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Dysethesia due to irritation of the dorsal root ganglion following lumbar transforaminal endoscopy: Analysis of frequency and contributing factors

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ABSTRACT

Background: New onset of acute dysethetic leg pain due to irritation of the dorsal root ganglion (DRG) following uneventful recovery from an expertly executed lumbar transforaminal endoscopic decompression is a common problem. Its incidence and relation to any risk factors that could be mitigated preoperatively are not well understood.

Methods: We performed a multicenter frequency analysis of DRG irritation dysesthesia in 451 patients who underwent lumbar transforaminal endoscopic decompression for herniated disc and foraminal stenosis. The 451 patients consisted of 250 men and 201 women with an average age of 55.77 ± 15.6 years. The average follow-up of 47.16 months. The primary clinical outcome measures were the modified Macnab criteria. Chi-square testing was employed to analyze statistically significant associations between increased dysesthesia rates, preoperative diagnosis, the surgical level(s), and surgeon technique.

Results: At final follow-up, *Excellent* (183/451; 40.6 %) and *Good* (195/451; 43.2 %) Macnab outcomes were observed in the majority of patients (378/451; 83.8 %). The majority of study patients (354; 78.5 %) had an entirely uneventful postoperative recovery without any DRG irritation, but 21.5 % of patients were treated for it in the immediate postoperative recovery period with supportive care measures including activity modification, transforaminal epidural steroid injections, non-steroidal anti-inflammatories, gabapentin, or pregabalin. There was no statistically significant difference in dysesthesia rates between lumbar levels from L1 to S1, or between single (DRG rate 21.8 %) or two-level (DRG rate 20.2 %) endoscopic decompression ($p = 0.742$). A statistically significantly higher incidence of postoperative dysesthesia was observed in patients who underwent decompression for foraminal stenosis (38/103; 27 %), and recurrent herniated disc (7/10; 41.2 %; $p = 0.039$). There were also statistically significant variations in dysesthesia rates between the seven participating clinical study sites ranging from 11.6%–33% ($p = 0.002$). Unrelenting postoperative dysesthetic leg pain due to DRG irritation was statistically associated with less favorable long-term clinical outcomes with DRG rates as high as 45 % in patients with a *Fair* and 61.3 % in patients with *Poor* Macnab outcomes ($p < 0.0001$).

Conclusions: Postoperative dysesthesia following transforaminal endoscopic decompression should be expected in one-fifth of patients. There was no predilection for any lumbar level. Foraminal stenosis and recurrent herniated disc surgery are risk factors for higher dysesthesia rates. There was a statistically significant variation of dysesthesia rates between participating centers suggesting that the surgeon skill level is of significance. Severe postoperative dysesthesia may be a predictor of *Fair* of *Poor* long-term Macnab outcomes.

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1. Introduction

Postoperative irritation of the dorsal root ganglion of the lumbar nerve roots following transforaminal endoscopic soft tissue or bony decompression for a herniated disc or spinal stenosis is a well-recognized sequela following this minimally invasive outpatient spinal surgery [1–3]. The low-burden nature of the endoscopic spinal surgery has been recognized by well-informed patients [4–7]. While the advantages of spinal endoscopy including minimal blood loss, short time to postoperative narcotic independence, and early social reintegration have been well-publicized, new and acute onset of unfamiliar dysesthetic leg pain typically developing five to ten days postoperatively is less well-known to patients and may catch many of them off guard [8,9] – a problem that has been attributed to the surgical irritation of the dorsal root ganglion often of the exiting nerve root rather than the traversing nerve root [10–14].

In this study, authors from different institutions and training backgrounds came together to contribute their patient outcome data to this dysesthesia analysis after routine lumbar endoscopy. The pooling of clinical, imaging, and anatomical data was intended to normalize for the wide variability in the application of endoscopic techniques and, most importantly, the surgeon skill level. Although all contributing authors have many years of clinical experience with spinal endoscopy, [14–21] the surgeon factor may impact the incidence of this often self-limiting postoperative sequelae most significantly. Therefore, the authors wanted to provide a baseline study on postoperative dysesthesia following transforaminal endoscopic discectomy or stenosis decompression in the foramen or lateral recess by investigating its frequency and contributing anatomical and other confounding comorbid factors.

