SURGICAL TREATMENT OF DISC HERNIATION IN CHILDREN AND ADOLESCENTS

A.A. Kuleshov[1], A.V. Krutko[2], O.S. Iskhakov[3], M.S. Vetrile[1], M.D. Abakirov[3], A.V. Peleganchuk[2], A.I. Vasilyev[2], I.N. Lisyansky[1], S.V. Meshcheryakov[3], A.I. Kokorev[1]

[1]Central Institute of Traumatology and Orthopaedics n.a. N.N. Priorov, Moscow, Russia
[2]Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, Novosibirsk, Russia
[3]Institute of Emergency Pediatric Surgery and Traumatology, Moscow, Russia

Objective. To analyze the features of surgical treatment of children and adolescents with herniated discs and radicular compression symptoms.

Material and Methods. A retrospective multicenter study of 34 patients with juvenile osteochondrosis with mean age of 15.4 years was performed. Surgical treatment included disc puncture methods, microdiscectomy through posterior approach, anterior discectomy, dynamic and rigid stabilization, and replacement of the fibrous ring defect.

Results. Positive clinical effect with complete relief of pain was achieved in all cases. Paretic syndrome regressed completely in all patients. All patients regained the level of physical activity in the next 2–3 months. Long-term follow-up was on average 45.5 months. No recurrence of pain was noted during the follow-up period.

Conclusion. Surgical treatment of disc herniation in children results in the relief of pain and full functional recovery. Among surgical methods, a preference should be given to microdiscectomy through minimally invasive surgical approaches. In the presence of indications, both rigid stabilization of spinal motion segment at the level of decompression and dynamic stabilization can be performed, and the latter is more preferable.

Key Words: juvenile osteochondrosis, microdisectomy, disc herniation, artificial disc implant, disc puncture method, fibrous ring defect, Barricaid closure device.

Please cite this paper as: *Kuleshov AA, Krutko AV, Iskhakov OS, Vetrile MS, Abakirov MD, Peleganchuk AV, Vasilyev AI, Lisyansky IN, Meshcheryakov SV, Kokorev AI. Surgical treatment of disc herniation in children and adolescents. Hir. Pozvonoc. 2017;14(1):68–77. In Russian.*
DOI: http://dx.doi.org/10.14531/ss2017.1.68-77.

It is known that back pain is a quite common in adults. At least one back pain episode occurs in 70–80 % of all adults [1, 12, 14, 19]. Previously, it was thought that this pain is rare in children and adolescents. However, relatively recent studies of foreign authors revealed quite high incidence of low back pain among the school-aged children, amounting to 30 to 60 % [5, 10, 15, 21, 22, 24, 25]. Pain radiating into the legs occurs in 1.8 to 4.7 % of cases [10, 21, 25]. A comprehensive conservative therapy is the main treatment method. However, in some cases, the persistent severe pain with significant functional limitation is an indication for surgical treatment of intervertebral disc herniation in children and adolescents [17, 21]. There is no accurate statistics reflecting the number of operations for herniated discs in children and adolescents. According to Bruske-Hohlfeld et al. [4], surgical treatment for herniated discs is required in 5.5 of 100 thousand population under the age of 25 years. De Orio and Bianco [8] pointed out that only 0.5 % of 9991 discectomy operations at the Mayo clinic (USA) were carried out in children and adolescents under 16 years of age. There are only scarce publications reporting surgical treatment of herniated discs in children and adolescents. Given the relatively small number of children and adolescents who require surgical treatment for herniated discs of the lumbar spine and radicular pain syndrome, this article combined experience of three clinics, specialized in the field of spinal surgery.

The study was aimed at analyzing the characteristics of surgical treatment of children and adolescents with herniated discs and compression radicular symptoms.

Material and Methods

We conducted a retrospective multicenter study, which summarized the experience of surgical treatment of degenerative changes in the lumbosacral spine in children and adolescents at three specialized institutions: Central Research Institute of Traumatology and Orthopedics n.a. N.N. Priorov (CITO, vertebrology group), Novosibirsk

Research Institute of Traumatology and Orthopedics n.a. Ya.L. Tsivyan (NRITO, neurosurgery department No 2), Research Institute of Emergency Pediatric Surgery and Traumatology (RI EPST, Department of Neurosurgery). A total of 34 patients (23 girls and 11 boys) were operated on, patients' age averaged 15.4 years (11 to 17 years).

Approximately 300 surgical interventions for degenerative changes of the spine were carried out at the CITO n.a. N.N. Priorov in 2012—2015 in patients of all ages, most of the patients were 25—63 years old. Nine patients aged 11 to 17 years were found.

More than 7,000 surgical procedures for degenerative diseases of the spine, in particular osteochondrosis of the lumbosacral spine, were carried out at the NRITO n.a. Ya.L. Tsivyan in 1998—2015. A total of 17 children under 17 years old were operated on.

Eight patients aged 12—16 years were operated on at the Department of Neurosurgery of the RI EPST in 2015 for juvenile osteochondrosis of the lumbar spine with severe radicular syndrome.

Age and sex distribution of patients is shown in Table 1. At admission, all patients had pronounced radicular pain, five patients complained of weakness in the leg. All patients experienced significant functional limitation of daily physical activity.

