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Technical challenges and surgical outcomes of percutaneous transforaminal endoscopic discectomy in patients with upper lumbar disc herniation: a prospective clinical study

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Abstract

Introduction Upper lumbar disc herniation (ULDH) constitutes a considerably complex and rare anatomic entity. As such, there are only a handful of studies investigating the application of percutaneous transforaminal endoscopic discectomy (PTED) in the management of this cause of low back pain.
Research question To elucidate the safety and effectiveness of PTED in patients with ULDH.
Materials and Methods Twenty-six (26) individuals with diagnosed ULDH (L1–L2, L2–L3) according to clinical and radiologic criteria were prospectively evaluated in a 2-year follow-up period. All patients were assessed preoperatively and at 6 weeks and 3, 6, 12, and 24 months postoperatively. Clinical evaluation was conducted with visual analogue scale for lower limb (VAS-LP) and low back (VAS-BP) pain in conjunction with Short-Form 36 (SF-36) Medical Health Survey Questionnaire. Potential complications were recorded in each follow-up interval.
Results One patient (3.8%) featured temporary postoperative dysesthesia that was completely resolved at 6 weeks. No other major perioperative complications were observed. Values of all studied indices were found to be statistically significantly ameliorated at the end of follow-up. Improvement was depicted to be quantitatively maximal at 6 weeks postoperatively.
Conclusions PTED constitutes a safe and effective technique for surgical management of ULDH that merits further assessment in current clinical practice in the framework of multicenter randomized controlled trials.
Level of evidence Level III.

Keywords Lumbar disc herniation · Percutaneous transforaminal endoscopic discectomy · Endoscopic spine surgery · Minimally invasive spine surgery · Quality of life

Introduction

Lumbar disc herniation (LDH) represents a major etiology of low back pain in adult individuals [1]. Upper LDH (ULDH) constitutes a considerably complex and rare anatomic entity, comprising 1% to 11% of clinically detectable disc herniations [2]. Precise definition of ULDH remains controversial in current literature. Therefore, while L1–L2 and L2–L3 LDHs are conventionally considered as ULDHs, no universal consensus for T12–L1 and L3–L4 LDHs among published reports exists [2–5]. Despite their infrequent clinical emergence, ULDHs have gained remarkable interest in the field of spine surgery, fundamentally due to their unique clinical manifestations and technically challenging surgical management [6, 7].

Percutaneous transforaminal endoscopic discectomy (PTED) represents a novel and pioneering technique that has substantially altered philosophy of LDH surgical management in current years [8]. PTED is associated with a plethora of surgical advantages as minimization of intraoperative hemorrhage, preservation of dorsal musculature and related osseous-ligamentous structures, minimal skin incision and epidural space scarring, diminished hospitalization

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duration as well as more rapid rehabilitation and return to daily activities [9, 10]. Advantages of percutaneous transforaminal endoscopic surgery (PTES) have crucially contributed to expansion of its indication's spectrum in current years, rendering technique a powerful weapon in current spine surgeon's armamentarium [11, 12].

Within this surgical framework, implementation of PTED for surgical management of ULDH has been studied in specific literature reports [4, 5, 13–15]. However, all these studies were retrospectively designed. Furthermore, neither study focused on assessment of alterations in overall health-related quality of life (HRQoL) in patients with ULDH undergoing PTED.

Aim of this study is to meticulously investigate the clinical outcomes and overall impact of PTED in HRQoL in patients with ULDH. Prospective character, HRQoL analysis as well as the comparable number of participants with relative literature investigations underline the originality of our study.

Materials and methods

Study population and acquired approvals

All consecutive patients enrolled in this study were diagnosed with ULDH (L1–L2, L2–L3) according to clinical and radiologic criteria. Furthermore, all patients completed indications for conventional microdiscectomy according to currently established guidelines. All surgical operations were performed by the same experienced in PTED spine surgeon (KS) in two distinct tertiary centers. Patients were initially meticulously informed about study design, rationale and aims, verifying their agreement for participation via written consent. Protection of patients' rights and privacy was rigorously protected during study conduction. Protocol of this study was approved by Institutional Review Board of primary tertiary hospital. Moreover, all distinct perspectives of this study were in complete agreement with Ethical Principles for Medical Research involving Human Subjects as defined in Declaration of Helsinki in 1964 (and as revised in 2013).