2. Materials and methods

2.1. Patients

All patients in this case series suffered from sciatica-type low back and leg pain with claudication symptoms due to a contained lumbar disc herniation contributing to stenosis in the lateral recess, or extruded migrated disc herniations. This retrospective study selected from groups of consecutive patients seen in clinics of the seven participating study sites. All patients provided informed consent. The total study population consisted of 451 patients 201 (44.6 %) of which were female and 250 (55.4 %) were male. Patients were matched to age, gender, and diagnosis. To minimize the introduction of selection bias [22] and other additional confounding factors compounding such unforeseen bias, the participating surgeons were asked analyze their annualized DRG incidence and submit a representative patient group with longest possible follow-up with the same proportion of patients with and without this unintended postoperative sequelae. Patient enrollment at the study sites took place between 2010 and 2019. The mean follow-up was 47.16 months ranging from 2 to 111 months. The patients' age ranged from 19 to 99 years, with a mean age of 55.77 years (standard deviation [SDV] = 15.6 years) with a normal age distribution (Figs. 1 and 2). The inclusion and exclusion criteria for this study have been published elsewhere in detail and are briefly described in the following. [8,15]

2.2. Inclusion/exclusion and radiographic criteria

The history, physical examination, the findings of the advanced preoperative imaging studies were recorded. Only patients suffering from sciatica-type back and leg pain due to foraminal HNP or lateral recess stenosis who failed non-operative treatment for a minimum of 12 weeks were included in this study. The size and location of the compressive pathology, whether from disc herniations, or other types of soft tissue or bony stenosis in the spinal canal, lateral recess, and neuroforamen were classified according to well-established radiographic classification systems. [23–27] These have been employed in similar endoscopic outcome studies. Radiographic stenosis parameters including the posterior intervertebral disc and foraminal height were also recorded [23]. Crossectional imaging showing 15 mm or less for the height of the neuroforamen, 3 mm or less measured as posterior intervertebral disc height, or the width of the neuroforamen was recorded as abnormal [23]. As previously published and validated, diagnostic selective nerve root blocks were used to determine the symptomatic painful level. This protocol was highly relevant in choosing the surgical level(s) in patients with multilevel disease [28–35]. Exclusion of patients from the study was prompted by a concurrent diagnosis of infection, tumor or metastatic disease, overt spondylolisthesis with more than 3 mm of translational motion on dynamic extension/flexion views, and claudication due to severe central (< 100 mm^2) at the surgical level(s). [20]

2.3. Directly visualized transforaminal endoscopic surgical technique

The majority participating surgeons of this study with the exception of the senior author employed the transforaminal "outside-in" technique. [36] Serial dilation and foraminoplasty was employed to place the working cannula regardless of whether the "inside-out" or "outside-in" technique was followed. A foraminoplasty was performed were needed with power drills, trephines, chisels, and rongeurs following published techniques. [4,8,15–17,36,37], If bleeding occurred, a radiofrequency probe (Elliquence®) was used for coagulation [38]. The endoscopic decompression procedure was directly visualized throughout the surgery. Anatomical anomalies leading to inflammation or tethering the nerve roots bordering the triangular safe zone at the surgical level were recorded as the authors thought that they potentially could be causally related the postoperative development of DRG irritation. Fluoroscopic surveillance images were occasionally taken for orientation and verification of the decompression.

2.4. Clinical follow-up

Primary clinical outcome measures outcomes were the modified Macnab criteria. [39,40] All patients were instructed to be seen in follow-up for examination and management of any problems at 2 and 6 weeks and then at 3, 6, 12, and 24 months postoperatively. Unplanned visits to the emergency room, hospital admissions, or unforeseen postoperative problems or complications were recorded. Acute onset of new dysesthetic leg pain due to irritation of a dorsal root ganglion (DRG) was listed as sequelae (unavoidable problems even following an expertly executed surgery) per the Dindo classification. [41,42]

2.5. Postoperative rehabilitation

Most patients did not require postoperative rehabilitation and supportive care requirements. Study patients treated for any acute onset of dysesthetic leg pain after an initial postoperative period of good pain relief during the first 5–10 days with nonsteroidal anti-inflammatories, gabapentin, pregabalin, and transforaminal epidural steroid injections (TESI) pain syndromes were counted as having an irritation of the dorsal root ganglion (DRG).

