Scientific Research Publishing

Surgical Science, 2018, 9, 63-84
http://www.scirp.org/journal/ss
ISSN Online: 2157-9415
ISSN Print: 2157-9407

Percutaneous Endoscopic Lumbar Spine Surgery for Lumbar Disc Herniation and Lumbar Spine Stenosis: Emphasizing on Clinical Outcomes of Transforaminal Technique

Singh Ratish[1,2], Zeng-Xin Gao[1,2*], Hirachan Mangal Prasad[2], Zhang Pei[1], Dangol Bijendra[1,2]

[1]Depatment of Spine Surgery, Zhongda Hospital Affiliated to Southeast University, Nanjing, China
[2]School of Medicine, Southeast University, Nanjing, China
Email: *55236015@qq.com

How to cite this paper: Ratish, S., Gao, Z.-X., Prasad, H.M., Pei, Z. and Bijendra, D. (2018) Percutaneous Endoscopic Lumbar Spine Surgery for Lumbar Disc Herniation and Lumbar Spine Stenosis: Emphasizing on Clinical Outcomes of Transforaminal Technique. *Surgical Science*, **9**, 63-84.
https://doi.org/10.4236/ss.2018.92007

Received: January 10, 2018
Accepted: February 10, 2018
Published: February 13, 2018

Abstract

Lumbar Disc Herniation and Lumbar Spine Stenosis are the most common spine diseases which are mainly due to age related Spine degeneration. Diagnosis of both Lumbar Disc Herniation and Lumbar Spine Stenosis depends on clinical findings as well as radiological investigations. Treatment of choice of these conditions is on the basis of the patient conditions. Surgical treatment is the option only when the conservative treatment does not improve the patient's clinical condition. Advancement and improvement of the technology have resulted in the traditional open surgical treatment into minimal invasive surgery. Intervention of the different surgical instruments with expert spinal surgeons had made percutaneous endoscopic lumbar Spine surgery as one of the preferred choices of surgery for treating Lumbar Disc Herniation and Lumbar Spine Stenosis. The concept of percutaneous endoscopic surgery for lumbar region is to provide surgical options without producing iatrogenic morbidity associated with the open surgical procedures. Conventionally, there are different approaches/techniques for Percutaneous Endoscopic Lumbar Spine Surgery, but in this review we are mainly focusing on the Transforaminal Technique. Regarding the Lumbar Disc Herniation treatment with transforaminal approach, a number of articles have been published due to which we mainly focused on those articles which were published after 2009 onwards. While fewer articles related to Lumbar Spine Stenosis treatment with Transforaminal approach were found, we tried to brief out all those articles. On the basis of comparative study of different surgeries done for Lum-

bar Disc Herniation and Lumbar Spine Stenosis, Percutaneous Transforaminal endoscopic Lumbar Surgery provides a substantial benefit. Transforaminal approach for treating Lumbar Disc Herniation and Lumbar Spine Stenosis is safe and effective. The Percutaneous Transforaminal Endoscopic Lumbar Surgery has advantage as it is performed under local anesthesia with shorter length of hospitalization and early return to normal life. The clinical outcome of the patient that underwent Percutaneous Transforaminal Endoscopic Lumbar Surgery for Lumbar Disc Herniation and Lumbar Spine Stenosis is quite good in regard of its fewer complication and more benefits.

Keywords

Lumbar Disc Herniation, Lumbar Spine Stenosis, Percutaneous Endoscopic Lumbar Surgery, Transforaminal Technique, Lumbar Spine Decompression

1. Introduction

1.1. Lumbar Disc Herniation (LDH)

Lumbar disc herniation [1] [2] [3] (**Figure 1(a)**) is a medical condition affecting the spine in which a tear in the outer, fibrous ring of an intervertebral disc allows the soft, central portion to bulge out beyond the damage outer rings (**Figure 1(b)**). Also known as slipped disc, it is commonly related to age degeneration of the outer ring, known as the annulus fibrous [4] [5]. A Lumbar disc herniation may develop suddenly or gradually over weeks or months. The 4 stages to a herniated disc are: Disc degeneration, Prolapse, extrusion and sequestration or sequestered disc [6] [7] [8] (**Figure 1(c)**). Lumbar disc herniation may be located as central prolapse, Posterolateral (paracentral), foraminal and axial. Lumbar disc herniation may cause severe pain even in the absence of nerve root compression. The common regions for Lumbar disc herniation are between 4th and 5th lumbar vertebral bodies and between 5th lumbar vertebrae and Sacrum [4] [7]. Symptoms of herniated disc range from little or no pain to severe lower back pain that will radiate into the portion served by affected nerve roots that are irritated or impinged by the herniated materials. Numbness, tingling, parasthesia and motor changes like muscle weakness, paralysis and affection of reflexes are the symptoms [9] [10]. In LDH, the patient may also experience sciatica due to irritation of sciatic nerve [11]. Radiating pain may result from prolapsed disc in the lumbar spine. In case that the prolapsed is large and presses on nerves within the spinal column or the cauda equine, both sides of the body may be affected, often with serious consequences [6] [12]. Diagnosis of herniation is based on the history, symptoms and physical examination [13]. Investigations are performed to confirm and rule out other causes as spondylolisthesis, tumors, and metastasis as well as for treatment option of herniation. X-ray, CT and MRI (**Figure 1(d)**) are the choice of investigations [9] [13].

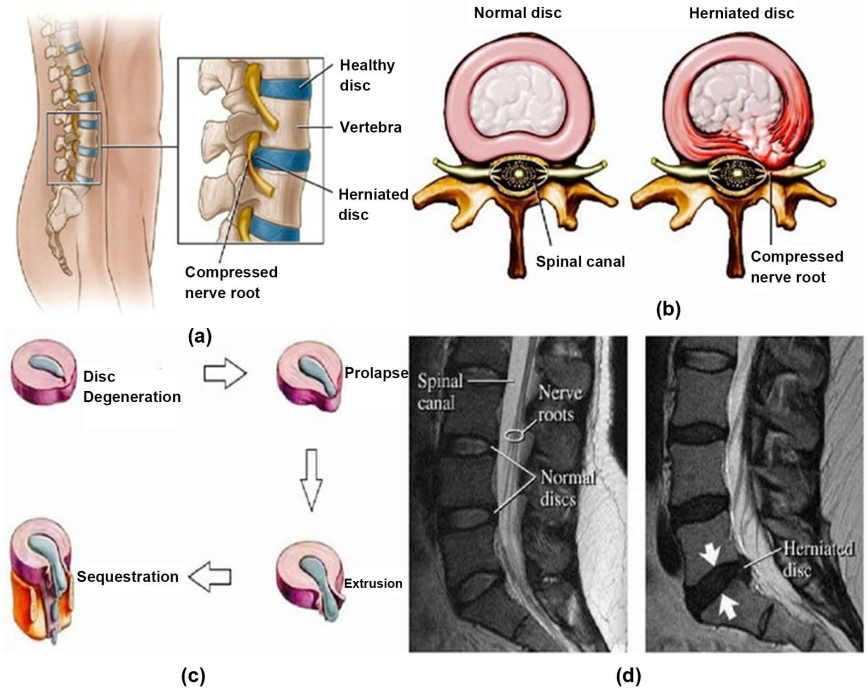


Figure 1. Lumbar Disc Herniation (a) Showing herniated disc at L4/L5 level [14]; (b) Shows normal Lumbar disc and Herniated Lumbar disc [15]; (c) Represents the stages of Lumbar Disc herniation [16]; (d) MRI showing Lumbar disc herniation at L5/S1 level taken at Zhongda Hospital.

1.2. Lumbar Spinal Stenosis (LSS)

Lumbar spine stenosis [17] [18] [19] is a medical condition described by Verbiest [20] in 1950 in which the spinal canal narrows and compresses the nerves at the level of the lumbar vertebrae (**Figure 2**). Spinal degeneration that occurs with aging is the common cause of LSS [18]. It can also be due to osteoporosis, spinal disc herniation or tumors. It can be also due to congenital conditions [21]. LSS may cause low back pain, abnormal sensations and the absence of sensations (numbness) in the legs, thighs, feet or buttocks, or loss of bladder and bowel control [21]. Symptoms include pain or cramping in the legs when standing for long periods or when walking [9] [21]. The discomfort usually eases when bending forward or sitting down. The first symptoms of LSS include low back pain. After few months and years, that may progress to claudication [21] [22]. The LSS is most common in older community and retirement communities [23].