There were no apparent reason for the development of pain syndrome in 21 patients, pain was associated with a weight lifting in seven cases, with intensive sport activities (martial arts, acrobatics) — in two cases.

Patients' body mass index averaged 22.1 (16.2 to 35.1). Seven patients were overweight (obesity), five patients were underweight.

The average duration of clinical symptoms and conservative treatment before surgery was 9.2 months (on the average, 1 to 45 months.).

Conservative treatment based on the standard protocol (NSAIDs, centrally acting muscle relaxants, B vitamins, massage, physiotherapy, exercise therapy) did not result in pain relief.

Examination of all patients showed flattening of the lumbar lordosis. Antalgic bend of the trunk was observed in 11 patients. There was characteristic limitation of the forward tilt of the body. In all cases, there was radicular pain syndrome. In three cases, it was bilateral. The straight leg raise test was positive in all patients. Paretic syndrome was observed in five patients, but pareses were not severe and decrease in muscle strength ranged 3—4 points.

All patients underwent standard radiographic examination of the spine in two projections, functional radiography of the lumbosacral spine, MRI and, in some cases, CT. X-ray diagnostics detected signs of spinal osteochondropathy, including Schmorl's nodules, as well as intervertebral disc degeneration with dehydration of the nucleus pulposus and slight decrease in the interbody space height in almost all patients. Distribution of herniated disc location was as follows: L4—L5 — 15 patients, L5—S1 — 8, L3—L4 — 2, L4—L5, L5—S1 — 9.

All hernias were detected at the stage of disc protrusion, no cases of extrusion were observed. Changes in MRI signal from the vertebral bodies were minimal (Modic 0—1). There were no cases of spondylosis and osteophytes.

Distribution by treatment methods is show in Table 2.

In all cases except for three patients, surgery did not include immobilization (spinal fusion) of the spinal segment involved in the pathological process.

Disc puncture treatments were used in five cases. In one patient with protrusion sized up to 5 mm at the level of L4—L5, transcutaneous nucleotomy was carried out using mechanical destructor, three patients underwent nucleoplasty with cold plasma, one patient — alcohol-lidocaine disc denervation.

In most cases, microdiscectomy was carried out through the posterior approach. This type of surgery is similar to those carried out in adult patients. Microdiscectomy and decompression of neural structures was carried out either endoscopically, using the Destandau procedure, or through a small, up to 2—3 cm, skin incision using a microscope or special magnifying glass. Minimum required resection of the yellow ligament and the edges of the arches was carried out in order to provide approach to the spinal canal, remove disc herniation, and decompress neural structures.

Case study 1. Patient M., 11 years old, was admitted to the neurosurgery department No 2 of the Novosibirsk RITO complaining of intense pain in the lumbus, gluteal area on the right, along the posterior surface of the right femur and tibia, and weakness in the right foot. The patient suffered from recurrent back pain for about a year, the pain was relieved by analgesics. The neuro-

Table 1
Age and sex distribution of patients

Clinic	Patients, n	Age, years			Sex	
		10—11	12—14	15—17	Male	Female
CITO n.a. N.N. Priorov	9	1	2	6	4	5
NRITO n.a. Ya.L. Tsivyan	17	1	3	13	5	12
RI EPST	8	0	5	3	2	6
Total	34	2	10	22	11	23

logical status showed reduced strength of the plantar flexors in the right foot to 4 points, no Achilles and plantar reflexes on the right, pronounced tension symptoms (Lasegue's sign 10° on the right). At admission, there was noticeable antalgic position of the body and flattened physiological curves (Fig. 1a).

Survey (Fig. 1b) and functional radiographs of the lumbar spine showed signs of juvenile osteochondrosis of the lumbar spine mostly localized at the level of L5—S4 intervertebral disc, apophyseal fracture of the caudodorsal angle of L5 vertebral body with fragment displacement into the vertebral canal, left antalgic thoracic scoliosis, antalgic kyphotic deformity of the lumbar spine, pelvis skewed to the right by 4°. MRI of the lumbar spine showed degenerative changes mostly localized at the level of L5—S4 intervertebral disc, paramedian herniation of L5—S1 disc on the right (Fig. 1c).

Based on clinical and radiographic examination, the patient was diagnosed with juvenile osteochondrosis of the lumbar spine, primarily involving L5—S1 intervertebral disc, L5—S1 disc herniation on the right, compression-ischemic radiculopathy on the right. The patient underwent Destandau endoscopic microdiscectomy at L5—S1 on the right. Intraoperatively, subligamentous disc herniation at L5—S1 on the right was detected, compressing S1 root. Hernia was removed. S1 root straightened and clear pulsation of the dural sac and root was observed. No disc curettage was performed. The patient was activated (allowed to walk) on the first day after surgery. During the first 3 days, the patient received analgesia with nonsteroidal anti-inflammatory drugs due to the pain at the area of surgical intervention. The postoperative period was uneventful, pain regressed completely. The patient was discharged on the 4th day after the operation with the persistent neurological deficit (reduced strength of the plantar flexors in the right foot to 4 points and no Achilles and plantar reflexes on the right). Outpatient conservative treatment (physiotherapy, vascular courses, and neuroprotective drug therapy) was continued. Follow-up examination in 1 month showed that weakness in the left foot completely regressed and the patient returned to normal life. Control MRI of the lumbar spine in 3 months showed degenerative changes in the intervertebral discs L4—L5 and L5—S1. Dextral paramedian protrusions at L4—L5, L5—S1 without signs of compression of neural structures (Fig. 1d).