Inclusion and exclusion criteria

Inclusion criteria were as follows: (1) mono- or poly-radiculopathy, (2) positive femoral nerve stretch test, (3) sensory or motor neurologic deficit in clinical examination, (4) L1–L2 or L2–L3 LDH confirmed by MRI of the lumbar spine with clinically referable findings (Fig. 1), (5) 12-week conservative treatment (limitation of intense physical activity, pharmaceutic regimen, physical therapy sessions, and spinal injections) failure.

Exclusion criteria were as follows: (1) non-contained disc hernia exceeding one third of the spinal canal on the sagittal MRI scans, (2) sequestration of the disc, (3) central or lateral recess spinal stenosis, (4) recurrent herniated disc or previous surgery at the affected level, (5) segmental instability or spondylolisthesis, (6) spinal tumor or infection, and/or (7) vertebral fracture.

Methods

Thirty (30) consecutive individuals with confirmed ULDH were initially evaluated for eligibility. Four (4) patients were excluded from study due to decline for participation ($n=1$) or fulfillment of exclusion criteria ($n=3$). Hence, twenty-six (26) patients were included in final analysis. All patients were subjected to PTED for ULDH from February 2017 to December 2019. Clinical evaluation was performed preoperatively and at pre-determined intervals at 6 weeks and at 3, 6, 12, and 24 months postoperatively. Visual analogue scale (VAS) for lower limb (VAS-LP) and low back (VAS-BP) pain was recruited for pain evaluation. Furthermore,

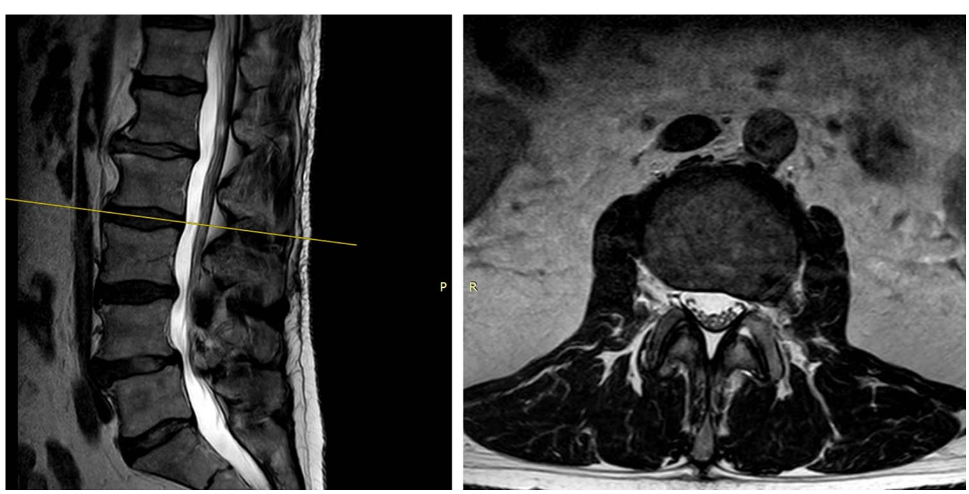

Fig. 1 Preoperative MRI of an enrolled individual demonstrating a foraminal/extraforaminal disc herniation in L2-L3 level

Short-Form 36 (SF-36) Medical Health Survey Questionnaire was sequentially implemented at aforementioned follow-up checkpoints for HRQoL analysis. Assessment of enrolled individuals in each follow-up interval was conducted in person in an outpatient framework.

Surgical technique

All patients were subjected to routine PTED under local anesthesia and controlled sedation by the same experienced in minimally invasive spine surgery operator (KS). Patients were intraoperative continuously monitored in in terms of vital signs (heart rate, blood pressure, and oxygen saturation) and ECG. Initially, they were placed in lateral decubitus position lying down on the opposite side, in order to accomplish maximal enlargement of respective foraminal space. Sequentially implemented steps for technique performance in all patients were as follows:

1. Skin marking of midline and inferior edge of 12th rib ipsilateral to disc pathology with surgical field draping.
2. Identification of needle (16G) entrance point (7–9 cm laterally of midline) and local anesthesia administration.
3. Insertion of needle adopting a steeper trajectory in contrast to lower lumbar levels. Advancement of needle and verification of rational position were accomplished with C-Arm fluoroscopy in anteroposterior (AP) and lateral (L) views. Tip of needle was advanced to posterolateral edge of superior endplate of underlying vertebral ipsilateral to disc pathology, with transit corridor leading in Kambin's triangle (safe zone) (Fig. 2) [16].
4. Insertion of K-wire through needle trajectory with subsequent meticulous withdrawal of needle and minor extension of skin incision with a scalpel.
5. Promotion of two muscle dilators and sequential advancement of reamers with gradually increasing diameters (4, 5, 6, and 7 mm), so that adequate foraminal enlargement via foraminotomy/foraminoplasty is accomplished (Fig. 3).
6. Advancement of cannula, endoscope (30°), and removal of herniated disc material with graspers until visualization of decompressed pulsatile nerve root (Fig. 4).

