ANNULOPLASTY AS A METHOD TO PREVENT THE RECURRENCE OF THE LUMBAR INTERVERTEBRAL DISC HERNIATION: A LITERATURE REVIEW

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The presented literature review highlights epidemiological aspects of the unfavorable outcome following surgical treatment of patients with herniated lumbar intervertebral discs, the risk factors for hernia recurrence, and the annuloplasty as one of the methods to prevent recurrent herniation. The concept of the annuloplasty is based on a number of favorable factors: maintaining the height of the intervertebral disc, preventing the hernia recurrence due to the barrier function, reducing lumbodynia due to limited microdiscectomy, and slowing down the degenerative cascade both in the intervertebral disc and facet joints. The study material included abstracts from the Scopus and PubMed databases, articles published in Spine, European Spine Journal, and in Russian periodicals over the past 10 years, as well as publications of the previous years, when required.

Key Words: microdiscectomy, recurrence of lumbar disc herniation, annuloplasty.

Please cite this paper as: *Sanginov AJ. Annuloplasty as a method to prevent the recurrence of the lumbar intervertebral disc herniation: a literature review. Hir. Pozvonoc. 2017;14(2):63–69. In Russian.*

DOI: http://dx.doi.org/10.14531/ss2017.2.63-69.

Intervertebral disc herniation is the most common degenerative disease of the lumbosacral spine that causes pain and neurological syndromes. Surgical methods are important in the treatment of patients with this pathology. Currently, microdiscectomy has been the most commonly performed neurosurgical procedure [7]. Despite the advanced achievements in vertebrology, the interest of scientists to the surgical treatment of lumbar disc herniation does not fade out, as seen by continually rising numbers of studies, publications, and developments aimed at improving the outcomes of surgical treatment [4, 6, 17, 21].

According to Russian and foreign authors [37, 38], microsurgical decompressive interventions for lumbar intervertebral disc herniations carry favorable outcomes in 80–90 % of cases. However, 5 to 25 % of patients continue to suffer from pain syndrome of different intensity in the lumbar spine or leg pain postoperatively. Patient satisfaction is only 75 % one year after surgery and the rate of revision surgeries following primary microdiscectomy ranges from 9 to 25 % [1, 18].

Recurrent lumbar disc herniation is one of the main reasons for revision surgery [10, 28, 34, 37]. According to various authors, the total rate of recurrent intervertebral disc herniation ranges from 2 to 27 % [10, 18, 21, 22, 25, 31, 39, 40, 43, 44]. The literature has a sufficient number of studies concerning the issue of recurrent intervertebral disc herniation; however, there is still no common definition. The most common view appears to regard the recurrence of disc herniation as the reappearance of radicular pain after a pain-free period and the presence of ipsilateral and/or contralateral herniated fragment at the operated level on MRI/CT [9, 39].

The major risk factors for recurrent lumbar intervertebral disc herniation can be age, smoking, gender, trauma, body mass, the stage of degeneration and intervertebral disc height, the segmental range of motion, herniation type, etc. [5, 14, 16, 22, 25, 33]. The following biomechanical and radiographic characteristics have a significant correlation with a poor outcome of microdiscectomy: disc height, segment hypermobility, flattening of the lumbar lordosis, the protrusion type of herniation, Modic type I endplate changes, and grade III of disc degeneration on the Pfirrmann grading system [2].

In recent years, researchers have taken into account the annular defect size and the volume of removed nucleus pulposus as a prognostic factor. Carragee et al. [18] reported in a prospective study of 187 patients with a median follow-up of 6 years that the herniation type, the size of the annular defect, and the volume of removed nucleus pulposus after discectomy correlated with the recurrence rate of herniation. They classified disc herniations into four categories: I – disc extrusion with a minimal (slit-like) annular defect; II – sequestrated herniation with a large annular defect (>6 mm); III – disc extrusion with an intact annulus fibrosus (iatrogenic slit-

like defect); IV – disc protrusion with an intact annulus fibrosus (iatrogenic large defect). In all cases, limited microdiscectomy (sequestrectomy) was performed. In type II, the recurrence of disc herniation and reoperation for reherniation were found to be 27 and 21 %, respectively. In type IV herniation, an adverse outcome was observed in 38 % of cases in form of recurrent disc herniation causing back/leg pain. The best outcomes were observed at type I, with recurrent disc herniation being recorded in 1 % of cases. In a next study, Carragee et al. [19] studied the rate of lumbar disc reherniation in relation to the size of the annular defect and the volume of removed nucleus pulposus. It was found that reherniation and reoperation were observed in 18 and 10 % of cases, respectively, in the limited microdiscectomy group versus 9 and 7 % of cases in the aggressive (subtotal) microdiscectomy group. However, in follow-up periods of up to two years, the patient satisfaction with the outcomes of surgery was higher in the limited microdiscectomy group.