Table 2
Distribution of patients by the type of surgery

Clinic	Surgical technique	Patients, n
CITO n.a. N.N. Priorov	Transcutaneous nucleotomy	1
	Interlaminectomy, microdiscectomy	1
	Interlaminectomy, microdiscectomy, plastic repair of the fibrous ring defect with Barricaid implant	5
	Foraminotomy, removal of the disc herniation, TPF, TLIF	1
	Interlaminectomy, microdiscectomy, dynamic stabilization with the interspinous implant	1
NRITO n.a. Ya.L. Tsivyan	Destandau's endoscopic microdiscectomy	3
	Interlaminectomy, microdiscectomy	7
	Cold plasma nucleoplasty	3
	Interlaminectomy, microdiscectomy. Dynamic stabilization with the interspinous implant	3
	Medicamentous (alcohol-lidocaine) disc denervation	1
RI EPST	Interlaminectomy, microdiscectomy	6
	Anterior discectomy with artificial disc installation at two levels	1
	Anterior discectomy, ALIF	1

In five cases, the operations were supplemented by closing the defect of the annulus fibrosus formed after removal of the herniation and part of the disc with Barricaid implant. Implant placement did not necessitate expanding the surgical approach and additional surgical aggression.

Case study 2. Patient N., 16 years, consulted the vertebrology group of the CITO n.a. N.N. Priorov with complaints of pain in the lumbar spine radiating along the posterior surface of the left thigh, left tibia, and weakness in the left foot. The patient suffered from low back pain for 9 months. She received conservative treatment with a temporary positive effect. A month after the onset of pain, it radiated to the left lower limb, conservative therapy was ineffective. The patient was examined by neurologist, who detected decreased tone of the left plantar flexors to 4 points, reduced Achilles reflexes on the left, Lasegue's sign 25° on the left. X-ray showed signs of osteochondropathy of the lumbar spine, antalgic left-sided lumbar scoliosis, flattened lumbar lordosis. MRI of the lumbar spine (Fig. 2a) showed the initial degenerative changes in the lumbar spine, herniated disc L5—S1 on the left. Taking into account the results of clinical examination and radiological findings, the patient underwent surgery: interlaminectomy L5—S1 on the left, revision and decompression of the neural structures, replacement of annulus fibrosus defect with Barricaid implant. Intraoperatively, herniated disc L5—S1 on the left, compressing S1 root, was visualized. Herniation was removed followed by partial curettage of the disc. Total decompression of S1 root was observed. The defect of the annulus fibrosus was replaced by a Barricaid implant in order to prevent the recurrence of hernia. The postoperative period was uneventful. The patient reported reduction of pain in the left lower limb on the day after surgery. Before discharge,

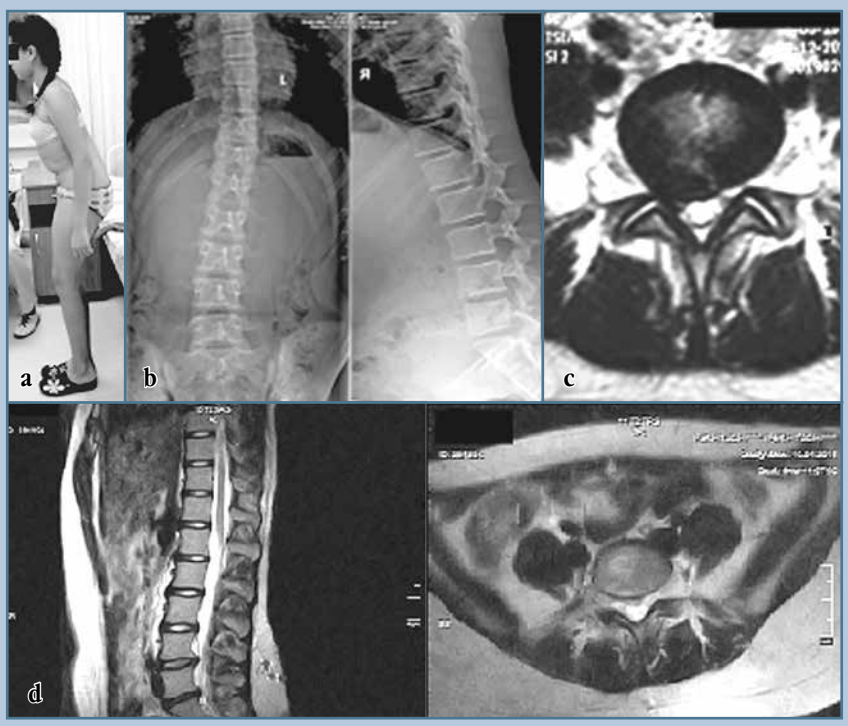

Fig. 1
The data of the patient M., 11 years old: **a** — appearance; **b** — preoperative X-ray; **c** — preoperative MRI; **d** — MRI 3 months after the operation

the patient was examined by a neurologist. Regression of neurological symptoms was observed. The patient was discharged on the 5th day with appropriate recommendations. The patient was followed for 20 months, there were no complaints or activity limitations, control X-ray and CT showed that implant was stable (Fig. 2b, c).