The diagnosis of LSS is based on clinical findings. When a patient presents with the typical symptoms of lumbar spinal stenosis (leg pain, with or without back pain, which is aggravated by walking), a conclusive diagnosis is made using imaging studies from an MRI scan or a CT scan with myelogram (using an x-ray dye in the spinal sack fluid) [25] [26]. Physical examination alone does not yield a conclusive LSS diagnosis. LSS can be central, lateral or foraminal stenosis (**Figure 3**) [27]. Plain X-rays may or may not show LSS. CT and MRI scanning are done for the definitive diagnosis of LSS.

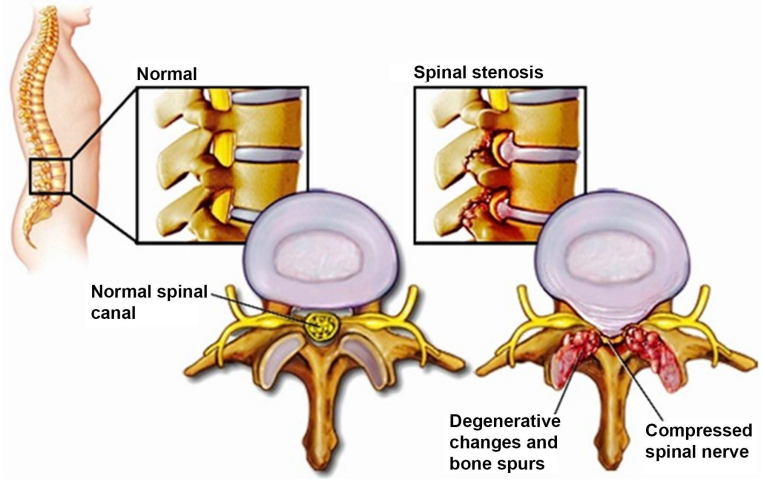


Figure 2. Showing Normal Lumbar spine and Spinal stenosis with degenerative changes and compressed spinal nerve [24].

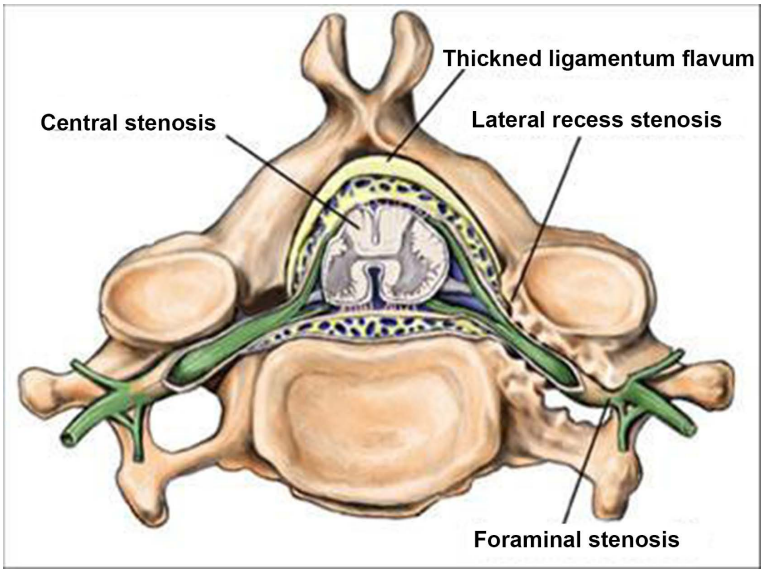


Figure 3. Schematic presentation of different types of Lumbar Spine Stenosis (central stenosis, Lateral stenosis and foraminal Stenosis) [28].

1.3. Brief History of Percutaneous Endoscopic Lumbar Spine Surgery

The concept of minimally invasive surgery for lumbar region is to provide surgical options without producing iatrogenic morbidity associated with the open surgical procedures. In 1973 Kambin and Gellmann in United States [29], and in 1975 Hijikata in Japan [30], independently performed a non-visualized percutaneous technique via a posteriolateral approach. In 1983, the direct visualization of the intervertebral disc space with modified arthroscope was report by Forst and Housaman [31]. In 1988, Kambin was the first to publish intraoperative discoscopic view of a herniated nucleus pulposus [32]. A "Percutaneous discoscopy" a bipolar endoscopic posterolateral techniques with modified instruments for direct view was described by Schreiber in 1989 and 1991 [33] [34]. In 1992

Mayer introduced percutaneous endoscopic laser discectomy combining forceps and laser [35]. Mayer and Brock described the technique for disc herniation by using angled optics for viewing the dorsal aspect of annular tear. The concept of posterolateral endoscopic lumbar nerve decompression changed from indirect central nucleotomy (inside out, in which fragments are extracted through an annular fenestration outside the spinal canal) to transforaminal direct extraction of the non-contained and sequestered disc fragments from inside the spinal canal. With the effort of Yeung *et al.*, the present single portal endoscopic discectomy is possible. Originally, this technique was devised for the treatment of lumbar disc herniation only. Yeaung and Knight used a holmium-YAG (yttrium-almunium-garnet)-laser for ablation of bony and soft tissue for decompression, enhanced access and to improve intracanal visualization [36] [37]. In 1997 Yeung developed Yeung Endoscopic Spine System (YESS) and in 1994 Hoogland developed the Thomas Hoogland Endoscopic Spine System (THESSYS) [38]. With THESSYS, enlargement of the intervertebral foramen near the facet joint with special reamers is possible which help to reach intracanal extruded and sequestered disc fragments and decompress foraminal stenosis [39]. With the advances in technology and increasing experiences, percutaneous lumbar surgery is gradually expanding day by day. Modern endoscopic surgeons are able to deal with treatment of lumbar stenosis with this procedure. Percutaneous endoscopic surgery has been regarded as a safe, minimally invasive procedure. Since 2000, various advanced endoscopic techniques have been developed to perform decompression under direct view and local anesthesia. The concept of endoscopic lumbar surgery is the reduction of lumbar segmental pain by removal of casual pain sources. The procedure involves enlargement of the foramen by removal of disc compression, removal of osteophytes impacting upon the nerve, removal of ligaments impinging upon the nerve, shrinkage of redundant annulus and removal of perineural scarring or granulation tissue.

2. Surgical Procedure (Percutaneous Transforaminal Endoscopic Lumbar Spine Surgery)

2.1. Surgical Equipment/Instruments

The surgical instruments of percutaneous endoscopic surgery consist (**Figure 4**):

a) Working channel endoscope with angle optics.

b) Flexible forceps, which can reach the intended site and dissect or decompress any lesions around the endoscopic field.

c) Steerable radiofrequency coagulator for coagulation or ablation of soft tissues.

d) Articulating bone burr, which can remove wide range of bone tissues.

e) Endoscopic punch that can remove bone and soft tissues under endoscopic vision.

2.2. Surgical (Transforaminal) Technique

The pathological zone determines the Choice of approach. The patient is placed in prone position on a radiological compatible table (**Figure 5**). Cannula

Figure 4. Shows various surgical instruments for percutaneous endoscopic Lumbar surgery used at Zhongda Hospital.

Figure 5. Showing patient in prone position on a radiological compatible table at Zhongda Hospital.

insertion point is confirmed before surgery by the guidance of CT and MRI. The procedure is performed under local anesthesia with regular monitoring of the vitals of the patient. 1% lidocaine is the choice for local anesthesia given at the distance of 8 to 12 cm from the midline of the back (**Figure 6**). Under the local anesthesia the surgeon uses a 25 cm 18 gauge needle to place it in the disc space through Kambin's triangle (**Figure 7**) [40] [41], which is the safe region. Further, discography is conducted to dye the nucleus polposus. The procedure is done under proper visualization taken by C-arm in both anteroposterior and lateral view.