It is noted that surgeons in practice encounter two types of microdiscectomy based on the volume of removed nucleus pulposus: aggressive and limited (conservative). The aggressive (subtotal) microdiscectomy involves the removal of the protruded herniated fragment, adjacent tissues of the nucleus pulposus, and disc curettage, while the limited discectomy (sequestrectomy) involves only the removal of the herniated fragment. The subtotal microdiscectomy is an effective way to reduce the rates of reherniation because of the removal of a large volume of the nucleus pulposus material. However, this causes loss of disc height, accelerates disc degeneration, reduces the ability of a disc to withstand axial loads, and increases axial loads on the facet joints violating the biomechanics of segmental motion and causes the formation of persistent pain syndrome. In a prospective cohort study of 108 patients undergoing microdiscectomy with a follow-up length of 24 months, McGirt et al. [32] revealed a more than 25 % loss of disc height in 50 % of patients. To minimize this adverse effect, some surgeons employ limited discectomy; however, it increases disc herniation recurrence to 27 % [18, 19, 31, 32, 37, 45].

McGirt et al. [31] conducted a meta-analysis of 54 studies comprising 13 359 cases of microdiscectomy (6135, limited discectomy; 7224, aggressive discectomy) and revealed that the early postoperative outcomes were matched, but the follow-up periods of more than two years were characterized by a 2.5-time greater incidence of recurrent pain syndrome in the aggressive microdiscectomy group (11.6 and 27.8 %, respectively; $p = 0.0001$) and a greater incidence of recurrent intervertebral disc herniation in the limited microdiscectomy group (7.0 and 3.5 %, respectively; $p = 0.0001$).

In a prospective randomized study, Barth et al. [13] evaluated the outcomes of surgical treatment of 84 patients with disc herniation depending on the extent of microdiscectomy. The patients were treated with sequestrectomy or subtotal microdiscectomy in equal parts. The follow-up period was 24 months. Patients treated with limited microdiscectomy were reported to carry good clinical outcomes with less back pain. In addition, significant differences in the reherniation rates within the two-year period were not revealed in this study.

According to different authors, a loss of disc height was observed in 49–100 % of patients following microdiscectomy, which correlates with radiographic signs of instability and the severity of clinical manifestations in form of pain syndrome. Radiographic signs of instability were not observed with a loss of disc height by less than 25 % of the original values. A loss of disc height by more than 25 % was coupled with the appearance of low back pain, changes in the biomechanics of spinal motion segment, and the occurrence of segmental instability [30, 45]. McGirt et al. [32] revealed a 26 % loss of disc height in intraoperative removal of 2.0 ± 1.1 cm^3 nucleus pulposus material, with the area of the annular defect of 45.6 mm^2. A less than 8 % loss of disc height was observed in patients after the removal of 1.5 ± 0.6 cm^3 nucleus pulposus. In addition, the likelihood of disc reherniation was found to increase in patients with a larger area of the annular defect and a smaller volume of removed nucleus pulposus.

The development of new medical technologies, the advancement of surgical techniques, and the introduction of minimally invasive procedures for removal of intervertebral disc herniations have improved the short-term outcomes of the operation. But the issue of reherniation remains central. I.A. Drakin et al. [3] used non-destructive laser irradiation as a prevention method for recurrent disc herniation to induce reparative response in the annulus fibrosus and posterior longitudinal ligament in Caspar microsurgical discectomy. However, the authors did not provide the outcomes of applying this technique.

Various methods of plastic reconstruction of the annular defect and restoration of the annular integrity after microdiscectomy have been offered to prevent the recurrence of lumbar intervertebral disc herniations. Cauthen et al. perform more nuanced studies of this issue, in which they conducted annuloplasty with autofascia and noted the reduction of intervertebral disc reherniation by 2 times during the follow-up period of up to two years [20].