Four patients underwent dynamic stabilization at the level of decompression with an interspinous implant. In two cases, 16 and 17-years-old patients underwent rigid fixation of the spinal motion segments due to the large size of hernias and severe segmental instability. Additional stabilization with interspinous implant was carried out in one case, taking into account the protrusion of the superjacent disc L4—L5. Another patients underwent two-level anterior decompression of neural structures followed by endoprosthesis replacement of the intervertebral discs.

Case study 3. Patient L., 14 years old, with an adolescent osteochondrosis of the lumbosacral spine and the secondary radicular pain. Weigh — 72 kg, height —172 cm. Four months before admission to the RI EPST, she started to experience low back pain radiating along the posterior surface of the left thigh and tibia to the plantar surface of the foot and heel, numbness of the anterolateral surface of the left thigh and posterolateral surface of the tibia and the plantar surface of the foot. The patients believes that onset of the disease is associated with the episode, when she played with her friends and carried her mate pickaback. She received conservative treatment for a long time, but pain significantly increased in recent months. Back muscle guarding, antalgic posture, and flattened lumbar lordosis were observed. There were severe tension symptoms (Lasegue's sign 20° on the left and 60° on the right), reduced Achilles reflex on the left, paresis of the left foot, hypoesthesia at the area of innervation of L5 and S1 roots on the left.

X-ray examination of the thoracolumbar spine at admission (Fig. 3a) showed signs of lumbosacral spine osteochondrosis in the form of reduced height of the intervertebral discs L4—L5, L5—S1, grade II antalgic right-sided scoliosis of the lumbar spine, pelvis skewed to the left. MRI of the lumbar spine (Fig. 3b) showed signs of osteochondrosis of the lumbar spine, median disc herniation at L4—L5, L5—S1 (up to 15—20 mm), which was more pronounced on the left, accompanied by compression of the dural sac and roots on the left.

Taking into account the severity and duration of pain, the presence of large posterior median disc hernia at L4—L5, L5—S1 with a significant protrusion into the spinal canal and compression of the spinal roots, ineffective conservative treatment, as well as patient's age and the absence of signs of instability in the lumbar spine, retroperitoneal anterior discectomy at L4—L5 and L5—S1, removal of disc herniations, decompression of the neural structures, and endoprosthesis replacement of L4—L5 and L5—S1 discs with artificial disc M6-L were carried out in order to preserve the function of the operated spinal segments and eliminate neurological symptoms.

Postoperatively, complete regression of radicular syndrome was observed on day 1 after surgery. Postoperative X-ray and CT showed satisfactory position of endoprostheses, correct spinal column axis, no narrowing of the spinal canal (Fig. 3c, d). Movements in the lumbosacral region and the function of the operated spinal segments were preserved. Follow-up examination 6 months after surgery showed no pain or neurological loss.

Results and Discussion

Clinical benefit with complete relief of pain was achieved in all cases. Paretic syndrome regressed completely in all patients and they regained the level of physical activity within the next 2—3 months. Long-term follow-up averaged 45.5 months. There was no pain recurrence.