2.6. Correlative surgical outcomes analysis

For the clinical outcome analysis, descriptive statistics (mean and standard deviation), crosstabulation statistics and measures of association were computed for two-way tables using IBM SPSS Statistics software, Version 25.0. The Pearson χ^2 and the likelihood-ratio χ^2 tests were used as statistical measures of association. Expected cell counts, continuity corrections, and likelihood ratios were calculated for some analyses. The confidence intervals (95 %) for the likelihood ratios were calculated using the "log method" according to Altman et al. [43,44]

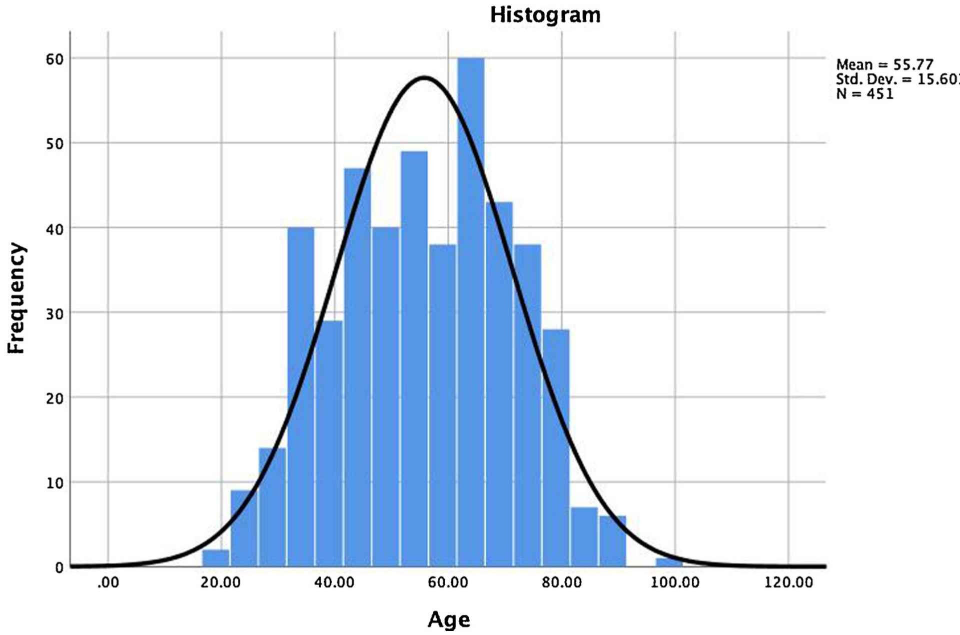

Fig. 1. Age Distribution of the 451 study patients with the superimposed expected normal distribution (black line). Patient's age ranged from 19 to 99 years of age and averaged 55.77 years.

3. Results

The 451 endoscopic decompression patients were compiled from seven author surgeons from 4 countries who contributed their clinical outcomes to this study in nearly equal proportions. As expected, the L4/5 level was the most commonly operated level (187/451; 41.5 %), followed by L5/S1 (124/451; 27.5 %), and two-level surgery from L4 to S1 (61/451; 13.5 %), respectively. The most common indication for surgery was herniated disc (273/451; 63.6 %), followed by spinal stenosis (141/451; 31.3 %), and recurrent herniation (17/451; 3.77 %). The remaining 20 patients underwent surgery for foraminal stenosis associated with low grade spondylolisthesis and degenerative deformity. The majority of patients had Excellent (183/451; 40.6 %) and Good (195/451; 43.2 %) Macnab outcomes (378/451; 83.8 %)