Visual analogue scale

Visual analogue scale (VAS) constitutes an accurate and facile measure for evaluation of pain intensity [17]. A unipolar horizontal line of 100 mm length was utilized in this study. This line was delineated by two distinct vertical lines, one left (representing "no pain"), and a respective right (representing "the most severe pain ever perceived"). After

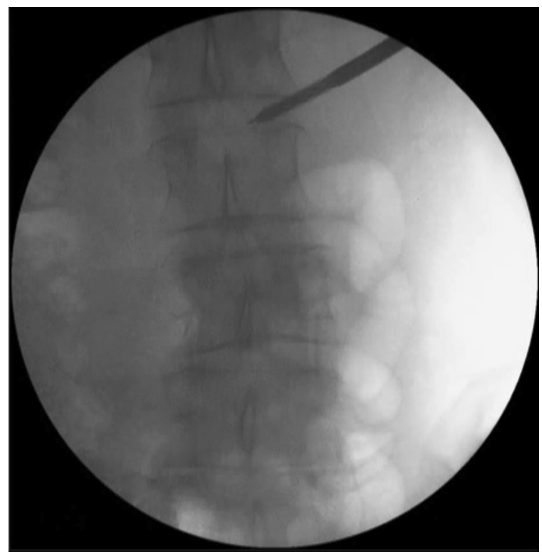

Fig. 3 Introduction of reamers with gradually increasing diameters and foraminoplasty

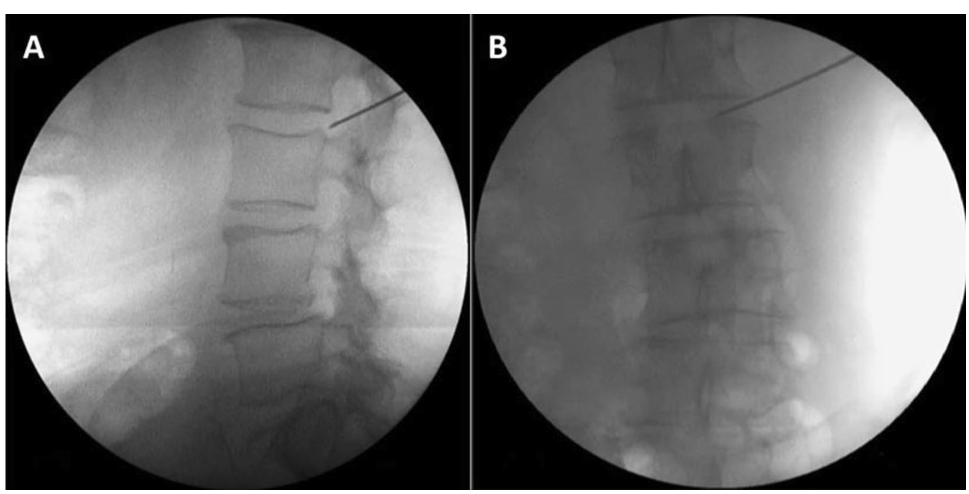

Fig. 2 Intraoperative verification of operated level via C-Arm fluoroscopy in (A) lateral and (B) anteroposterior views

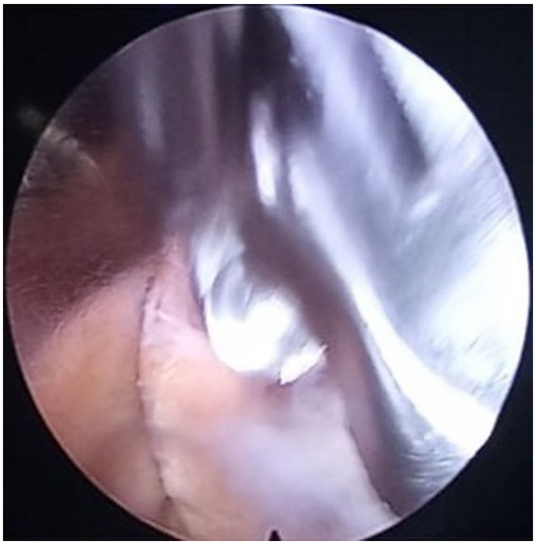

Fig. 4 Endoscopic excision of herniated disc material with graspers

thorough explanation of this data, patients were asked to nominate the level of realized pain with a mark in two distinct scales [representing lower limb (VAS-LP) and low back (VAS-BP) pain] in each follow-up checkpoint. Retrieved scores were calculated in millimeters (mm) adopting a one-decimal place approach. Level of minimal clinically significant alteration was defined at 9 mm. No other distinct parameters as age, gender, and etiology of perceived pain were separately considered in data retrieval [18].