The concept of annuloplasty technique is based on several favorable factors: maintaining the disc height, preventing the hernia recurrence due to the barrier function, reducing low back pain due to limited microdiscectomy, and slowing down the degenerative cascade both in the intervertebral disc and facet joints [36].

Ahlgren et al. [8] examined the closure of iatrogenic defect of the annulus fibrosus using vicryl sutures in an experimental study in sheep. According to the study, repair of the annular incision showed no advantage in the healing and the strength to biomechanical loads over the discs left to heal unrepaired.

The importance of restoring the integrity of the annulus fibrosus is apparent. In recent years, biodegradable glues for annulus fibrosus repair have been studied actively in experiments *in vivo* and *in vitro*. Likhitpanichkul et al. [29] described criteria for such glues: 1) high adhesion

to the fibrous tissue; 2) identical properties with the annulus fibrosus; 3) biocompatibility; 4) longevity of properties and structures under mechanical stress; 5) injection route of administration; 6) ease of use during surgery.

Vergoesen et al. [41] tested the strength and endurance of the annulus fibrosus of a goat intervertebral disc in in vivo experiments after annular defect closure with biodegradable glue. Defects were punctured with a 2.4-mm needle (n = 11), unglued discs were used in the control group (n = 11). The strength and endurance in biomechanical loads in a bioreactor with 864 000 load cycles in each group, healing of the defect, and the fact of herniation in the study region were tested. A series of biomechanical tests showed the strength and endurance of the glued defect. In the control group, 40 % of discs failed to withstand loading, disc herniation occurred, and the disc height decreased. The authors concluded that biodegradable glues are effective in restoration of the annulus fibrosus and increase the annulus strength in biomechanical loads. However, the clinical use requires long-term studies, including *in vivo*.

Wang et al. [42] used soluble gelatin sponge, platinum coil, bone cement, and tissue glue for defect closure on a porcine model after microdiscectomy. Two months after the surgery, the area subjected to repair, intradiscal pressure, and disc capacity to withstand various loads were studied. The gelatin sponge group carried the best results. The authors emphasize that gelatin sponge could be potentially used to prevent recurrent disc herniation.

In an experimental study *in vitro*, Kang et al. [24] performed annular defect repair by placing bioscaffold on the defect, suture, and further sealing with medical cyanoacrylate glue. Under laboratory conditions, the experimental group withstood biomechanical load after this type of annuloplasty. Regeneration in the defect area was evaluated using histological sections. No toxic effect on tissues was identified. The authors conclude that this technique merits further studies, including *in vivo*.

A range of implants is used in clinical practice for annuloplasty, which find a growing application.

The Inclose Surgical Mesh System (Anulex Technologies Inc., Minnetonka, MN) is woven cylindrical flexible mesh of biocompatible material, which consists of polyethylene terephthalate. A 3.5-mm implant having a cylindrical shape is implanted under the annulus fibrosus in the annular defect using a delivery device. The latter is also used to expand an implant to the size of a cavity formed after the removal of the nucleus pulposus. Following insertion, the implant expands, acquires a desired form and position within the intervertebral space and holds the nucleus pulposus surrounded by the annulus fibrosus [15]. A disc height at disc posterior portions must be at least 6 mm for adequate implant expansion and function. The size of an annular defect should be at least 3 mm in width and height. The main advantage of this implant is its efficacy in the prevention of contralateral reherniation due to a large closure of the annulus fibrosus along the entire length of the posterior half of intervertebral disc area [20].

Another implant used in annuloplasty is the Xclose Tissue Repair System. It consists of two threads with hooks and a disposable delivery device. Bailey et al. [11] conducted a prospective multicenter single-blind randomized study to evaluate the effectiveness of method for closing annulus defect using this implant. The first group (n = 500) included patients who underwent microdiscectomy followed by annular repair using the Xclose system, the second group (n = 250) included the subjects operated on without annular repair system. The outcomes of treatment (assessment of pain syndrome using the VAS scale, Oswestry disability index, questionnaire SF-12, the fact of the recurrent disc herniation and pain syndrome) were assessed 2 weeks, 6, 12, and 24 months after surgery. Significant differences between the groups on scales assessing the clinical condition were not observed. The rate of disc reherniation requiring reoperation was lower for the Xclose group. In 3, 6, and 24 months after surgery, recurrent disc herniation was noted in 2.4, 4.1, and 9.7% for the Xclose patients and 4.5, 6.2, and 11.2 % for patients in the comparison group, respectively. Thus, the rate of recurrence was lower in the Xclose group, but this difference was not significant. The authors conclude that annular repair using Xclose reduces the rate of recurrent disc herniation. Despite this, the patients need further postoperative long-term monitoring [17].