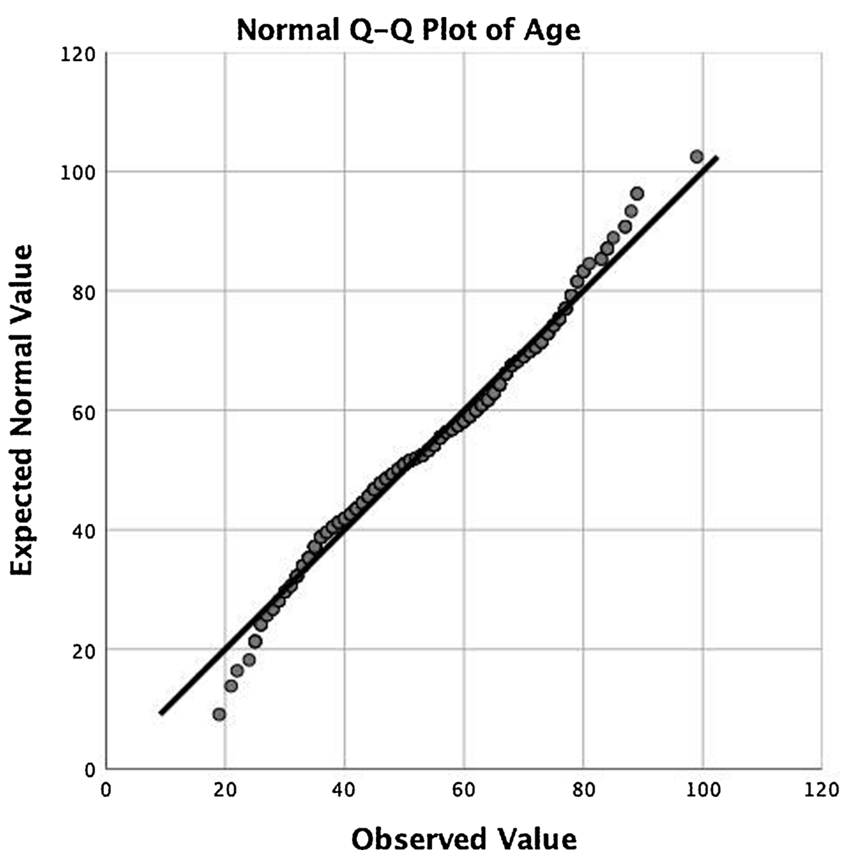

Fig. 2. The quantile-quantile plot of the endoscopy patients' age shows normal distribution. The average age was 55.77 ± 15.6 years ranging from 19 to 99 years.

Table 1
Frequency distribution of postoperative DRG irritation by surgical level in spinal endoscopy patients (n = 451).

DRG		Surgical Level									Total
		L1/2	L2-L4	L2/3	L3-L5	L3-S1	L3/4	L4-S1	L4/5	L5/S1	
Negative	Count	1	2	13	15	3	27	51	149	93	354
	% Level	100.0 %	100.0 %	81.3 %	71.4 %	60.0 %	79.4 %	83.6 %	79.7 %	75.0 %	78.5 %
Positive	Count	0	0	3	6	2	7	10	38	31	97
	% Level	0.0 %	0.0 %	18.8 %	28.6 %	40.0 %	20.6 %	16.4 %	20.3 %	25.0 %	21.5 %
Total	Count	1	2	16	21	5	34	61	187	124	451
	% Level	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	4.542a	8	.805
Likelihood Ratio	5.023	8	.755
N of Valid Cases	451		

a 8 cells (44.4 %) have expected count less than 5. The minimum expected count is .22.

DRG – Dorsal Root Ganglion.

regardless of treatment. Fair and Poor results were achieved in another 73 patients (16.2 %). There were no complications such as dural tears, or hematomas. Of the 451 study patients, 97 patients (21.5 %) had a postoperative irritation of the dorsal root ganglion (DRG). Over three-thirds of the study patients (354; 78.5 %) had an entirely uneventful postoperative recovery without any DRG symptoms. Cross-tabulating presence or absence of a DRG irritation against the surgical level showed a relatively equal distribution around the mean of 21.5 % ranging from 40 % (based on 2/5 patients with L3-S1 endoscopic decompression) to 16.4 % without a statistically significant difference on Chi-square testing (Table 1).