Short-form 36 (SF-36) medical health survey questionnaire

SF-36 has been established as a reliable and valid method for assessment of HRQoL in spine surgery [19]. This multimodal questionnaire is constituted of 36 distinct questions that are finally aggregated in 8 separate aspects of general health status; physical function (PF), role-physical (RP), bodily pain (BP), general health (GH), energy, fatigue and vitality (V), social function (SF), role-emotional (RE), and mental health (MH). All patients completed the aforementioned questionnaire in each follow-up checkpoint. Retrieved data were subsequently collected and accordingly processed so that precise percentage for each aspect in each patient was calculated and recorded. Numerically, greater values in these 8 parameters are related to ameliorated HRQoL.

Statistical analysis

Statistical process of collected data was performed with STATISTICA 10.0 (StatSoft 1984–2010) and MATLAB 2016 (The MathWorks, Inc., 2016). Figures were created using MATLAB 2016 (The MathWorks Inc., 2016) and Adobe Illustrator CS3 (Adobe Systems, 2007).

Table 1 Demographic and clinical data of enrolled individuals

Index	Value (percentage)
Age (years)	40.7 ± 9.1
Sex	
Male	15 (57.7)
Female	11 (42.3)
Level of operation	
L1–L2	10 (38.5)
L2–L3	16 (61.5)

Continuous variables were represented as mean ± standard deviation, whereas categorical variables were expressed as percentage. For non-parametric variables, chi-square, Mann–Whitney *U* test, and Kruskal–Wallis *H* test were implemented to detect statistical differences between two and multiple groups, respectively. Statistical comparison of paired data was conducted with Wilcoxon signed-rank test and Friedman's analysis of variance (ANOVA). Level of statistical significance was determined in p value < 0.05 in all cases. The Bonferroni correction for multiple comparisons was accordingly applied.

Results

All patients were subjected to successful and uneventful PTED under local anesthesia and mild sedation. No patient required conversion to open surgery, and no intraoperative complications as major hemorrhage, kidney injury, dural tear, or nerve root injury were observed. All patients were ambulated with a lumbar orthosis on the same day, being discharged at the first postoperative day. One patient (3.8%) featured postoperative dysesthesia at level of exiting nerve root (L2), which was albeit totally at 6 weeks postoperatively resolved.

Demographic characteristics of enrolled individuals are represented in Table 1. All patients successfully completed established follow-up intervals until 24 months postoperatively.

General analysis of retrieved values demonstrated that all studied outcome measures followed a similar amelioration pattern. Therefore, all indices featured a major quantitative improvement at 6 weeks, depicting numerically lesser amelioration at 3 months postoperatively. Moreover, values of studied parameters were observed to present minimal further enhancement at 6 months with subsequent stabilization until the end of follow-up at 2 years (Table 2, Fig. 5).

Regarding VAS scores, VAS-LP values exhibited a statistically significant amelioration at 6 weeks, 3- and

Table 2 Representation of quantitative and statistical alteration of evaluated outcome measures during various follow-up checkpoints