A technique of annular repair using the Barricaid implant received the greatest recognition among spine surgeons. The product consists of two components: a flexible polyester mesh closing an annular defect and a titanium fixator (anchor), which is attached to one of the adjacent vertebral bodies.

Indications for using this implant are posterolateral hernia involving L2–L3, L3–L4, L4–L5, L5–S1 segments, an intervertebral disc height in the posterior portions of ≥5 mm, protrusive type of herniation, and grades I–III of disc degeneration on the Pfirrmann grading system. It is not recommended to insert this implant in spondylolisthesis, degenerative lumbar spinal stenosis, segmental instability, scoliotic deformity of the lumbar spine, recurrent intervertebral disc herniation, syndrome of polyradicular nerve root compression of the cauda equina, foraminal and/or extraforaminal disc herniation, osteoporosis (T-score < -2.0), anomalies, and non-degenerative injuries of the lumbar spine [24].

Parker et al. [35] in a prospective comparative multicenter study assessed the outcomes of annular repair within two years. It was revealed that recurrent disc herniation did not occur in any patients with the annular closure device (ACD) and the recurrence of disc herniation was found in 6.5 % of cases in the comparison group (microdiscectomy alone). The authors concluded that the reduction in the incidence of reherniation was associated with potentially significant cost savings.

Ledic et al. [26] in a multicenter prospective study investigated the rate of recurrent intervertebral disc herniation and the change of disc height in the postoperative period in 75 patients treat-

ed with limited microdiscectomy with annular defect repair using the annular closure device. In a follow-up within two years, the recurrence of ipsilateral disc herniation was noted in 1 (1.5 %) of 68 patients. A disc height was at the level of no more than 75 % of the preoperative values in 97 % patients 12 months after surgery and in 92 % patients in 24 months.

Lequin et al. [27] conducted a prospective study of 45 patients with a follow-up period of 24 months, who underwent limited discectomy and annuloplasty using the annular closure device. The authors found a significant decrease in the intensity of pain syndrome and improvement in quality of life of the patients. An intervertebral disc height was on average 92.8 % of the preoperative values in 12 months. Three (6.7 %) cases needed reoperation: one case for ipsilateral recurrent disc herniation, the second case for contralateral recurrent disc herniation, and the third patient for excessive scar tissue formation.

Barth et al. [12] in a prospective controlled study with a 18 month-follow-up noted a statistically significant decrease in the rate of recurrent intervertebral disc herniation with ACD compared to microdiscectomy alone (2.2 and 12.5 %, respectively).

Despite the available hypothetical and practical positive aspects of the annuloplasty technique, studies showing the long-term outcomes of its application are currently missing. Comparative analyses of the effectiveness of annuloplasty with other techniques that reduce the rate of recurrent lumbar disc herniation are not available. Few studies published in literature have a low level of evidence. The solution to these issues will be helpful for annuloplasty to take a niche within a range of other methods, which are aimed at improving the outcomes of surgical treatment of patients with lumbar intervertebral disc herniation.

The issue of recurrent disc herniation after lumbar microdiscectomy has not been resolved. The restoration of integrity of the annulus fibrosus through defect closure with preservation of an intervertebral disc height and disc biomechanical properties is a promising direction in solving the issue related to the improvement of surgical outcomes in patients with lumbar disc herniation. The development of effective methods and technologies for the prevention of adverse surgical outcomes for lumbar intervertebral disc herniations should be the subject of future high-quality trials.