A guide wire was inserted in the disc through the needle channel. The needle is removed and a bluntly tapered tissue dilating obturator was slipped over the guide wire till its tip firmly engaged in the annular window (**Figure 8(a)** & **Figure 8(b)**), then an endoscope was inserted into the working sleeve. Later, the

Figure 6. 1% Lidocaine given at the distance of 8 to 12 cm from the midline of the back at Zhongda Hospital.

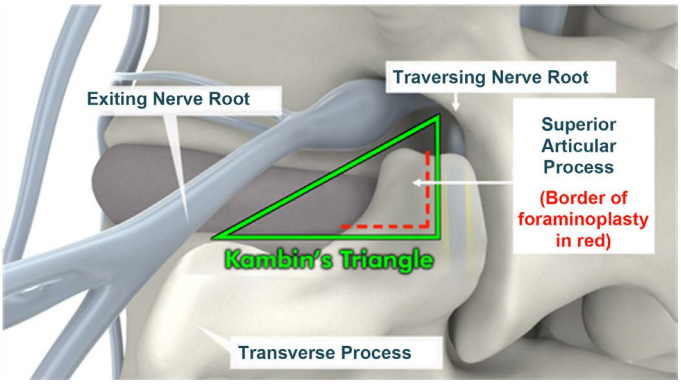
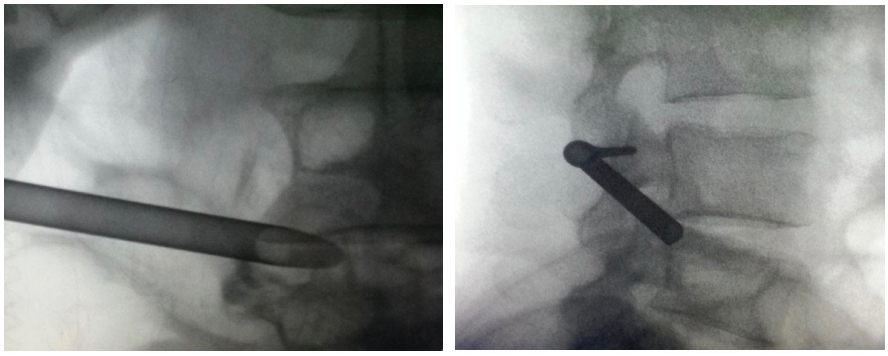


Figure 7. Shows Kambin's triangle indicating its boundary [41].



(a) (b)

(c)

Figure 8. Demonstrating the Transforaminal approach and the decompressed nerve root figures taken at Zhongda Hospital. (a) Shows the anteroposterior view of the approach (b) Shows Lateral view of the approach (c) Shows the free nerve root after decompression.

working zone and the annulus fibrous were observed and working sleeve is pushed into the disc space. Decompression is continued under a direct clear visual field and constant saline irrigation. After complete decompression, the dural sac and lumbar exiting nerve root is checked for free movable (**Figure 8(c)**). Bleeding of small vessels is controlled by bipolar frequency probe. After the decompression, all the instruments are removed carefully. A single or two skin stiches are given at the incision point. Communication is maintained with patient throughout the surgical procedure.

3. Clinical Evaluation

The clinical evaluation of pre and postoperative cases of Lumbar disc herniation and Lumbar Spine Stenosis is done by different methods. Normally the considered methods for clinical evaluation are by ODI [42], VAS [43] and Macnab criteria [44].

3.1. The Oswestry Disability Index (ODI) [42]

ODI is an index derived from the Oswestry Low Back Pain Questionnaire used by clinicians and researchers to quantify disability for low back pain. The Oswestry Disability Index is currently considered by many as the gold standard for measuring degree of disability and estimating quality of life in a person with low back pain. The self-completed questionnaire contains ten topics concerning intensity of pain, lifting, ability to care for oneself, ability to walk, ability to sit, sexual function, ability to stand, social life, sleep quality, and ability to travel. 6 statements describing different potential scenarios in the patient's life relating to the topic follow each topic category. The patient then checks the statement, which most closely resembles their situation. Each question is scored on a scale of 0 - 5 with the first statement being zero and indicating the least amount of disability and the last statement is scored 5 indicating most severe disability. The scores for all questions answered are summed, and then multiplied by two to obtain the index (range 0 to 100) (**Table 1**). Zero is equated with no disability and 100 are the maximum disability possible.

3.2. A Visual Analogue Scale (VAS) [44]

VAS is a measurement instrument that tries to measure a characteristic or attitude that is believed to range across a continuum of values and cannot easily be directly measured. For example, the amount of pain that a patient feels ranges across a continuum from none to an extreme amount of pain. From the patient's perspective this spectrum appears continuous ± their pain does not take discrete jumps, as a categorization of none, mild, moderate and severe would suggest. To capture this idea of an underlying continuum, the VAS was devised.

3.3. Macnab Criteria [44]

Macnab's outcome is based on assessment of patient satisfaction. The patient is asked to rate his level of well-being, generally after surgery. The patient choose

Table 1. ODI scoring pattern.

Score	Disability Pattern
0 - 20	Minimal disability
21 - 40	Moderate Disability
41 - 60	Severe Disability
61 - 80	Crippling back pain
81 - 100	These patients are either bed-bound or have an exaggeration of their symptoms

one of the four: Excellent, Good, Fair, Poor (Excellent: no pain, no restriction of mobility, return to normal work and level of activity; Good: occasional non radicular pain, relief of presenting symptoms, able to return to modified work; Fair: some improved functional capacity, still handicapped and/or unemployed; Poor: continued objective symptoms of root involvement, additional operative intervention needed at the index level irrespective of the length of postoperative follow-up).

4. Review of Literature

4.1. Percutaneous Transforaminal Endoscopic Lumbar Spine Surgery for Lumbar Disc Herniation

The reviews of different original articles were done which focus on the Percutaneous Endoscopic Lumbar surgery. Different search engine as GOOGLE SCHOLAR, PUBMED, SCOPUS and RESEARCHGATE were used to find out the published articles that were related with the LDH, LSS and Percutaneous Endoscopy Lumbar Surgery (**Figure 9**).

Around 97 Lumbar spines related articles were studied of which 48 articles were extracted which were either related to LDH, LSS or PTELSS. Of 48 articles only 25 articles were extracted which were related to Endoscopic Lumbar Spine Surgery done for LDH. But we included only those articles which were published after 2009 onwards, so that we can analyze the recent advancement and updates regarding Transforaminal endoscopic Lumbar Spine Surgery. Thus, 11 articles were included which focused on Transforaminal technique but one article deals with less than 30 number of cases due to which we excluded the particular article. Finally, we have 10 articles for the review and all these articles presented with clinical outcomes on the basis of either Macnab criteria, VAS score or ODI score (**Table 2**). The review mainly emphasizes on the clinical outcome of Percutaneous Transforaminal Endoscopic Lumbar Spine Surgery associated with or without the surgical complications.

4.1.1. J Wang, Y Zhou, C Li, *et al.*; 2009 [45]

The cases evaluated were operated from June 2007 to May 2008. Retrospective study of 52 patients including 15 males and 37 females with averaged 38.2 years old was done. The average surgery time was 30.7 minutes with 3.7 days of hospital stay No complications such as infection and the injury of blood vessels and