Interval Index	Preoperative	6 weeks	3 months	6 months	12 months	24 months
PF (%)	41.0 ± 2.7	68.7 ± 2.7 (**p < 0.001**)*	79.6 ± 2.9 (**p < 0.001**)*	83.3 ± 3.0 (**p < 0.001**)*	86.2 ± 3.3 (**p < 0.001**)*	87.8 ± 3.3 (**p < 0.001**)*
RP (%)	39.9 ± 3.3	68.8 ± 3.6 (**p < 0.001**)*	79.1 ± 3.5 (**p < 0.001**)*	84.2 ± 3.6 (**p < 0.001**)*	86.9 ± 3.6 (**p < 0.001**)*	87.9 ± 3.5 (**p < 0.001**)*
BP (%)	38.6 ± 2.9	69.1 ± 3.0 (**p < 0.001**)*	78.5 ± 3.6 (**p < 0.001**)*	84.2 ± 3.6 (**p < 0.001**)*	87.6 ± 3.5 (**p < 0.001**)*	90.2 ± 3.5 (**p < 0.001**)*
GH (%)	41.2 ± 2.7	69.8 ± 3.1 (**p < 0.001**)*	81.3 ± 2.9 (**p < 0.001**)*	85.8 ± 2.9 (**p < 0.001**)*	88.9 ± 2.9 (**p < 0.001**)*	89.6 ± 3.0 (**p < 0.001**)*
V (%)	40.3 ± 1.7	68.9 ± 1.8 (**p < 0.001**)*	81.1 ± 2.0 (**p < 0.001**)*	84.5 ± 2.0 (**p < 0.001**)*	87.2 ± 1.8 (**p < 0.001**)*	88.3 ± 2.0 (**p < 0.001**)*
SF (%)	40.1 ± 2.2	69.4 ± 2.2 (**p < 0.001**)*	80.8 ± 2.1 (**p < 0.001**)*	84.9 ± 2.2 (**p < 0.001**)*	87.0 ± 2.4 (**p < 0.001**)*	87.5 ± 2.3 (**p < 0.01**)*
RE (%)	38.0 ± 2.2	68.8 ± 2.2 (**p < 0.001**)*	80.8 ± 2.1 (**p < 0.001**)*	85.6 ± 2.1 (**p < 0.001**)*	88.2 ± 2.2 (**p < 0.001**)*	89.6 ± 2.3 (**p < 0.001**)*
MH (%)	41.5 ± 3.1	69.7 ± 3.5 (**p < 0.001**)*	82.2 ± 3.5 (**p < 0.001**)*	87.1 ± 3.8 (**p < 0.001**)*	89.7 ± 3.7 (**p < 0.001**)*	90.2 ± 3.7 (**p < 0.001**)*
VAS-LP (mm)	86.9 ± 9.3	32.3 ± 11.8 (**p < 0.001**)*	10.8 ± 8.9 (**p < 0.001**)*	6.9 ± 8.4 (**p < 0.01)***	6.5 ± 7.5 (p = 1.000)*	6.5 ± 7.5 (p = 1.000)*
VAS-BP (mm)	89.6 ± 8.2	33.5 ± 8.5 (**p < 0.001**)*	9.6 ± 8.2 (**p < 0.001**)*	7.7 ± 7.6 (p = 0.04)*	7.7 ± 7.6 (p = 1.000)*	7.7 ± 7.6 (p = 1.000)*

PF physical function, *RP* role-physical, *BP* bodily pain, *GH* general health, *V* energy, fatigue and vitality, *SF* social function, *RE* role-emotional, *MH* mental health, *VAS-LP* visual analogue scale for lower limb pain, *VAS-BP* visual analogue scale for low back pain

*P values are derived from statistical comparison of retrieved values in each follow-up interval with analogous values obtained from directly previous follow-up checkpoint. Level of statistical significance was determined at p value < 0.01 according to Bonferroni correction. Statistically significant p values are featured with boldface

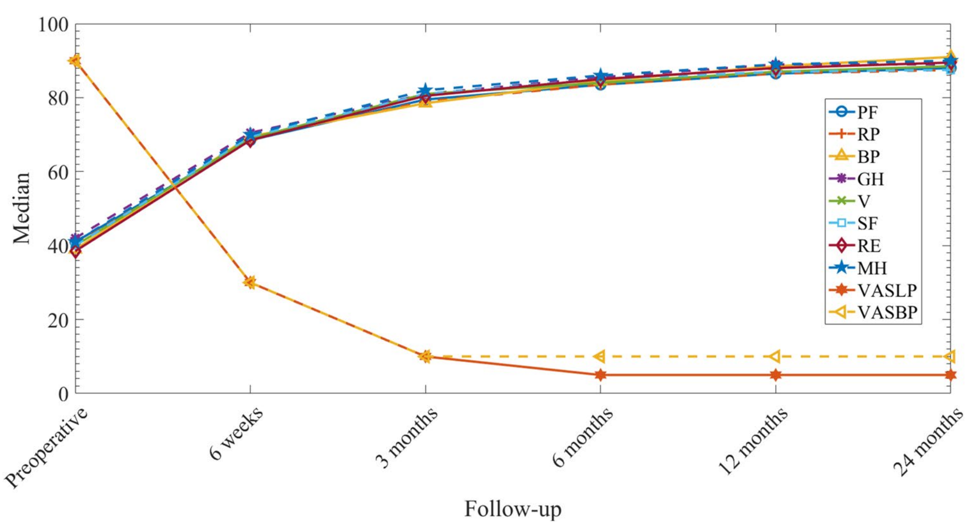

Fig. 5 Schematic representation of evaluated indices' values alteration within various follow-up checkpoints

6-months follow-up checkpoints, demonstrating a subsequent stabilization with no further significant alteration until the end of follow-up. In contrast, improvement of VAS-BP values was depicted to be statistically significant only at 6 weeks and 3-month intervals postoperatively (Table 2, Fig. 5).