This study was not supported by sponsorship. The author declare that he has not competing interests

References

1. **Akhmetyanov ShA, Krutko AV.** Results of surgical treatment of degenerative lesions of the lumbosacral spine. Problems of modern science and education.2015;(5):324. In Russian.
2. **Baikov ES.** Predicting the results of surgical treatment of herniated lumbar intervertebral discs: MD/PhD Thesis. Novosibirsk, 2014. In Russian.
3. **Drakin IA, Baskov VA, Dreval ON, Baskov AV.** Risk factors and prevention methods for recurrent lumbar disc herniations. Pacific Medical Journal. 2015;(4):11–16. In Russian.
4. **Konovalov NA.** New technologies and algorithms for diagnosis and surgical treatment of degenerative diseases of the lumbar spine: DMSc Thesis. Moscow, 2010. In Russian.
5. **Krutko AV, Baikov ES.** The role of radiological parameters of spinal motion segment in the outcome of surgical treatment for lumbar intervertebral disc hernia. Hir Pozvonoc. 2013;(1):55–63. In Russian. DOI: http://dx.doi.org/10.14531/ss2013.1.55-63.
6. **Krylov VV, Lebedev VV, Grin AA, Ioffe YuS.** The state of neurosurgical care for patients with traumas and spinal diseases in Moscow (data from neurosurgical hospitals of the Health Committee in 1997–1999). Neyrohirurgiya. 2001;(1):60–66. In Russian.
7. **Lutsik AA, Sadovoy MA, Krutko AV, Epifantsev AG.** Degenerative Dystrophic Diseases of the Spine. Novosibirsk, 2012. In Russian.
8. **Ahlgren BD, Lui W, Herkowitz HN, Panjabi MM, Guiboux JP.** Effect of annular repair on the healing strength of the intervertebral disc: a sheep model. Spine. 2000;25:2165–2170.
9. **Ambrossi GL, McGirt MJ, Sciubba DM, Witham TF, Wolinsky JP, Gokaslan ZL, Long DM.** Recurrent lumbar disc herniation after single-level lumbar discectomy: incidence and health care cost analysis. Neurosurgery. 2009;65:574–578. DOI: 10.1227/01.NEU.0000350224.36213.F9.
10. **Atlas SJ, Keller RB, Wu YA, Deyo RA, Singer DE.** Long-term outcomes of surgical and nonsurgical management of sciatica secondary to a lumbar disc herniation: 10 year results from the maine lumbar spine study. Spine. 2005;30:927–935.
11. **Bailey A, Araghi A, Blumenthal S, Huffmon GV.** Prospective, multicenter, randomized, controlled study of anular repair in lumbar discectomy: two year follow up. Spine. 2013;38:1161–1169. DOI: 10.1097/BRS.0b013e31828b2e2f.
12. **Barth M, Fontana J, Thome C, Bouma GJ, Schmieder K.** Occurrence of discal and non-discal changes after sequestrectomy alone versus sequestrectomy and implantation of an anulus closure device. J Clin Neurosci. 2016;34:288–293. DOI: 10.1016/j.jocn.2016.09.013.
13. **Barth M, Weiss C, Thome C.** Two-year outcome after lumbar microdiscectomy versus microscopic sequestrectomy: part 1: evaluation of clinical outcome. Spine. 2008;33:265–272. DOI: 10.1097/BRS.0b013e318162018c.
14. **Belykh E, Krutko AV, Baykov ES, Giers MB, Preul MC, Byvaltsev VA.** Preoperative estimation of disc herniation recurrence after microdiscectomy: predictive value of a multivariate model based on radiographic parameters. Spine J. 2016;17:390–400. DOI: 10.1016/j.spinee.2016.10.011.
15. **Bourgeault C, Beaubien B, Griffith S.** Biomechanical assessment of annulus fibrosus repair with suture tethered anchors. In: Spine Arthroplasty Society. Vol. 7. Berlin, 2007.
16. **Bridwell KH, Anderson PA, Boden SD, Vaccaro AR, Wang JC.** What's new in spine surgery. J Bone Joint Surg Am. 2011;93:1560–1566. DOI: 10.2106/JBJS.K.00508.
17. **Bron JL, Helder MN, Meisel HJ, Van Royen BJ, Smit TH.** Repair, regenerative and supportive therapies of the annulus fibrosus: Achievements and challenges. Eur Spine J. 2009;18:301–313. DOI: 10.1007/s00586-008-0856-x.
18. **Carragee EJ, Han MY, Suen PW, Kim D.** Clinical outcomes after lumbar discectomy for sciatica: the effects of fragment type and anular competence. J Bone Joint Surg Am. 2003;5:102–108. DOI: 10.2106/00004623-200301000-00016.