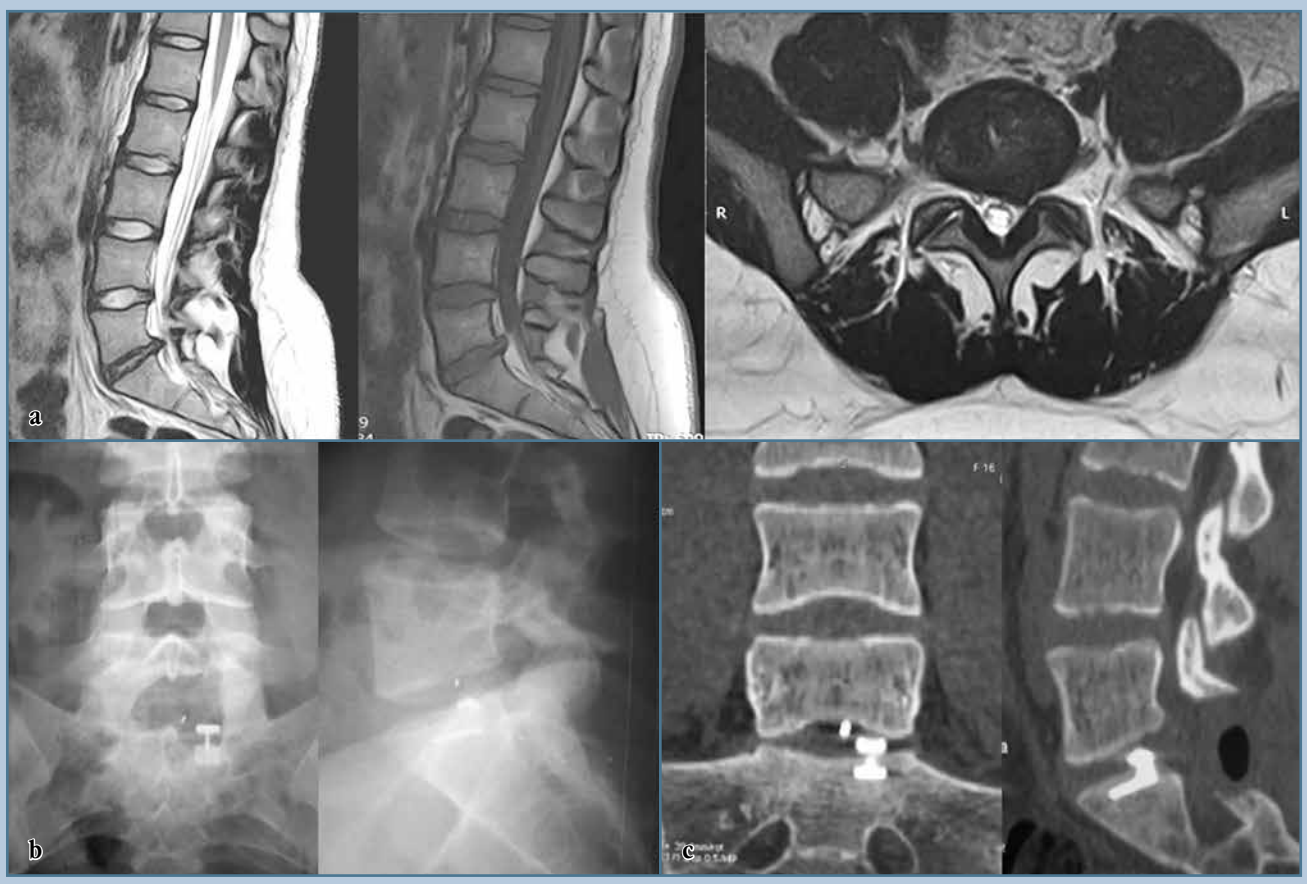

Fig. 2
The data of patient N., 16 years old: **a** — preoperative MRI; **b** — postoperative X-ray; **c** —postoperative CT

Back pain in children and adolescents was previously believed to be a relatively rare clinical phenomenon. In recent years, it attracts attention of vertebrologists. An epidemiological study aimed at assessing the incidence of manifestations of adolescent osteochondrosis [15] involved 12,058 Finnish children born in the northern part of the country in 1966 from birth to 28 years. The results showed that none of the test subjects has been hospitalized with confirmed lumbar intervertebral disc herniation up to the age of 15, but this value increased up to 0.1—0.2 % at the age of 20 years. From that moment, the prevalence sharply increased. At the age of 28 years, 9.5 % of males and 4.2 % of females were hospitalized with a diagnosis "herniated disc".

Conservative therapy is the main treatment method, which includes both drug treatment and rehabilitation complex. However, conservative treatment of disc herniation in children is less effective than in adults [21], which was confirmed by our clinical observations. There are relatively scarce publications in Russian and international scientific literature on the surgical treatment of herniated discs in children and adolescents.

The indications for surgical treatment of herniated discs in children are similar to those in adult patients and include neurological deficits, severe pain with limited daily physical activity, and ineffective conservative treatment for 6 weeks [17, 21].

There are extremely scarce data on the use of disc puncture methods to treat herniated discs in children and adolescents. Bradbury et al. [3] reported the results of the comparative analysis of the treatment for herniated discs in two groups of patients aged 13—19 years old, who underwent intradiscal administration of chymopapain and surgical microdiscectomy, respectively. Good to excellent long-term outcomes were observed in 81 % of operated patients versus 64 % of patients in the chemonucleolysis group. However, the authors emphasized that the patients, whose treatment using chemonucleolysis was ineffective and who were then operated on with a good outcome, demonstrated a total of 82 % of positive outcomes together with the group with isolated administration of papain. Thus, intradiscal injection of papain as a primary invasive treatment is justified, and open surgery can be used in the case of failure. In our series, we used intradiscal puncture methods only in five patients, and two of them subsequently

underwent microdiscectomy due to persistent pain. In is not possible to draw conclusions on the use of this method in children and adolescents, but the fact that this procedure is minimally traumatic for all anatomical structures and the possibility of any subsequent decompressive surgery are undeniable [3].

Microdiscectomy with decompression of neural structures is the main method to treat herniated discs in children and adolescents [6, 9, 20, 23].

Stromqvist et al. [23] published the long-term outcomes of surgical treatment of 288 patients with herniated discs younger than 20 years obtained using the Swedish national register (SweSpineregister). Surgical treatment was performed after failure of conservative treatment. Analysis of the results showed that the operation led to the recovery and restoration of physical activity in all cases, only 4.5 % of patients were not satisfied with the quality of life one year after surgery.

In our series of patients, surgical treatment also resulted in complete pain relief and functional recovery in the long term period in all cases.