Regarding SF-36, values of all studied indices featured a statistically significant amelioration in each chronic interval until the end of follow-up at 2 years. No significant quantitative differentiation was found in amelioration percentages between indices (Table 2).

Discussion

ULDH represents an infrequent entity with unique pathogenesis and clinical manifestations. The limited range of motion and relatively diminished stress in the upper in comparison with lower lumbar spine are consistently considered responsible for the rarity of clinically evident LDHs in this region [20, 21]. Furthermore, distinct predisposing factors for clinical emergence of ULDH have been reported in current literature. Except for classical risk factors as smoking history, age, sex, and obesity, miscellaneous clinical conditions as previous spine surgeries, segmental instability, trauma, and pre-existing anatomical abnormalities have been all related to predisposition to ULDH [6, 21]. However, precise pathogenesis of ULDH remains largely unknown [6].

Importantly, ULDH is associated with special and potentially devastating clinical sequelae in the scenario of misdiagnosis. Clinical symptomatology is majorly nonspecific, consisting of atypical back pain, buttock pain, and potentially numbness or radicular pain in distribution of affected nerve root. Furthermore, ULDH may provoke compression of conus medullaris and multiple nerve roots, clinically resulting in poly-radiculopathies, neurogenic claudication, and, even, autonomic dysfunction [21–23]. Clinical examination findings may include motor and sensory deficits referable to affected nerve roots distribution. Furthermore, femoral nerve stretch test is consistently reported to present high sensitivity in diagnosis of ULDH [21, 23].

Despite the accomplished advances in surgical treatment of degenerative spine conditions in recent years, surgical management of ULDH continues to feature a veritable challenge for spine surgeon. First, upper lumbar spine is characterized by distinct anatomic particularities that render surgical decompression—in cases of ULDH—considerably challenging. The reduced anteroposterior and lateral dimensions of vertebral canal, the minor laminar length, the presence of minor distance between dural sac and associated nerve roots as well as the brief intracanal length of the latter may substantially increase the risk of intraoperative complications emergence [5, 23]. Second, patients with such lesions are usually presented with more severe neurologic deficits at initial examination preoperatively. Hence, postoperative surgical outcomes are a priori rendered degraded, independently from degree of decompression and complications emergence [22].

PTED represents a revolutionary surgical technique that has marked a novel era in the management of LDH in current years. PTED is capable of being conducted under local anesthesia and controlled sedation, not requiring general anesthesia. This fact is of paramount importance for specific patients with severe cardiopulmonary and other comorbidities that are considered high risk for general anesthesia administration [11]. Furthermore, the minimal invasiveness and related advantages of PTED has admirably widened the spectrum of indications to include recurrent LDH, postoperative recurrent foraminal stenosis, adjacent segment disease after previous fusion surgery, and, even, adult degenerative scoliosis with clinically remarkable foraminal stenosis [11, 12].

To our best knowledge, implementation of PTED for surgical treatment of ULDH has been reported in five studies in recent literature [4, 5, 13–15]. Principal characteristics of these investigations are highlighted in Table 3.

Ahn et al. were the first to investigate utility of PTED in surgical management of patients with ULDH. 45 patients with diagnosed ULDH were retrospectively evaluated for an at least 2-year follow-up with VAS score and Prolo scale [4]. Results demonstrated that the majority (77.8%) of studied individuals accomplished excellent or good functional outcomes, featuring alongside a clinically significant diminish of perceived pain. Hence, authors concluded that PTED performance may be associated with favorable outcomes in cases of ULDH, provided that proper patient selection and surgical technique conduction are warranted [4]. Designing a methodologically similar study, Wu et al. later verified these results advocating for safety and effectiveness of PTED in ULDH cases [13].