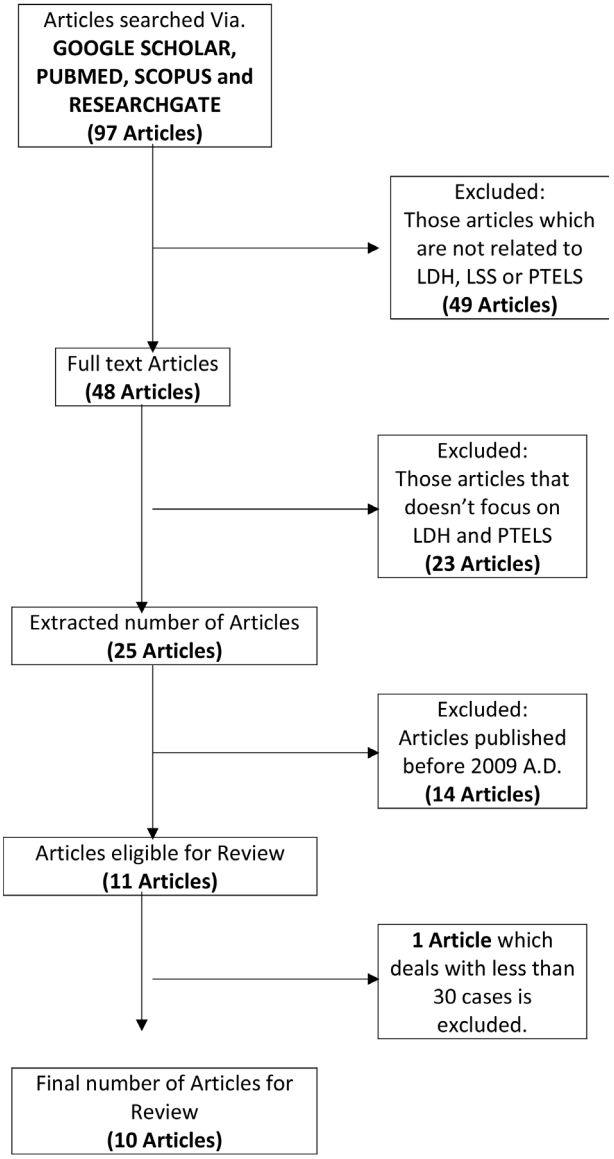


Figure 9. Flow diagram showing selection process of articles included in the review.

nerves seen. Transient paralysis of nerve occurred in 5 cases on operative day and disappeared at final follow-up without any special treatment. Fifty-two cases were followed up for 3 - 15 months (average 7.3 months). VAS score before operation, 1 month after operation and at the final follow-up was (7.34+/−1.52), (3.62+/−0.92) and (1.57+/−0.48) points, respectively, indicating there were significant differences compared with preoperative score ($P < 0.01$). According to the Macnab criteria, 11 cases were graded as excellent, 23 as good, 13 as fair, 5 as bad, and the excellent and good rate was 65.38%.

4.1.2. Yi-Bing Bai, Ling Xu, Jian Cheng Xi *et al.*; 2012 [46]

The retrospective analysis done for 119 patients with lumbar disc herniation treated. All of them underwent percutaneous transforaminal endoscopic surgery

Table 2. Different study regarding PTELS done for LDH published after 2009 onward.

Source and Publication Year	Year of Study Conducted	Study Design	No. of Patients	Age of Patients	Gender	Research Evaluation in aspect of Clinical Outcomes based on VAS, ODI or Macnab criteria
J Wang, Y Zhou, C Li, *et al.* 2009	June 2007 to 2008	Retrospective Study	52	Mean age was 38.2 years	15 Males & 37 Females	VAS score before operation, 1 month after operation and at the final follow-up was (7.34+/−1.52), (3.62+/−0.92) and (1.57+/−0.48) points, respectively. Macnab criteria: 11 cases were graded as excellent, 23 as good, 13 as fair, 5 as bad, and the excellent and good rate was 65.38%.
Yi-Bing Bai, Ling Xu, Jian Cheng Xi *et al.* 2012	December 2009 to June 2010	Retrospective Study	119	Mean age was 44.8 years	75 Males & 44 Females	VAS improved statistically significantly from preoperative 6.8 to postoperative 1.8 ($P < 0.05$). ODI decreased from preoperative 70.06 to 19.09 at the last follow-up. The Macnab results were excellent (n = 82, 68.9%), good (n = 20, 16.7%), fair (n = 8, 6.7%) and bad (n = 9, 7.7%) (Including all patients lost to follow-up). And the excellent-to-good rate was 85.6%.
Gun Choi, Hitesh N Modi, Nicolas Prada *et al.* 2013	2004 to 2006	Prospective study	89	Average age was 46.6 years	59 Men & 30 Women	Postoperative mean ODI decreased from 67.4% to 5.61%. Mean VAS score for back and leg pain improved significantly from 4 to 2.3 and from 7.99 to 1.04, respectively. MacNab's criteria, 76 patients (85.4%) showed excellent, 8 (8.89%) good, 3 (3.37%) fair, and 2 (2.25) poor results.
Yi Jiang, Hua-Wei Song, Dong Wang *et al.* 2013	June 2011 to January 2012	Retrospective Study	46	Age from 11 years to 77 years old	28 Males & 18 Females	VAS score of lumbar before operation and at the 1st and 3rd, 6th, 12th month after operation were 5.3+/−1.2, 1.9+/−1.1, 1.0+/−0.8, 0.9+/−0.8, 0.8+/−0.6, respectively. VAS score of leg before operation and at the 1st and 3rd, 6th, 12th month after operation were 7.2+ 1.2, 0.8+/−1.2, 0.5+/−0.8, 0.5+/−0.8, 0.3+/−0.8, respectively.
Ku Wang, Xin Hong, Bao-Yi Zhou *et al.* 2015	January 2013 to September 2014	Retrospective Study	207	108 cases in the ≤45-year-old age group and 99 cases in the >45-year-old	Male and Female	The mean pre-operative and postoperative VAS and ODI scores significantly improved. In age ≤45 group, 56 % had excellent outcomes, 28% good, 14% fair, and 3% poor. In the age > 45 group, 51% had excellent outcomes, 20% good, 25% fair, and 4% poor.
Mehmet Haluk Ozer, Guven Citak, Muhammet Bahadir Yilmaz *et al.* 2016	2004 to 2010	Retrospective Study	67	Mean age was 52.3 years	30 Males & 37 Female	The mean pre-operative VAS score was 8.13 while the mean post-operative VAS score was 2.4 in the 1st month and 2.01 in the 12th month. Satisfaction according to MacNab criteria in the 12th month was excellent in 35 (52.2%) patients, good in 18 (26.9%) patients, fair in 11 (16.4%) patients, and poor in 3 (4.5%) patients.
Pravesh S. Gadjradj, Maurits W. van Tulder, Clemens M. F. Dirven *et al.* 2016	January 2009 and December 2012	Prospective Study	166	Ages from 18 to 80 years	Women & Men	The mean reported scores on the VAS was 82.5 ± 17.3. Six weeks after surgery, the score on the VAS was significantly reduced to 28.8 ± 24.5 ($P < 0.001$). After 52 weeks of follow-up, the scores were further reduced compared with baseline scores ($P < 0.001$) to 19.6 ± 23.5 on the VAS.

Continued

Kanthila Mahesha *et al.* 2017	May 2012 to January 2014	Retrospective Study	100	Mean age was 40.29 years	67 Males & 33 Females	Excellent outcome was noted in 90 patients, good outcome in six patients, fair result in 2 patients and poor result in 2 patients. The mean VAS reduced drastically from 8.2 preoperatively to 1.8 postoperatively ($P < 0.001$). ODI also showed marked improvement from a preoperative 54% to a postoperative 8% ($P < 0.001$).
Yu-tong Gu, Zhan Cui, Hong-Wei Shao *et al.* 2017	January 2012 to June 2013.	Retrospective Study	209 cases	Average age of male was 46.4 ± 14.9 years and female was 46.8 ± 11.1 years	116 Male and 93 Female	The VAS score of leg pain significantly dropped from 9 (6 - 10) before operation to 1 (0 - 3) ($P < 0.001$) immediately after the operation and to 0 (0 - 3) ($P < 0.001$) 2 years after operation. At 2-year follow-up, 95.7% (200/209) of the patients showed excellent or good outcomes, 2.9% (6/209) fair and 1.4% (3/209) poor.
Z Gao, S Yin, T Xiang *et al.* 2017	March 2015 to September 2015	Retrospective Study	32	-	Male and Female	The patients had VAS score of low back and leg pain decreased from preoperative (6.75 ± 1.29) and (8.69 ± 1.51) to (2.35 ± 0.49) and (1.45 ± 0.36) in 6 months after surgery. Compared with preoperative score, the postoperative VAS score was statistically significant ($P < 0.05$). MacNab was as follows: excellent in 25 cases; good in 4 cases; common in 3 cases. The excellent and good rate was 90.63%.

from in December 2009 to June 2010. There were 75 males and 44 females with mean age of 44.8 years. The mean follow-up period was 26 months. Eight-nine patients had protruded discs while 30 had prolapsed and sequestered discs. Among 119 patients, 117 cases had the surgery performed successfully. The mean operative duration was 85 minute and the mean blood loss 13 ml. One patient had L5 nerve root injury complicated with paraesthesia and weakness of the affected lower extremity and was relieved gradually after conservative treatment for over 3 months. Another one complicated with postoperative intradiscal infection was referred to another institution and lost follow-up thereafter. Five cases had no improvement at 6 months after the first surgery and were re-operated endoscopically. VAS improved statistically significantly from preoperative 6.8 to postoperative 1.8 ($P < 0.05$). ODI decreased from preoperative 70.06 to 19.09 at the last follow-up. The Macnab results were excellent (n = 82, 68.9%), good (n = 20, 16.7%), fair (n = 8, 6.7%) and bad (n = 9, 7.7%) (Including all patients lost to follow-up). And the excellent-to-good rate was 85.6%.