The patient self-reported clinical outcomes using the Macnab criteria were impacted by the presence or absence of a postoperative DRG irritation following the endoscopic decompression procedure. While only 10.4 % of patients with *Excellent* Macnab outcomes (19/183) had a DRG irritation, the percentage of patients with DRG irritation rose higher with less favorable outcomes: *Good* 22.1 % (43/195), *Fair* 45 % (27/60), and *Poor* 61.5 % (8/13), respectively, at a statistically significant level ($p < 0.0001$; Table 2). Cross-tabulating Macnab outcomes and DRG irritation symptoms by surgical level did not reveal any statistically significant association between these variables (Table 3).

Table 2
Macnab clinical outcomes versus DRG irritation in patients treated with transforaminal spinal endoscopy (n = 451).

Recovery		Macnab				Total
		Excellent	*Good*	*Fair*	*Poor*	
Uneventful	Count	164	152	33	5	354
	% within Recovery	89.6 %	77.9 %	55.0 %	38.5 %	78.5 %
DRG irritation	Count	19	43	27	8	97
	% within Recovery	10.4 %	22.1 %	45.0 %	61.5 %	21.5 %
Total	Count	183	195	60	13	451
	% within Recovery	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %

Chi-Square Tests

	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	45.405a	3	< .0001
Likelihood Ratio	41.913	3	< .0001
N of Valid Cases	451		

1 cells (12.5 %) have expected count less than 5. The minimum expected count is 2.80.

DRG – Dorsal Root Ganglion.

Recoding the patients in single-level and two- or multilevel surgery also did not show any statistically significant difference. The authors found a 21.8 % DRG irritation incidence for a single-level operation and 20.2 % for a two-level surgery ($p = 0.742$), respectively. To ascertain whether or not transforaminal endoscopic surgery at the L5/S1 level results in higher DRG irritation rates, the authors recoded the level variable by comparing endoscopic surgeries, which included the L5/S1 level (including multilevel), to those who did not. This analysis did also not show any statistically significant association suggesting that the L5/S1 level poses no particular risk for developing a postoperative DRG irritation. To ascertain whether there was a higher rate of the DRG irritation at the L2/3 and L3/4 level with transforaminal endoscopic decompression, the authors compared patients who had surgery at the L4/5 level and below, or above the L4/5 level. Again, there was no statistically significant difference in this comparison, corroborating the concept that DRG irritation occurs at a relatively equal rate around the mean of 21.5 % for the whole group of 451 patients without any predilection to higher rates at any level. However, there were statistically significant difference in postoperative DRG irritation rates which impacted outcomes between the seven surgeons with a p-value of 0.002 for the entire study group of 451 patients (Table 4). This cross-tabulation chi-square analysis also showed a statistically significant association between a lower DRG irritation rate in patients with *Excellent* Macnab outcomes ($p = 0.003$) versus those with *Fair* outcomes ($p < 0.0001$). However, there was a statistically significant difference in the incidence of DRG irritation by surgeon ranging from 33.3 % (surgeon #5) to 11.6 % (surgeon #7) suggesting a "surgeon" or "technique" factor.

The authors also attempted to analyze whether there is a correlation between the incidence of postoperative dysesthetic leg pain, diagnosis, and intraoperative anatomical observations such as inflamed nerve roots, an inflamed facet cyst adherent to the DRG of the exiting nerve root, an inflamed toxic annular tears, and or tethering of the nerve roots by foraminal ligaments to name a few of the common problems (Fig. 3). While it was obvious to try to correlate these findings ascertained intraoperatively during the directly visualized endoscopic surgery, the authors could not determine a statistically significant association because of lack of observational numbers required for sufficient statistical power (data not shown). However, there was a statistically significantly high rates of postoperative DRG irritation symptoms in patients who underwent surgery for spinal stenosis (38/103; 27 %) or for recurrent disc herniations (7/10; 41.2 %; $p = 0.039$; Table 5). Moreover, the type of disc herniation did not impact the rate of DRG irritation at a statistically significant level. The rates for central (20.8 %), paracentral (24.5 %), and combined central- paracentral herniations (21.3 %) were

Table 3
Macnab clinical outcomes versus DRG irritation and surgical level in patients treated with transforaminal spinal endoscopy (n = 451).