Examining the favorable outcomes of PTED, specific groups of scholars recently endeavored to compare surgical outcomes of PTED with these of other standard open procedures for ULDH management. Li et al. retrospectively analyzed 42 patients treated with either PTED or conventional microdiscectomy to draw further conclusions about the theoretically comparative superiority of PTED versus conventional surgery. Patients were evaluated for 1–4 years postoperatively. Results demonstrated that there was no statistically significant differentiation in terms of VAS and Oswestry Disability Index (ODI) scores between assessed groups in either follow-up interval. Moreover, satisfactory rates and complications were similar between the two groups. Therefore, authors concluded that outcomes of PTED for ULDH are comparable to conventional microdiscectomy surgery, with the first owning albeit the advantage of minimal invasiveness and accelerated ambulation retrieval postoperatively [14]. In a relative recently published investigation, Jing et al. compared the clinical outcomes of PTED versus micro-endoscopic discectomy (MED) in surgical treatment of ULDH. 62 individuals were retrospectively studied for at least 12 months postoperatively. Results demonstrated that operation duration, volumes of intraoperative hemorrhage and drainage, incision length as well as hospitalization times were statistically significantly lesser in PTED group. Interestingly, patients in PTED group scored also statistically

Table 3 Principal characteristics of studies discussing surgical outcomes of PTED for ULDH in current literature

Authors	Year	Study Design	Sample Size	Operated levels	Interventions	Outcome Measures	Follow-up Duration	Complications
Ahn et al	2009	Retrospective	45	L1–L2 ($n=9$) L2–L3 ($n=35$)Both levels ($n=1$)	PTED	Prolo ScaleVAS	38.8 (25–52)	Incomplete decompression (4.4%) Recurrence (2.2%) Dural tear with motor deficit (2.2%) Temporary dysesthesia (6.7%)
Wu et al.	2016	Retrospective	55	L1–L2, L2–L3 ($n=13$) L3–L4 ($n=42$)	PTED	VASODI JOAMcNab criteria	29.9 ± 16.4	Recurrence (12.7%)
Li et al.	2020	Retrospective comparative study	42	Endoscopic: L1–L2 ($n=1$)L2–L3 ($n=7$)L3–L4 ($n=13$) Open: L1–L2 ($n=2$) L2–L3 ($n=6$) L3–L4 ($n=13$)	PTED ($n=21$) Microdiscectomy ($n=21$)	VASODImodified McNab criteria	34.1 (12–48)	Endoscopic / Open CSF leak: 9.5% / 4.8% Dysesthesia: 4.8% / 4.8% DVT: (−) / 4.8% Poor wound healing: (−) / 9.6%
Yang et al.	2020	Retrospective comparative study	32	PTED: L1–L2 ($n=5$)L2–L3 ($n=6$)L3–L4 ($n=8$) PIED: L1–L2 ($n=3$)L2–L3 ($n=4$)L3–L4 ($n=6$)	PTED ($n=19$) PIED ($n=13$)	VASODIMcNab criteria	15.80 ± 3.48 (PTED) 16.70 ± 4.66 (PIED)	PTED / PIED Dural tear: 5.3% / (−)

Table 3 (continued)

Authors	Year	Study Design	Sample Size	Operated levels		Interventions	Outcome Measures	Follow-up Duration	Complications	
Jing et al	2021	Retrospective comparative study	62	PTED L1–L2 ($n=10$) L2–L3 ($n=21$)	MED L1–L2 ($n=8$) L2–L3 ($n=23$)	PTED ($n=31$) MED ($n=31$)	VASODI JOAmodified-McNab criteria	> 12 months (N/S)	PTED Neural injury 6.5% CSF leak 6.5% Postoperative dysesthesia 3.2% Infection (−) Poor wound healing (−) Persistent pain 3.2% Recurrence/residue 6.5%	MED 3.2% 3.2% 9.7% 3.2% 3.2% (−) 3.2%
Our study		Prospective	26	L1–L2 ($n=10$) L2–L3 ($n=16$)		PTED	VASSF-36	24 months	Postoperative dysesthesia (3.8%)	

PTED percutaneous transforaminal endoscopic discectomy, *VAS* visual analogue scale, *ODI* oswestry disability index, *JOA* japanese orthopaedic association, *CSF* cerebrospinal fluid, *DVT* deep vein thrombosis, *PIED* percutaneous interlaminar endoscopic discectomy; *MED* micro-endoscopic discectomy, *N/S* not specified, *SF-36* short-form 36 medical health survey questionnaire significantly higher in JOA and VAS scores in the majority of follow-up intervals in comparison with their counterparts. Therefore, authors concluded that PTES is related to enhanced outcomes in management of MED [5].

In the framework of clinical success of endoscopic spine surgery in ULDHs, Yang et al. attempted to delineate the clinical outcomes of PTED versus percutaneous interlaminar endoscopic discectomy in 32 patients with ULDH. After retrospective evaluation with VAS, ODI, and MacNab criteria for at least 12 months postoperatively, authors stated that both techniques own comparable utility in cases of ULDH, with PTED depicting greater efficiency in cases with central and paracentral herniation [15].