4.1.3. Gun Choi, Hitesh N Modi, Nicolas Prada *et al.*; 2013 [47]

The Prospective study included 89 patients who underwent PELD via the transforaminal approach. The subjects included 30 women and 59 men with average age of 46.6 years. The mean operative time for Transforaminal Percutaneous Endoscopic Lumbar discectomy was 60 min. The minimum follow-up time for the subjects was 2 years. Postoperative mean ODI decreased from 67.4% to 5.61%. Mean VAS score for back and leg pain improved significantly from 4 to

2.3 and from 7.99 to 1.04, respectively. Four (4.49%) patients underwent a second-stage Percutaneous Endoscopic Lumbar decompression due to remnant fragments after the first stage. As per MacNab's criteria, 76 patients (85.4%) showed excellent, 8 (8.89%) good, 3 (3.37%) fair, and 2 (2.25) poor results. All of these patients had either highly migrated or sequestrated disc fragments preoperatively. Four (4.49%) other patients needed a second, open surgery due to symptomatic postoperative hematoma and recurrent disc herniation.

4.1.4. Yi Jiang, Hua-Wei Song, Dong Wang *et al.*; 2013 [48]

46 patients from June 2011 to January 2012 were retrospectively analyzed of which 28 males and 18 females ranging age from 11 to 77 years old. All the patients underwent transforaminal endoscopic technique for lumbar disc herniation. All operations were successful, Postoperative straight-leg raising test were all negative. Operative time, volume of blood loss, length of stay, duration of back to work or daily life, follow-up time were (93.0+/−28.0) min, (20.0+/−9.0) ml, (3.1+/−1.5) d, (11.6+/−4.2) d, (13.9+/−1.6) months, respectively. VAS score of lumbar before operation and at the 1st and 3rd, 6th, 12th month after operation were 5.3+/−1.2, 1.9+/−1.1, 1.0+/−0.8, 0.9+/−0.8, 0.8+/−0.6, respectively; VAS score of leg before operation and at the 1st and 3rd, 6th, 12th month after operation were 7.2+ 1.2, 0.8+/−1.2, 0.5+/−0.8, 0.5+/−0.8 ,0.3+/−0.8, respectively. The postoperative VAS score had significantly improved ($P < 0.05$).

4.1.5. Ku Wang, Xin Hong, Bao-Yi Zhou *et al.*; 2015 [49]

A total of 207 consecutive LDH patients who had undergone Transforaminal Endoscopic Lumbar disectomy with the THESSYS system from January 2013 to September 2014 with 108 cases in the ≤45-year-old age group and 99 cases in the >45-year-old group were analyzed retrospectively. The mean pre-operative and postoperative VAS and ODI scores significantly improved in both age ≤45 group and age >45 group, with no significant differences between them. In age ≤45 group, 56% had excellent outcomes, 28% good, 14% fair, and 3% poor. In the age >45 group, 51% had excellent outcomes, 20% good, 25% fair, and 4% poor. The average lengths of hospital stay for the age ≤45 and age >45 groups were 6.8 and 8.4 days, respectively. The mean time to return to work or normal activities was ten days for the age ≤45 group and 15 days for the age >45 group. The mean operative time for the age ≤45 group was 94 minutes and that for age >45 group was 97 minutes. Three and five recurrences were reported in the age ≤45 group and age >45, respectively.

4.1.6. Mehmet Haluk Ozer, Guven Citak, Muhammet Bahadir Yilmaz *et al.*; 2016 [50]

A retrospective examination performed with 67 cases of disc herniation that underwent percutaneous transforaminal endoscopic lumbar discectomy from 2004 to 2010. 37 patients were female and 30 were males. The mean age of the patient was 52.3 years. The mean pre-operative VAS score was 8.13 while the mean post-operative VAS score was 2.4 in the 1st month and 2.01 in the 12th month.

Satisfaction according to MacNab criteria in the 12th month was excellent in 35 (52.2%) patients, good in 18 (26.9%) patients, fair in 11 (16.4%) patients, and poor in 3 (4.5%) patients. 3 patients required microdisectomy due to continuing symptoms. 3 patients were found with temporary dysesthesia. No other complication occurred.

4.1.7. Pravesh S. Gadjradj, Maurits W. van Tulder, Clemens M. F. Dirven *et al.*; 2016 [51]

Patients who underwent Percutaneous Endoscopic Lumbar discectomy for LDH between January 2009 and December 2012 were prospectively followed. A total of 166 patients underwent surgery. Patients between ages 18 to 80 years were in the study. The mean duration of surgery was 51 minutes. The 1-year follow-up rate was 95.2%. The mean reported scores on the VAS was 82.5 ± 17.3. Six weeks after surgery, the score on the VAS was significantly reduced to 28.8 ± 24.5 ($P < 0.001$). After 52 weeks of follow-up, the scores were further reduced compared with baseline scores ($P < 0.001$) to 19.6 ± 23.5 on the VAS. A total of 4 complications were observed, namely 1 dural tear, 1 deficit of ankle dorsiflexion, and 2 cases of transient paresis in the foot due to the use of local anesthetics.

4.1.8. Kanthila Mahesha *et al.*; 2017 [52]

100 patients with lumbar disc prolapse treated with percutaneous endoscopic discectomy from May 2012 to January 2014 were included for the study. There were 67 males and 33 females. It was a retrospective study with mean follow-up period of 2 years to access clinical outcome and complications. In 84 patients transforaminal approach was used, seven patients interlaminar approach and combined approach in nine patients. The mean age of patients was 40.29 years. The mean operative time was 45 minute. The mean hospitalization was 1.6 days. Excellent outcome was noted in 90 patients, good outcome in six patients, fair result in 2 patients and poor result in 2 patients. The mean VAS reduced drastically from 8.2 preoperatively to 1.8 postoperatively ($P < 0.001$). ODI also showed marked improvement from a preoperative 54% to a postoperative 8% ($P < 0.001$). In 3 patient minor complications were seen. One patient had a dural puncture and post-spinal headache, which settled uneventfully. One patient had an accidental intrathecal injection of urograffin during epidurography. One patient with two level disc prolapse had transient weakness of L1 root and recovered completely in 6 weeks. Two patients had recurrent disc Prolapse.

4.1.9. Yu-Tong Gu, Zhan Cui, Hong-Wei Shao *et al.*; 2017 [53]

The retrospective study was done, where percutaneous transforaminal endoscopic surgery was performed to treat 209 cases of intracanal or extracanal herniations from January 2012 to June 2013. The mean duration of the operation was 50.9 ± 9.9 min per level. The mean blood loss was 5 ml per level. The mean stay in the hospital was 3 days. The patients were followed for an average of 26.3 ± 2.3 months. The VAS score of leg pain significantly dropped from 9 (6 - 10) before operation to 1 (0 - 3) ($P < 0.001$) immediately after the operation and to 0

(0 - 3) (P < 0.001) 2 years after operation. At 2-year follow-up, 95.7% (200/209) of the patients showed excellent or good outcomes, 2.9% (6/209) fair and 1.4% (3/209) poor. No patients had any form of permanent iatrogenic nerve damage and a major complication, although there were one case of infection and one case of recurrence.