Macnab Outcomes				Endoscopy Level									Total
				L1/2	L2-L4	L2/3	L3-L5	L3-S1	L3/4	L4-S1	L4/5	L5/S1	
Excellent	DRG	Negative	Count		2	1	6	2	13	18	67	55	164
			% Level		100.0 %	50.0 %	100.0 %	100.0 %	92.9 %	90.0 %	90.5 %	87.3 %	89.6 %
		Positive	Count		0	1	0	0	1	2	7	8	19
			% Level		0.0 %	50.0 %	0.0 %	0.0 %	7.1 %	10.0 %	9.5 %	12.7 %	10.4 %
	Total		Count		2	2	6	2	14	20	74	63	183
			% Level		100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %
Good	DRG	Negative	Count			10	6		10	26	68	32	152
			% Level			90.9 %	60.0 %		83.3 %	89.7 %	81.0 %	65.3 %	77.9 %
		Positive	Count			1	4		2	3	16	17	43
			% Level			9.1 %	40.0 %		16.7 %	10.3 %	19.0 %	34.7 %	22.1 %
	Total		Count			11	10		12	29	84	49	195
			% Level			100.0 %	100.0 %		100.0 %	100.0 %	100.0 %	100.0 %	100.0 %
Fair	DRG	Negative	Count	1		1	3	1	3	5	14	5	33
			% Level	100.0 %		50.0 %	75.0 %	33.3 %	50.0 %	55.6 %	56.0 %	50.0 %	55.0 %
		Positive	Count	0		1	1	2	3	4	11	5	27
			% Level	0.0 %		50.0 %	25.0 %	66.7 %	50.0 %	44.4 %	44.0 %	50.0 %	45.0 %
	Total		Count	1		2	4	3	6	9	25	10	60
			% Level	100.0 %		100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %
Poor	DRG	Negative	Count			1	0		1	2	0	1	5
			% Level			100.0 %	0.0 %		50.0 %	66.7 %	0.0 %	50.0 %	38.5 %
		Positive	Count			0	1		1	1	4	1	8
			% Level			0.0 %	100.0 %		50.0 %	33.3 %	100.0 %	50.0 %	61.5 %
	Total		Count			1	1		2	3	4	2	13
			% Level			100.0 %	100.0 %		100.0 %	100.0 %	100.0 %	100.0 %	100.0 %

Chi-Square Tests

Macnab		Value	df	Asymptotic Significance (2-sided)
Excellent	Pearson Chi-Square	5.124b	7	.645
	Likelihood Ratio	4.759	7	.689
	N of Valid Cases	183		
Good	Pearson Chi-Square	10.461d	5	.063
	Likelihood Ratio	10.417	5	.064
	N of Valid Cases	195		
Fair	Pearson Chi-Square	2.227c	7	.946
	Likelihood Ratio	2.644	7	.916
	N of Valid Cases	60		
Poor	Pearson Chi-Square	5.958e	5	.310
	Likelihood Ratio	7.959	5	.159
	N of Valid Cases	13		
Total	Pearson Chi-Square	4.542a	8	.805
	Likelihood Ratio	5.023	8	.755
	N of Valid Cases	451		

[a] 8 cells (44.4 %) have expected count less than 5. The minimum expected count is 0.22.
[b] 9 cells (56.3 %) have expected count less than 5. The minimum expected count is 0.21.
[c] 13 cells (81.3 %) have expected count less than 5. The minimum expected count is 0.45.
[d] 3 cells (25.0 %) have expected count less than 5. The minimum expected count is 2.21.
[e] 12 cells (100.0 %) have expected count less than 5. The minimum expected count is 0.38.
DRG – Dorsal Root Ganglion.

nearly equal. All patients with an acute DRG irritation were treated with oral gabapentin or pregabalin, and with one or two transforaminal epidural steroid injections (TESI) during the first few postoperative weeks ultimately resolving their symptoms.