Considering principal characteristics and underlying limitations of existent studies, we designed a prospective non-randomized analysis in order to better elucidate the precise outcomes of PTED in patients with ULDH. Unlike other studies, no patients with L3–L4 LDHs were included in our analysis since no universal consensus about inclusion of these lesions in ULDH general definition exists [5]. Adopting a 24-months follow-up approach, patients were regularly evaluated with VAS scores for lower limb and low back pain in conjunction with SF-36 postoperatively. Additional assessment of HRQoL in enrolled individuals underlines the originality of our work. Overall analysis of retrieved data demonstrated that values of all studied indices were statistically significantly enhanced at the end of follow-up in comparison with preoperative baseline values. This fact reflects the favorable impact of PTED in general health status and associated quality of life in affected individuals. Concerning that pain, especially if chronic, is accompanied by noteworthy psychosocial sequelae; amelioration of emotional, social, and mental status (as investigated in respective domains of SF-36) is veritably of paramount importance post a pain-relieving surgical procedure as PTED.

Temporary postoperative dysesthesia in affected nerve root distribution represented the only recorded complication in our study. This complication is also reported to be relatively frequent in other published investigations, demonstrating a varying incidence from 3.2 to 6.7% (Table 3). Intraoperative irritation of dorsal root ganglion may be the primary etiology of this finding. Logically, the lesser dimensions of vertebral canal in upper lumbar spine in conjunction with remarkable proximity of dural sac with nerve roots may substantially increase the potentiality of dorsal root ganglion irritation or veritable injury. Nevertheless, it should be stated that intraoperative visualization of dorsal root ganglion may be feasible in PTED, avoiding thus the eventuality of injury [24].

Technically speaking, conduction of conventional microsurgical decompression in cases of ULDH features considerable surgical challenges that majorly render postoperative outcomes unpredictable [25]. The aforementioned consistent in upper lumbar spine anatomic particularities may substantially increase the risk of semantic intraoperative complications emergence [7]. Therefore, classical posterior interlaminar approach may result in laminar isthmus fracture or excessive violation of ipsilateral facet joint during the endeavors of disc space approach. These injuries may lead in postoperative spondylolysis and segmental instability, increasing the risk of revision surgery necessity [26]. Furthermore, existent proximity of dura with surrounding osseous structures increases the risk of tear in the intraoperative stage of neurolysis [25].

PTED is capable of overcoming aforementioned limitations as a purely lateral transforaminal approach. However, appropriate technical modifications should be considered in order to enhance safety and effectiveness. Ahn et al. proposed that initial insertion of needle with a steeper angle (35–45°) is capable of ensuring satisfactory working space with minimization of neural damage risk, considering the greater concavity of upper lumbar discs in comparison with lower. Furthermore, the optimal entry point should be located more medially and, in all cases, under 9 cm from midline. At the stage of endoscopic LDH excision, selection of a 30° endoscope is ideal for warranting an adequate visual field including herniated disc, dura and associated neural structures according to surgeon's requirements. The presence of inherently greater foraminal dimensions with lower incidence of acquired foraminal stenosis in upper lumbar levels renders also proper conduction of PTED feasible in most cases [4]. Nevertheless, surgeon should be constantly on alert for emergence of potentially devastating complications as kidney, large vessel, or intestinal injury [27]. Appropriate pre- and intraoperative modifications in PTED conduction may increase efficacy and diminish risk of complications [28].

Conclusion

To our best knowledge, this study represents the first prospective investigation of surgical outcomes of PTED in patients with ULDH in current literature. VAS scores for lower limb and low back pain, as well as all indices of multifaceted SF-36, were found to be statistically significantly ameliorated at the end of follow-up at 2 years, advocating for the multimodally favorable impact of technique in general health status of affected individuals. No considerable complications were observed, and no patients required a revision open surgery for recurrence or residue. Nevertheless, auspicious outcomes of PTED in patients with ULDH should be verified from future randomized controlled trials with greater sample sizes and more extended follow-up duration. Moreover, qualitative and quantitative systematic appraisal of available data may shed more light on delineation of safety and efficacy of PTED in these patients [29].

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Declarations

Conflict of interest The authors declare no conflict of interest.

Ethical approval Protocol of this study was approved by the Institutional Review Board of Interbalkan European Medical Center.

Informed consent Patients provided written informed consent for the collection, processing and publication of their data.

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