4.1.10. Z Gao, S Yin, T Xiang *et al.*; 2017 [54]

A retrospective analysis of 32 patients with lumbar disc herniation, underwent percutaneous transforaminal endoscopic discectomy, was conducted from March 2015 to September 2015. The patients were followed up for 1-6 months. No significant complication occurred. The patients had VAS score of low back and leg pain decreased from preoperative (6.75 ± 1.29) and (8.69 ± 1.51) to (2.35 ± 0.49) and (1.45 ± 0.36) in 6 months after surgery. Compared with preoperative score, the postoperative VAS score was statistically significant (P < 0.05). Last follow-up evaluation standard according to the MacNab was as follows: excellent in 25 cases; good in 4 cases; common in 3 cases. The excellent and good rate was 90.63%.

4.2. Percutaneous Transforaminal Endoscopic Lumbar Spine Surgery for Lumbar Stenosis

Till now there have been a number of articles published regarding the Percutaneous Transforaminal approach for Lumbar disc herniation. But only few of the articles deal with the Transforaminal approach for Lumbar Stenosis. Since, the surgery requires expert endoscopic surgeon, only the well-trained surgeon preferred to do transforaminal approach for lumbar stenosis. Thus, in this section few articles have been mentioned which deals with the transforaminal approach for lumbar stenosis. Three studies [55] [56] [57] described the use of the transforaminal endoscopic technique for disc herniation with central lumbar stenosis. Most cases involved lumbar disc herniation combined with lumbar stenosis, and the results were not reported for the stenosis subgroup. In Kambin P, Casey K, O'Brien E *et al.* [58] 82% of patients with lateral recess stenosis rated the results as satisfactory that underwent PTED. Bingtao Wen, Xifeng Zhang, Lin Zhang *et al.* [59] retrospectively studied 64 patients with lumbar stenosis who underwent Percutaneous Endoscopic Lumbar Spine Decompression. The mean preoperative VAS score was 7.7+/−1.2, while Postoperative 3 months, 6 months and final follow-up VAS scores were 2.8+/−0.7, 2.1+/−0.6, and 0.8+/−0.6, respectively (P < 0.001). The mean preoperative ODI score was 72+/−1.2, while postoperative 3 months, 6 months, and final follow-up ODI scores were 29.7+/−4.9, 23.9+/−4.0, and 12.5+/−3.9, respectively (P < 0.0010). The excellent and good rate reached 73.4% at the final follow-up. No complication was seen intraoperative and postoperatively.

5. Comparative Analysis of PTELS

Compared with traditional Surgery, PTELSS has advantages such as clear opera-

tive field, few trauma, and quick recovery. Yeung and Tsou [38] reported that the clinical outcome of Percutaneous Endoscopic Lumbar Surgery in comparison with conventional method of treatment for lumbar disc herniation was almost similar by performing Percutaneous Endoscopic Lumbar Surgery in 307 cases. They found that the outcome was satisfactory in 90% of cases, which is also observed in conventional method. The incidence rates of postoperative complications such as infection, dural laceration and postoperative reoccurrence were lower in Percutaneous Transforaminal Endoscopic Lumbar Spine Surgery than those of traditional open surgery. Ruetten *et al.* [60] also have conducted Percutaneous Transforaminal Endoscopic Lumbar Surgery in several patients and compared it with microdiscectomy where he found that 82% of patients have no pain after surgery and few have occasional pain that were treated by microdiscectomy. The transforaminal approach and decompression can be performed under simple local anesthesia as a result dural sac manipulation and irritation symptoms are minimal. The disadvantage of this approach is that it is not effective for decompress the central stenosis properly because of the limitation of the surgical field. In some cases, there may be irritation of nerve root during the approach, which can cause postoperative dysthesia. Lei Pan *et al.* [61] A randomized trial between open lumber discectomy and Percutaneous Transforaminal Endoscopic Lumbar Surgery which showed MacNab satisfaction of above 90% in both groups after surgery while no significant difference noted in pain index ($p > 0.05$). Comparative Study by Lei Pan *et al.* found PTELS has less hospital stays 1.9 ± 0.74 days compared to open lumbar decompression 5.6 ± 1.26 respectively. Kyung-Chul Choi *et al.* [62] compared Percutaneous Transforaminal Endoscopic Lumbar Surgery and Percutaneous Interlaminar Endoscopic Surgery; a significant difference between groups was demonstrated in terms of disc type, location, and migration. Percutaneous Transforaminal Endoscopic Lumbar Surgery was preferred for shoulder type, centrally located, and recurrent disc herniation, while Percutaneous Interlaminar Endoscopic Lumbar Surgery was preferred for axillary type and migrated discs, especially those of a high grade.

A number of patients are unable to undergo open surgical treatment due to poor medical condition or the inability to tolerate general anesthesia and the associated sufficient recovery. Percutaneous lumbar decompression provides a substantial benefit for these patient groups. There are numerous advantages of percutaneous endoscopic lumbar surgery over conventional surgery [38] [60] [63] [64] [65] [66] (**Table 3**).

6. Conclusion

Transforaminal approach for percutaneous endoscopic Lumbar Spine Surgery for treating LDH and LSS is safe and effective. The PTELS has advantage as it is performed under local anesthesia with shorter length of hospitalization and early return to normal life. Since this technique required expert endoscopic spine surgeon, still this approach is not preferred by every Spine Surgeon. This review

Table 3. Advantages of Percutaneous Transforaminal Endoscopic Lumbar surgery over Conventional surgery.

a.	There is immediate pain relief after surgery in almost all cases.
b.	The ligament and the disc-annulus remain intact.
c.	Herniated disc/Sequester can be accessed directly.
d.	No General anesthesia, thus lower risk of nerve damage and thrombosis.
e.	Short duration of hospital stay.
f.	Faster recovery for daily life and work.
g.	Small incision given with single stich applied for closure.
h.	Minimal invasive approach, thus lower risk of infection and bleeding.

concluded that the clinical outcome of the patient underwent PTELS for LDH and LSS is quite good in regard of its fewer complication and more benefits.

Acknowledgements

We would like to thank all the faculty members from Department of Spine, Zhongda Hospital Affiliated to Southeast University for their coordination. Further, we express our gratitude towards Maharjan Promish from School of Medicine, Southeast University China for his valuable academic vision.

Conflict of Interest

There is no conflict of interest relevant to this article.

References

[1] Postacchini, F. (1998) Lumbar Disc Herniation. Springer Science & Business Media, Berlin.

[2] Burke, G.L. (1964) Backache from Occiput to Coccyx.

[3] Bendix, T. (2004) Disc Herniation: Definition and Types. The Lumbar Spine, Lippincott Williams & Wilkins, Philadelphia, 399-406.

[4] Buckwalter, J.A. (1995) Aging and Degeneration of the Human Intervertebral Disc. *Spine*, **20**, 1307-1314. https://doi.org/10.1097/00007632-199506000-00022

[5] Modic, M.T. and Ross, J.S. (2007) Lumbar Degenerative Disk Disease. *Radiology*, **245**, 43-61. https://doi.org/10.1148/radiol.2451051706

[6] Kostuik, J., Harrington, I., Alexander, D., Rand, W. and Evans, D. (1986) Cauda Equina Syndrome and Lumbar Disc Herniation. *JBJS*, **68**, 386-391. https://doi.org/10.2106/00004623-198668030-00011

[7] McCall, I.W. (2000) Lumbar Herniated Disks. *Radiologic Clinics*, **38**, 1293-1309. https://doi.org/10.1016/S0033-8389(08)70007-1

[8] Dewing, C.B., Provencher, M.T., Riffenburgh, R.H., Kerr, S. and Manos, R.E. (2008) The Outcomes of Lumbar Microdiscectomy in a Young, Active Population: Correlation by Herniation Type and Level. *Spine*, **33**, 33-38. https://doi.org/10.1097/BRS.0b013e31815e3a42

[9] Arya, R. (2014) Low Back Pain-Signs, Symptoms, and Management. *Journal, Indian*

Academy of Clinical Medicine, **15**, 31.

