

Further prospective randomized studies, devoted to the comparative analysis of decompressive and decompressive-and-stabilizing techniques on a larger number of respondents, as well as a comparison of their economic expense, are required.

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Compliance with ethical standards

CRediT authorship contribution statement

Each author made significant individual contributions to this manuscript. VAB (0000–0003–4349–7101)* and AAK (0000–0002–6059–4344)* were the main contributors to the drafting of the manuscript. VAB, AAK, VVS (0000–0001–5135–8115)* and YYP (0000–0001–7076–571X)* performed the surgery and patient follow-up, and gathered clinical data. AAK, YYP, VVS, and BAJ (0000–0003–0102–8817)* evaluated the data from the statistical analysis. VAB and AAK performed the literature search and review of the manuscript, and contributed to the intellectual concept of the study. *ORCID (Open Researcher and Contributor ID).

Conflict of interest

All authors certify that they have no affiliations with or involvement in any organization or entity with any financial interest (such as honoraria; educational grants; participation in speakers' bureaus; membership, employment, consultancies, stock ownership, or other equity interest; and expert testimony or patent-licensing arrangements), or non-financial interest (such as personal or professional relationships, affiliations, knowledge or beliefs) in the subject matter or materials discussed in this manuscript.

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