De Orio et al. [8] analyzed the results of treatment of 50 patients under the age of 16 years, who underwent discectomy at the Mayo clinic (USA) in 1950—1976. The immediate postoperative outcomes were rated as good or excellent in 94 % of cases. Long-term outcomes were followed for an average of 19 years (5 to 30 years). In 12 of 37 patients, discectomy was followed by reoperations due to recurrent herniation or in order to perform spinal fusion. High percentage of reoperations was most likely due to the aggressive tactics of decompression practiced during that period. Thus, in this group of 16 patients, who underwent subtotal multilevel hemilaminectomy, reoperations were required in seven cases. Nevertheless, long-term results were rated as good or excellent in 73.5 % of cases, unsatisfactory — in 26.5 % of cases.

Kevin et al. [Cited according to 6] analyzed the results of treatment of 87 patients aged on the average 16.6 years (12 to 18). All the patients underwent microdiscectomy in 1999—2008 at the Boston Children's Hospital (USA). Preoperative motor deficit was observed in 26 % of patients, sensory disturbances — in 41 %, reflex loss — in 22 %, positive Lasegue's sign — in 95 %. These clinical symptoms were similar to those in our patients, who had a positive Lasegue's sign in 100 % of the cases, paretic syndromes — in 14.7 %. According to the authors, the average duration of primary conservative treatment before the decision towards surgery was 12.2 months, which also correlates with our findings. In 1% of cases, the authors observed the development of postoperative neurological deficit and 6 % of patients required reoperation for stabilization of the spine.

Durham et al. [9] studied the long-term outcomes of 29 patients operated on under the age of 17 years for an average of 8.5 years (4 months to 30.5 years) after surgery. Reoperations were required in 24 % of patients. The authors noted that, in contrast to adults, it was difficult to determine any factors that predispose to the occurrence of an unsatisfactory outcome or need for reoperation in adolescents.

Thus, on the basis of literature data and our own experience, we believe that there is no point to completely refuse primary stabilization of the spinal motion segment during removal of disc herniation in children and adolescents. Differentiated approach is required: in the case of segmental instability, high weight, or large herniation, one or another fixation method can be used and the dynamic stabilization of the spinal motion segment is a preferred option.

There are reports that in children, back pain can prevail over the radicular symptoms in some cases, being discogenic similar to lumbalgia associated with degenerative disc changes in adults [20]. Kasliwal et al. [13] noted that in cases, where radicular pain is not the dominant symptom, microdiscectomy can result in incomplete pain relief. In 2010, the authors published the first report on the use of total prosthetic replacement of the lumbosacral intervertebral disc in adolescent patients. In this case, both patient, a young female (15 years old)

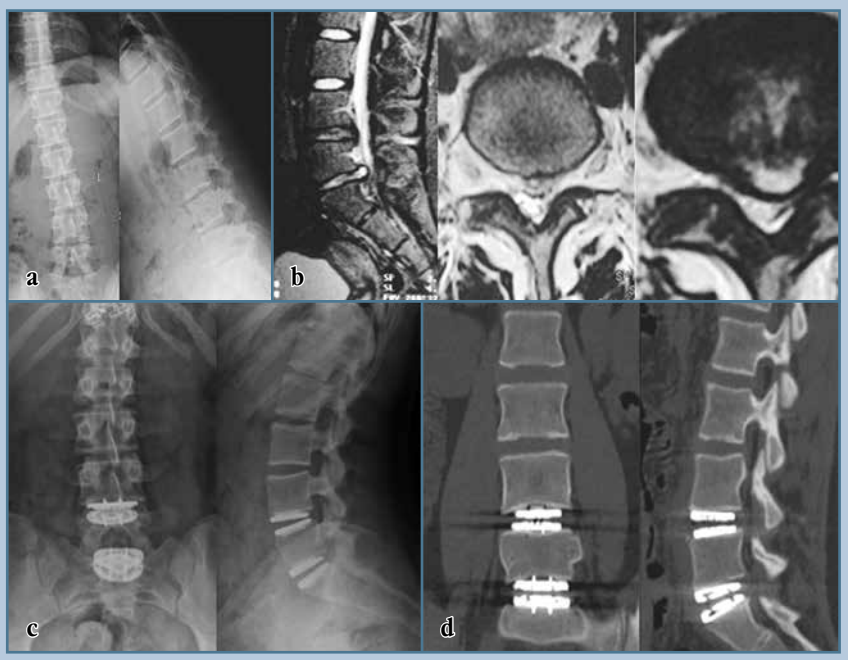

Fig. 3
The data of patient L., 14 years old: **a** — preoperative X-ray; **b** — preoperative MRI; **c** — postoperative X-ray; **d** — postoperative CT

and a young male (16 years old) had a history of microdiscectomy in connection with radicular pain and herniated discs at L4—L5 and C5—S1, respectively. The patients were followed for 6 months after the surgery. Full cure and functional recovery of the female patient and only partial elimination of pain in the male patient were observed. Our own experience of prosthetic replacement in two patients also resulted in good functional outcome with pain relief in the immediate postoperative period.