[10] Iyer, K.M. (2013) Back Pain and Slipped Intervertebral Disc. In: *General Principles of Orthopedics and Trauma*, Springer, Berlin, 243-272. https://doi.org/10.1007/978-1-4471-4444-1_16

[11] Jacobs, W.C., van Tulder, M., Arts, M., Rubinstein, S.M., van Middelkoop, M., Ostelo, R., Verhagen, A., Koes, B. and Peul, W.C. (2011) Surgery versus Conservative Management of Sciatica Due to a Lumbar Herniated Disc: A Systematic Review. *European Spine Journal*, **20**, 513-522. https://doi.org/10.1007/s00586-010-1603-7

[12] Schistad, E.I. (2014) Prognostic Factors for Recovery in Radicular Pain Caused by Lumbar Disc Herniation.

[13] Vroomen, P., De Krom, M., Wilmink, J., Kester, A. and Knottnerus, J. (2002) Diagnostic Value of History and Physical Examination in Patients Suspected of Lumbosacral Nerve Root Compression. *Journal of Neurology, Neurosurgery & Psychiatry*, **72**, 630-634. https://doi.org/10.1136/jnnp.72.5.630

[14] Clinic, M. Herniated Disc. Mayo Clinic Patient Care and Health Information. https://www.mayoclinic.org/diseases-conditions/herniated-disk/symptoms-causes/syc-20354095

[15] Torso, Y. (2014) Practicing Yoga with a Herniated Disc. Yogaanatomy. https://www.yoganatomy.com/practicing-yoga-with-a-herniated-disc/

[16] Tipster, D. (2011) Disc Herniation-Cause, Risk Factors and Symptoms. Doctor Tipster. http://www.doctortipster.com/4043-disc-herniation-causes-risk-factors-and-symptoms.html

[17] Storm, P.B., Chou, D. and Tamargo, R.J. (2002) Lumbar Spinal Stenosis, Cauda Equina Syndrome, and Multiple Lumbosacral Radiculopathies. *Physical Medicine and Rehabilitation Clinics*, **13**, 713-733. https://doi.org/10.1016/S1047-9651(02)00013-X

[18] Markman, J.D. and Gaud, K.G. (2008) Lumbar Spinal Stenosis in Older Adults: Current Understanding and Future Directions. *Clinics in Geriatric Medicine*, **24**, 369-388. https://doi.org/10.1016/j.cger.2007.12.007

[19] Maurice-Williams, R. (2013) Spinal Degenerative Disease. Butterworth-Heinemann, Oxford.

[20] Verbiest, H. (1950) Primary Stenosis of the Lumbar Spinal Canal in Adults, a New Syndrome. *Nederlands tijdschrift voor geneeskunde*, **94**, 2415-2433.

[21] Genevay, S. and Atlas, S.J. (2010) Lumbar Spinal Stenosis. *Best Practice & Research Clinical Rheumatology*, **24**, 253-265. https://doi.org/10.1016/j.berh.2009.11.001

[22] Siebert, E., Prüss, H., Klingebiel, R., Failli, V., Einhäupl, K.M. and Schwab, J.M. (2009) Lumbar Spinal Stenosis: Syndrome, Diagnostics and Treatment. *Nature Reviews Neurology*, **5**, 392-403. https://doi.org/10.1038/nrneurol.2009.90

[23] Suri, P., Rainville, J., Kalichman, L. and Katz, J.N. (2010) Does This Older Adult with Lower Extremity Pain Have the Clinical Syndrome of Lumbar Spinal Stenosis? *JAMA*, **304**, 2628-2636. https://doi.org/10.1001/jama.2010.1833

[24] Staff, M.C. (2017) Spinal Stenosis. Mayo Clinic Patient Care and Health Information. https://www.mayoclinic.org/diseases-conditions/spinal-stenosis/symptoms-causes/syc-20352961

[25] Katz, J.N., Dalgas, M., Stucki, G. and Lipson, S.J. (1994) Diagnosis of Lumbar Spinal Stenosis. *Rheumatic Disease Clinics of North America*, No. 2, 471-483.

[26] Kent, D., Haynor, D., Larson, E. and Deyo, R. (1992) Diagnosis of Lumbar Spinal Stenosis in Adults: A Metaanalysis of the Accuracy of CT, MR, and Myelography. *AJR American Journal of Roentgenology*, **158**, 1135-1144. https://doi.org/10.2214/ajr.158.5.1533084

[27] Lee, C.K., Rauschning, W. and Glenn, W. (1988) Lateral Lumbar Spinal Canal Stenosis: Classification, Pathologic Anatomy and Surgical Decompression. *Spine*, **13**, 313-320. https://doi.org/10.1097/00007632-198803000-00015

[28] Author Bcs (2017) Spinal Stenosis. Backcom: Back Pain Conditions. http://www.back.com/back-pain/conditions/lumbar-spinal-stenosis/index.htm

[29] Kafadar, A., Kahraman, S. and Akbörü, M. (2006) Percutaneous Endoscopic Transforaminal Lumbar Discectomy: A Critical Appraisal. *Minimally Invasive Neurosurgery*, **49**, 74-79. https://doi.org/10.1055/s-2006-932184

[30] Hijikata, S. (1989) Percutaneous Nucleotomy. A New Concept Technique and 12 Years' Experience. *Clinical Orthopaedics and Related Research*, **238**, 9-23.

[31] Forst, R. and Hausmann, B. (1983) Nucleoscopy—A New Examination Technique. *Archives of Orthopaedic and Trauma Surgery*, **101**, 219-221. https://doi.org/10.1007/BF00436774

[32] Kambin, P. and Schaffer, J.L. (1989) Percutaneous Lumbar Discectomy: Review of 100 Patients and Current Practice. *Clinical Orthopaedics and Related Research*, **238**, 24-34. https://doi.org/10.1097/00003086-198901000-00004

[33] Schreiber, A. and Leu, H. (1991) Percutaneous Nucleotomy: Technique with Discoscopy. *Orthopedics*, **14**, 439-444.

[34] Schreiber, A., Suezawa, Y. and Leu, H. (1989) Does Percutaneous Nucleotomy with Discoscopy Replace Conventional Discectomy? Eight Years of Experience and Results in Treatment of Herniated Lumbar Disc. *Clinical Orthopaedics and Related Research*, **238**, 35-42. https://doi.org/10.1097/00003086-198901000-00005

[35] Mayer, H., Brock, M., Berlien, H.-P. and Weber, B. (1992) Percutaneous Endoscopic Laser Discectomy (PELD). A New Surgical Technique for Non-Sequestrated Lumbar Discs. *Acta Neurochirurgica Supplement*, **54**, 53-58. https://doi.org/10.1007/978-3-7091-6687-1_7

[36] Knight, M., Vajda, A., Jakab, G. and Awan, S. (1998) Endoscopic Laser Foraminoplasty on the Lumbar Spine-Early Experience. *Minimally Invasive Neurosurgery*, **41**, 5-9. https://doi.org/10.1055/s-2008-1052006

[37] Yeung, A.T. (2000) The Evolution of Percutaneous Spinal Endoscopy and Discectomy: State of the Art. *The Mount Sinai Journal of Medicine*, **67**, 327-332.

[38] Yeung, A.T. and Tsou, P.M. (2002) Posterolateral Endoscopic Excision for Lumbar Disc Herniation: Surgical Technique, Outcome, and Complications in 307 Consecutive Cases. *Spine*, **27**, 722-731. https://doi.org/10.1097/00007632-200204010-00009

[39] Hoogland, T., Schubert, M., Miklitz, B. and Ramirez, A. (2006) Transforaminal Posterolateral Endoscopic Discectomy with or without the Combination of a Low-Dose Chymopapain: A Prospective Randomized Study in 280 Consecutive Cases. *Spine*, **31**, E890-E897. https://doi.org/10.1097/01.brs.0000245955.22358.3a

[40] Hilton, J., Eddy, R. and Connell, D. (2012) The "Safe" Triangle, Contrast Material, and Particulate Steroids in Lumbar Transforaminal Injections: What Are the Right Things to Do? *Clinical Radiology*, **67**, 619-622. https://doi.org/10.1016/j.crad.2012.02.001

[41] Yeung, A. and Gore, S. (2014) Endoscopic Foraminal Decompression for Failed Back Surgery Syndrome under Local Anesthesia. *International Journal of Spine*

Surgery, **8**, 22.