19. **Carragee EJ, Spinnickie AO, Alamin TF, Paragioudakis S.** A prospective controlled study of limited versus subtotal posterior discectomy: Short-term outcomes in patients with herniated lumbar intervertebral discs and large posterior anular defect. Spine. 2006;31:653–657. DOI: 10.1097/01.brs.0000203714.76250.68.
20. **Cauthen JC, Griffith SL.** Repair and reconstruction of the anulus fibrosus with the Inclose™ surgical mesh system. In: Motion Preservation Surgery of the Spine: Advanced Techniques and Controversies, ed. by Yue JJ, Bertagnoli R, McAfee PC, An HS. 1st ed. Saunders (W.B.) Co Ltd, 2008:623–628.
21. **Chou R, Baisden J, Carragee EJ, Resnick DK, Shaffer WO, Loeser JD.** Surgery for low back pain: a review of the evidence for an American Pain Society Clinical Practice Guideline. Spine. 2009;34:1094–1109. DOI: 10.1097/BRS.0b013e3181a105fc.
22. **Cinotti G, Roysam GS, Eisenstein SM, Postacchini F.** Ipsilateral recurrent lumbar disc herniation: a prospective, controlled study. J Bone Joint Surg Br. 1998;80:825–832.
23. **Gorensek M, Vilendecic M, Eustacchio S, Trummer M, Eskinja N, Ledic D, Lambrecht G, Einhorn J, Kamaric E, Yeh O.** P126. Clinical investigation of the intrinsic therapeutics Barricaid, a novel device for closing defects in the annulus. Spine J. 2006;6:144S. DOI: 10.1016/j.spinee.2006.06.335.
24. **Kang R, Li H, Lysdahl H, Quang Svend Le D, Chen M, Xie L, Bunger C.** Cyanoacrylate medical glue application in intervertebral disc annulus defect repair: Mechanical and biocompatible evaluation. J Biomed Mater Res B Appl Biomater. 2017;105:14–20. DOI: 10.1002/jbm.b.33524.
25. **Kim JM, Lee SH, Ahn Y, Yoon DH, Lee CD, Lim ST.** Recurrence after successful percutaneous endoscopic lumbar discectomy. Minim Invasive Neurosurg. 2007;50:82–85.
26. **Ledic D, Vukas D, Grahovac G, Barth M, Bouma GJ, Vilendecic M.** Effect of anular closure on disk height maintenance and reoperated recurrent herniation following lumbar diskectomy: two-year data. J Neurol Surg A Cent Eur Neurosurg. 2015;76:211–218. DOI: 10.1055/s-0034-1393930.
27. **Lequin MB, 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.
28. **Leven DD, Passias PG, Errico TJ, Lafage V, Bianco K, Lee A, Lurie JD, Tosteson TD, Zhao W, Spratt KF, Morgan TS, Gerling MC.** Risk factors for reoperation in patients treated surgically for intervertebral disc herniation: a subanalysis of eight-year SPORT data. J Bone Joint Surg Am. 2015;97:1316–1325. DOI: 10.2106/JBJS.N.01287.
29. **Likhitpanichkul M, Dreischarf M, Illien-Junger S, Walter BA, Nukaga T, Long RG, Sakai D, Hecht AC, Iatridis JC.** Fibrin-genipin adhesive hydrogel for annulus fibrosus repair: performance evaluation with large animal organ culture, in situ biomechanics, and *in vivo* degradation tests. Eur Cell Mater. 2014;28:25–38.
30. **Mariconda M, Galasso O, Attingenti P, Federico G, Milano C.** Frequency and clinical meaning of long-term degenerative changes after lumbar discectomy visualized on imaging tests. Eur Spine J. 2010;19:136–143. DOI: 10.1007/s00586-009-1201-8.
31. **McGirt MJ, Ambrossi GL, Datoo G, Sciubba DM, Witham TF, Wolinsky JP, Gokaslan ZL, Bydon A.** Recurrent disc herniation and long-term back pain after primary lumbar discectomy: review of outcomes reported for limited versus aggressive disc removal. Neurosurgery. 2009;64:338–344. DOI: 10.1227/01.NEU.0000337574.58662.E2.
32. **McGirt MJ, Eustacchio S, Varga P, Vilendecic M, Trummer M, Gorensek M, Ledic D, Carragee EJ.** A prospective cohort study of close interval computed tomography and magnetic resonance imaging after primary lumbar discectomy. factors associated with recurrent disc herniation and disc height loss. Spine. 2009;34:2044–2051. DOI: 10.1097/BRS.0b013e3181b34a9a.