A new method to prevent the risk of disc herniation recurrence after microdiscectomy, namely closing the annulus fibrosus defect with Barricaid implant, appears to be quite promising [2, 11]. This problem is particularly important in children and adolescents, since complete or maximum removal of the disc in this case is believed to be unjustified. Thus, according to Luukkonen et al. [18], it can lead to restenosis of the neural structures due to sharp decrease in disc height and the development of degenerative changes in the adjacent segments. Furthermore, according to Ishihara et al. [11], sparing discectomy preserving the inner surface of the annulus fibrosus can result in a certain disc regeneration in the late postoperative period.

We used the technique of closing the annulus fibrosus defect in five patients, which did not necessitate the expansion of surgical approach, showed good outcomes of surgical treatment, and was carried out without complications. Of course, a larger group of patients and long-term outcomes of the study are required for a more objective assessment of the method.

Analysis of the experience of these three hospitals in the treatment of herniated intervertebral discs in the age group up to 17 years has shown that our findings are similar to those reported in the available literature. On the contrary, the results of surgical treatment were only good and excellent. The methods of surgical treatment are still a debatable issue. It is advisable to use sparing minimally invasive procedures to remove herniae. In the cases where stabilization is required, it is better to use dynamic fixators. These results agree with the data obtained in the systematic review of the literature on this issue by Dang and Liu, 2010 [7].

Thus, surgical treatment for herniated intervertebral discs in children leads to excellent outcome with complete regression of pain and patients return to their usual active lifestyle.

Conclusion

The indications for surgical treatment of herniated discs in children and adolescents include persistent radicular pain, in some cases accompanied by neurological deficit, ineffective conservative therapy, and verified vertebrogenic morphological substrate.

Surgical treatment should be aimed at decompressing the intracanal neurovascular structures followed by subsequent dynamic and rigid stabilization of the segment, when possible. In this case, surgical intervention in children and adolescents will result in elimination of pain and full functional recovery.

The study was not sponsored. The authors declare no conflict of interest.

References

1. **Balague F, Dutoit G, Waldburger M.** Low back pain in schoolchildren: an epidemiological study. Scand J Rehabil Med. 1988;20:175–179.
2. **Bouma GJ, Barth M, Ledic D, Vilendecic M.** The high-risk discectomy patient: prevention of reherniation in patients with large anular defects using an anular closure device. Eur Spine J. 2013;22:1030–1036. DOI: 10.1007/s00586-013-2656-1.
3. **Bradbury N, Wilson LF, Mulholland RC.** Adolescent disc protrusions. A long-term follow-up of surgery compared to chymopapain. Spine. 1996;21:372–377. DOI: 10.1097/00007632-199602010-00024.
4. **Bruske-Hohlfeld I, Merritt JL, Onofrio BM, Stonnington HH, Offord KP, Bergstralh EJ, Beard CM, Melton LJ 3rd, Kurland LT.** Incidence of lumbar disc surgery. A population-based study in Olmsted County, Minnesota, 1950–1979. Spine. 1990;15:31–35. DOI: 10.1097/00007632-199001000-00009.
5. **Burton AK, Clarke RD, McClune TD, Tillotson KM.** The natural history of low back pain in adolescents. Spine. 1996;21:2323–2328. DOI: 10.1097/00007632-199610150-00004.
6. **Cahill KS, Dunn I, Gunnarsson T, Proctor MR.** Lumbar microdiscectomy in pediatric patients: a large single-institution series. J Neurosurg Spine. 2010;12:165–170. DOI: 10.3171/2009.9.SPINE09756.
7. **Dang L, Liu Z.** A review of current treatment for lumbar disc herniation in children and adolescents. Eur Spine J. 2010;19:205–214. DOI: 10.1007/s00586-009-1202-7.
8. **De Orio JK, Bianco AJ Jr.** Lumbar disc excision in children and adolescents. J Bone Joint Surg Am. 1982;64:991–996.
9. **Durham SR, Sun PP, Sutton LN.** Surgically treated lumbar disc disease in the pediatric population: an outcome study. J Neurosurg. 2000 Jan;92(1 Suppl):1–6.
10. **Harreby M, Nygaard B, Jessen T, Larsen E, Storr-Paulsen A, Lindahl A, Fisker I, Laegaard E.** Risk factors for low back pain in a cohort of 1389 Danish school children: an epidemiologic study. Eur Spine J. 1999;8:444–450. DOI: 10.1007/s005860050203.
11. **Ishihara I, Matsui H, Hirano N, Tsuji H.** Lumbar intervertebral disc herniation in children less than 16 years of age. Long-term follow up study of surgically managed cases. Spine 1997;22:2044–2049.
12. **Jones GT, Macfarlane GJ.** Epidemiology of low back pain in children and adolescents. Arch Dis Child. 2005;90:312–316. DOI: 10.1136/adc.2004.056812.
13. **Kasliwal MK, Deutsch H.** Lumbar disc replacement in adolescents: An initial experience in two cases. J Pediatr Neurosci. 2012;7:129–132. DOI: 10.4103/1817-1745.102577.
14. **Kelsey JK, White AA 3rd.** Epidemiology and impact of low back pain. Spine. 1985;5:133–142. DOI: 10.1097/00007632-198003000-00007.
15. **Leboeuf-Yde C, Kyvik KO.** At what age does low back pain become a common problem? A study of 29 424 individuals aged 12–41 years. Spine. 1998;23:228–234. DOI: 10.1097/00007632-199801150-00015.
16. **Lequin B, Barth M, Thome C, Bouma GJ.** Primary limited lumbar discectomy with an annulus closure device: one-year clinical and radiographic results from a prospective, multi-center study. Korean J Spine. 2012;9:340–347. DOI: 10.14245/kjs.2012.9.4.340.
17. **Lukhele M, Mayet Z, Dube B.** Lumbar disc herniation in a 9-year-old child. SA Orthopaedic Journal. 2011;10:93-96.
18. **Luukkonen M, Partanen K, Vapalahti M.** Lumbar disc herniations in children: a long-term clinical and magnetic resonance imaging study. Br J Neurosurg 1997;11:280–285. DOI: 10.1080/02688699746041.
19. **Maniadakis N, Gray A.** The economic burden of back pain in the UK. Pain. 2000;84:95–103. DOI: 10.1016/S0304-3959(99)00187-6.
20. **Micheli LJ, Wood R.** Back pain in young athletes. Significant differences from adults in causes and patterns. Arch Pediatr Adolesc Med. 1995;149:15–18.
21. **Salminen JJ, Pentti J, Terho P.** Low back pain and disability in 14-year-old schoolchildren. Acta Paediatr. 1992;81:1035–1039. DOI: 10.1111/j.1651-2227.1992.tb12170.x.
22. **Sato T, Ito T, Hirano T, Morita O, Kikuchi R, Endo N, Tanabe N.** Low back pain in childhood and adolescence: a cross-sectional study in Niigata city. Eur Spine J. 2008;17:1441–1447. DOI: 10.1007/s00586-008-0788-5.
23. **Stromqvist F, Stromqvist B, Jonsson B, Gerdhem P, Karlsson MK.** Outcome of surgical treatment of lumbar disc herniation in young individuals. Bone Joint J. 2015;97-B:1675–1682. DOI: 10.1302/0301-620X.97B12.36258.
24. **Watson KD, Papageorgiou AC, Jones GT, Taylor S, Symmons DPM, Silman AJ, Macfarlane GJ.** Low back pain in schoolchildren: occurrence and characteristics. Pain. 2000;97:87–92. DOI: 10.1016/S0304-3959(02)00008-8.
25. **Yao W, Mai X, Luo C, Ai F, Chen Q.** A cross-sectional survey of nonspecific low back pain among 2083 schoolchildren in China. Spine. 2011;36:1885–1890. DOI: 10.1097/BRS.0b013e3181faadea.