[42] Fairbank, J., Couper, J., Davies, J. and O'brien, J. (1980) The Oswestry Low Back Pain Disability Questionnaire. *Physiotherapy*, **66**, 271-273.

[43] Crichton, N. (2001) Visual Analogue Scale (VAS). *Journal of Clinical Nursing*, **10**, 706-706.

[44] Macnab, I. (1971) Negative Disc Exploration: An Analysis of the Causes of Nerve-Root Involvement in Sixty-Eight Patients. *JBJS*, **53**, 891-903. https://doi.org/10.2106/00004623-197153050-00004

[45] Wang, J., Zhou, Y., Li, C., Zhang, Z. and Zhang, N. (2009) Percutaneous Endoscopic Lumbar Discectomy for Treatment of Chronic Discogenic Low Back Pain. *Chinese Journal of Reparative and Reconstructive Surgery*, **23**, 400-403.

[46] Bai, Y., Xu, L., Xi, J. and Mu, X. (2012) Diagnosis and Treatment of Lumbar Disc Herniation by Discography and Percutaneous Transforaminal Endoscopic Surgery. *Chinese Medical Journal*, **92**, 3350-3353.

[47] Choi, G., Modi, H.N., Prada, N., Ahn, T.-J., Myung, S.H., Gang, M.S. and Lee, S.-H. (2013) Clinical Results of XMR-Assisted Percutaneous Transforaminal Endoscopic Lumbar Discectomy. *Journal of Orthopaedic Surgery and Research*, **8**, 14. https://doi.org/10.1186/1749-799X-8-14

[48] Jiang, Y., Song, H.-W., Wang, D. and Yang, M.-L. (2013) Treatment of Lumbar Intervertebral Disc Herniation and Sciatica with Percutaneous Transforaminal Endoscopic Technique. *China Journal of Orthopaedics and Traumatology*, **26**, 800-804.

[49] Wang, K., Hong, X., Zhou, B.-Y., Bao, J.-P., Xie, X.-H., Wang, F. and Wu, X.-T. (2015) Evaluation of Transforaminal Endoscopic Lumbar Discectomy in the Treatment of Lumbar Disc Herniation. *International Orthopaedics*, **39**, 1599-1604. https://doi.org/10.1007/s00264-015-2747-1

[50] Özer, M.H., Çıtak, G., Yılmaz, M.B., Kocaman, Ü. and Yılmaz, H. (2016) Our Experience with 67 Cases of Percutaneous Transforaminal Endoscopic Lumbar Discectomy. *Journal of Clinical and Analytical Medicine*, **7**, 466-469.

[51] Gadjradj, P.S., van Tulder, M.W., Dirven, C.M., Peul, W.C. and Harhangi, B.S. (2016) Clinical Outcomes after Percutaneous Transforaminal Endoscopic Discectomy for Lumbar Disc Herniation: A Prospective Case Series. *Neurosurgical Focus*, **40**, E3. https://doi.org/10.3171/2015.10.FOCUS15484

[52] Mahesha, K. (2017) Percutaneous Endoscopic Lumbar Discectomy: Results of First 100 Cases. *Indian Journal of Orthopaedics*, **51**, 36-42. https://doi.org/10.4103/0019-5413.197520

[53] Gu, Y.-T., Cui, Z., Shao, H.-W., Ye, Y. and Gu, A.-Q. (2017) Percutaneous Transforaminal Endoscopic Surgery (PTES) for Symptomatic Lumbar Disc Herniation: A Surgical Technique, Outcome, and Complications in 209 Consecutive Cases. *Journal of Orthopaedic Surgery and Research*, **12**, 25. https://doi.org/10.1186/s13018-017-0524-0

[54] Gao, Z., Yin, S., Xiang, T. and Yu, Y. (2017) Recent Effect of Transforaminal Endoscopic Spine System in Treatment of Lumbar Disc Herniation. *Journal of Medical Imaging and Health Informatics*, **7**, 856-861. https://doi.org/10.1166/jmihi.2017.2105

[55] Leu, H. and Schreiber, A. (1991) Percutaneous Nucleotomy with Disk Endoscopy—A Minimally Invasive Therapy in Non-Sequestrated Intervertebral Disk Hernia. *Revue suisse de medecine Praxis*, **80**, 364-368.

[56] Savitz, M.H. (1997) Soft Disc Herniation in Patients with Lumbar Stenosis. *Neurosurgical Focus*, **3**, E12. https://doi.org/10.3171/foc.1997.3.2.13

[57] Chiu, J. (2004) Evolving Transforaminal Endoscopic Microdecompression for Herniated Lumbar Discs and Spinal Stenosis. *Surgical Technology International*, **13**, 276-286.

[58] Kambin, P., Casey, K., O'Brien, E. and Zhou, L. (1996) Transforaminal Arthroscopic Decompression of Lateral Recess Stenosis. *Journal of Neurosurgery*, **84**, 462-467. https://doi.org/10.3171/jns.1996.84.3.0462

[59] Wen, B., Zhang, X., Zhang, L., Huang, P. and Zheng, G. (2016) Percutaneous Endoscopic Transforaminal Lumbar Spinal Canal Decompression for Lumbar Spinal Stenosis. *Medicine*, **95**, e5186. https://doi.org/10.1097/MD.0000000000005186

[60] Ruetten, S., Komp, M., Merk, H. and Godolias, G. (2008) Full-Endoscopic Interlaminar and Transforaminal Lumbar Discectomy versus Conventional Microsurgical Technique: A Prospective, Randomized, Controlled Study. *Spine*, **33**, 931-939. https://doi.org/10.1097/BRS.0b013e31816c8af7

[61] Pan, L., Zhang, P. and Yin, Q. (2014) Comparison of Tissue Damages Caused by Endoscopic Lumbar Discectomy and Traditional Lumbar Discectomy: A Randomised Controlled Trial. *International Journal of Surgery*, **12**, 534-537. https://doi.org/10.1016/j.ijsu.2014.02.015

[62] Choi, K.-C. and Park, C.-K. (2016) Percutaneous Endoscopic Lumbar Discectomy for L5-S1 Disc Herniation: Consideration of the Relation between the Iliac Crest and L5-S1 Disc. *Pain Physician*, **19**, E301-E308.

[63] Lew, S.M., Mehalic, T.F. and Fagone, K.L. (2001) Transforaminal Percutaneous Endoscopic Discectomy in the Treatment of Far-Lateral and Foraminal Lumbar Disc Herniations. *Journal of Neurosurgery*: *Spine*, **94**, 216-220. https://doi.org/10.3171/spi.2001.94.2.0216

[64] Jang, J.-S., An, S.-H. and Lee, S.-H. (2006) Transforaminal Percutaneous Endoscopic Discectomy in the Treatment of Foraminal and Extraforaminal Lumbar Disc Herniations. *Clinical Spine Surgery*, **19**, 338-343. https://doi.org/10.1097/01.bsd.0000204500.14719.2e

[65] Lee, S., Kim, S.-K., Lee, S.-H., Kim, W.J., Choi, W.-C., Choi, G. and Shin, S.-W. (2007) Percutaneous Endoscopic Lumbar Discectomy for Migrated Disc Herniation: Classification of Disc Migration and Surgical Approaches. *European Spine Journal*, **16**, 431-437. https://doi.org/10.1007/s00586-006-0219-4

[66] Hoogland, T., van den Brekel-Dijkstra, K., Schubert, M. and Miklitz, B. (2008) Endoscopic Transforaminal Discectomy for Recurrent Lumbar Disc Herniation: A Prospective, Cohort Evaluation of 262 Consecutive Cases. *Spine*, **33**, 973-978. https://doi.org/10.1097/BRS.0b013e31816c8ade

Abbreviations

LDH: Lumbar Disc Herniation
LSS: Lumbar Spine Stenosis
PTELS: Percutaneous Transforaminal Endoscopic Lumbar Surgery
VAS: Visual Analogue Score
ODI: Oswestry Disability Index
CT: Computed Tomography
MRI: Magnetic Resonance imaging
YESS: Yeung Endoscopic Spine System
THESSYS: Thomas Hoogland Endoscopic Spine System