33. **Miwa S, Yokogawa A, Kobayashi T, Nishimura T, Igarashi K, Inatani H, Tsuchiya H.** Risk factors of recurrent lumbar disc herniation: a single center study and review of the literature. J Spinal Disord Tech. 2012;28:E265–E269. DOI: 10.1097/BSD.0b013e31828215b3.
34. **Osterman H, Sund R, Seitsalo S, Keskim ki I.** Risk of multiple reoperations after lumbar discectomy: a population-based study. Spine. 2003;28:621–627. DOI: 10.1097/01.BRS.0000049908.15854.ED.
35. **Parker SL, Grahovac G, Vukas D, Ledic D, Vilendecic M, McGirt MJ.** Cost savings associated with prevention of recurrent lumbar disc herniation with a novel annular closure device: a multicenter prospective cohort study. J Neurol Surg A Cent Eur Neurosurg. 2013;74:285–289. DOI: 10.1055/s-0033-1341416.
36. **Parker SL, Grahovac G, Vukas D, Vilendecic M, Ledic D, McGirt MJ, Carragee EJ.** Effect of an annular closure device (Barricaid) on same level recurrent disc herniation and disc height loss after primary lumbar discectomy: two-year results of a multi-center prospective cohort study. Clin Spine Surg. 2016 May 11. [Epub ahead of print]. DOI: 10.1097/BSD.0b013e3182956ec5.
37. **Parker SL, Xu R, McGirt MJ, Witham TF, Long DM, Bydon A.** Long-term back pain after a single-level discectomy for radiculopathy: incidence and health care cost analysis. J Neurosurg: Spine. 2010;12:178–182. DOI: 10.3171/2009.9.SPINE09410.
38. **Peul WC, van den Hout WB, Brand R, Thomeer RT, Koes BW.** Prolonged conservative care versus early surgery in patients with sciatica caused by lumbar disc herniation: two year results of a randomised controlled trial. BMJ. 2008;336: 1355–1358. DOI: 10.1136/bmj.a143.
39. **Shin BJ.** Risk factors for recurrent lumbar disc herniations. Asian Spine J. 2014;8:211–215. DOI: 10.4184/asj.2014.8.2.211.
40. **Spengler DM, Ouellette EA, Battie M, Zeh J.** Elective discectomy for herniation of a lumbar disc. Additional experience with an objective method. J Bone Joint Surg Am. 1990;72:230–237.
41. **Vergoesen PP, Bochynska AI, Emanuel KS, Sharifi S, Kingma I, Grijpma DW, Smit TH.** A biodegradable glue for annulus closure: evaluation of strength and endurance. Spine. 2015;40:622–628. DOI: 10.1097/BRS.0000000000000792.
42. **Wang YH, Kuo TF, Wang JL.** The implantation of noncell-based materials to prevent the recurrent disc herniation: an *in vivo* porcine model using quantitative discomanometry examination. Eur Spine J. 2007;16:1021–1027. DOI: 10.1007/s00586-007-0306-1.
43. **Watters WC 3rd, McGirt MJ.** An evidence-based review of the literature on the consequences of conservative versus aggressive discectomy for the treatment of primary disc herniation with radiculopathy. Spine J. 2009;9:240–257. DOI: 10.1016/j.spinee.2008.08.005.
44. **Weinstein JN, Lurie JD, Tosteson TD, Tosteson AN, Blood EA, Abdu WA, Herkowitz H, Hilibrand A, Albert T, Fischgrund J.** Surgical versus nonoperative treatment for lumbar disc herniation: four-year results for the spine patient outcomes research trial (SPORT). Spine. 2008;33:2789–2800. DOI: 10.1097/BRS.0b013e31818ed8f4.
45. **Yorimitsu E, Chiba K, Toyama Y, Hirabayashi K.** Long-term outcomes of standard discectomy for lumbar disc herniation: a follow-up study of more than 10 years. Spine. 2001;26:652–657.

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Received 30.01.2017
Review completed 05.03.2017
Passed for printing 13.03.2017

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