Address correspondence to:
Vetrile Marchel Stepanovich
CITO n.a. N.N. Priorov, Priorova str., 10,
Moscow, 127299, Russia,
cito-spine@mail.ru

Received 16.09.2016
Review completed 17.11.2016
Passed for printing 05.12.2016

Aleksandr Alekseyevich Kuleshov, DMSc, leading researcher, head of Pediatric Vertebrology Group, Central Institute of Traumatology and Orthopaedics n.a. N.N. Priorov, Moscow, Russia, cito-spine@mail.ru;
Aleksandr Vladimirovich Krutko, MD, DMSc, Head of Neurosurgery Department No. 2, Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, Novosibirsk, Russia; orto-ped@mail.ru, AKrutko@niito.ru;
Olimdzhan Sadykovich Iskhakov, DMSc, leading researcher, high-level certificate neurosurgeon, Head of Neurosurgical Department, Institute of Emergency Pediatric Surgery and Traumatology, Moscow, Russia, niindbt@zdrav.mos.ru;
Marchel Stepanovich Vetrile, MD, PhD, senior researcher, Pediatric Vertebrology Group, Central Institute of Traumatology and Orthopaedics n.a. N.N. Priorov, Moscow, Russia, cito-spine@mail.ru;
Medetbek Dzhumabekovich Abakirov, DMSc, Professor in the department of traumatology and orthopaedics, Institute of Emergency Pediatric Surgery and Traumatology, Moscow, Russia, medetbek@mail.ru;
Aleksey Vladimirovich Peleganchuk, MD, PhD, junior researcher, traumatologist-orthopedist in the Neurosurgery Department No. 2, Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, Novosibirsk, Russia, APeleganchuk@mail.ru;
Andrey Igorevich Vasilyev, junior researcher, Novosibirsk Research Institute of Traumatology and Orthopaedics n.a. Ya.L. Tsivyan, Novosibirsk, Russia, AndreyIVasilev@gmail.com;
Igor Nikolayevich Lisyansky, MD, PhD, Pediatric Vertebrology Group, Central Institute of Traumatology and Orthopaedics n.a. N.N. Priorov, Moscow, Russia, lisigornik@list.ru;
Semyon Vladimirovich Meshcheryakov, MD, junior researcher, Institute of Emergency Pediatric Surgery and Traumatology, Moscow, Russia, niindbt@zdrav.mos.ru;
Aleksey Ivanovich Kokorev, MD fellow, Central Institute of Traumatology and Orthopaedics n.a. N.N. Priorov, Moscow, Russia, cito-spine@mail.ru.