4. Discussion

Dysesthetic leg pain following lumbar spinal endoscopy is frequently due to irritation of the dorsal root ganglion of the exiting nerve root rather than the traversing nerve root. These symptoms often develop 5–10 days postoperative and are often unfamiliar to the patient. The dysesthetic symptoms are often projecting into a different dermatome in the lower extremity, causing the patients to worry about its significance and prompting them to present in follow-up for additional medical and interventional management. The authors of this study attempted to understand the frequency of postoperative DRG irritation better and ascertain any contributing anatomical or comorbid factors to this well-known postoperative sequela. Most authors recommend preoperative patient education, and close postoperative follow-up within the first two weeks focusing on medical treatment by oral administration of gabapentin or pregabalin, and interventional management with transforaminal epidural steroid injections (TESI). [8,9,11–16,36,37,45], However, the question remains whether any underlying anatomical or comorbid factors make one particular lumbar level, or pathology more susceptible to the development of dysesthetic leg pain over another, or is it just related to surgeon skill level?

A commonly recirculated idea emphasizes that surgery at the L5/S1 level is much more likely to produce a postoperative dysesthesia since two DRGs are within the transforaminal surgical corridor. The DRG of the exiting L5 nerve root typically resides under the L5 pedicle in the mid-zone of the neuroforamen, and the DRG of the traversing S1 is often found in the lateral recess right above the S1 pedicle. [46,47] Surgery at the L2/3 has also been considered as riskier than transforaminal endoscopic surgery at the more commonly operated L3/4 and

Table 4
Macnab clinical outcomes versus DRG irritation and surgeon in patients treated with transforaminal spinal endoscopy (n = 451).

Macnab				Contributing Surgeons							Total
				#1	#2	#3	#4	#5	#6	#7	
Excellent	DRG	Negative	Count	22	11	19	57	19	7	29	164
			% Surgeon	68.8 %	91.7 %	95.0 %	93.4 %	100.0 %	100.0 %	90.6 %	89.6 %
		Positive	Count	10	1	1	4	0	0	3	19
			% Surgeon	31.3 %	8.3 %	5.0 %	6.6 %	0.0 %	0.0 %	9.4 %	10.4 %
	Total		Count	32	12	20	61	19	7	32	183
			% Surgeon	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %
Good	DRG	Negative	Count	38	10	20	17	21	11	35	152
			% Surgeon	74.5 %	58.8 %	71.4 %	73.9 %	91.3 %	84.6 %	87.5 %	77.9 %
		Positive	Count	13	7	8	6	2	2	5	43
			% Surgeon	25.5 %	41.2 %	28.6 %	26.1 %	8.7 %	15.4 %	12.5 %	22.1 %
	Total		Count	51	17	28	23	23	13	40	195
			% Surgeon	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %
Fair	DRG	Negative	Count	5	1	13	5	0		9	33
			% Surgeon	55.6 %	100.0 %	72.2 %	83.3 %	0.0 %		81.8 %	55.0 %
		Positive	Count	4	0	5	1	15		2	27
			% Surgeon	44.4 %	0.0 %	27.8 %	16.7 %	100.0 %		18.2 %	45.0 %
	Total		Count	9	1	18	6	15		11	60
			% Surgeon	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %		100.0 %	100.0 %
Poor	DRG	Negative	Count	0		2		0	0	3	5
			% Surgeon	0.0 %		50.0 %		0.0 %	0.0 %	100.0 %	38.5 %
		Positive	Count	2		2		3	1	0	8
			% Surgeon	100.0 %		50.0 %		100.0 %	100.0 %	0.0 %	61.5 %
	Total		Count	2		4		3	1	3	13
			% Surgeon	100.0 %		100.0 %		100.0 %	100.0 %	100.0 %	100.0 %

Chi-Square Tests

Macnab		Value	df	Asymptotic Significance (2-sided)
Excellent	Pearson Chi-Square	19.659b	6	.003
	Likelihood Ratio	18.012	6	.006
	N of Valid Cases	183		
Good	Pearson Chi-Square	9.725d	6	.137
	Likelihood Ratio	10.011	6	.124
	N of Valid Cases	195		
Fair	Pearson Chi-Square	26.452c	5	.000
	Likelihood Ratio	33.103	5	.000
	N of Valid Cases	60		
Poor	Pearson Chi-Square	8.775e	4	.067
	Likelihood Ratio	11.778	4	.019
	N of Valid Cases	13		
Total	Pearson Chi-Square	20.597a	6	.002
	Likelihood Ratio	21.100	6	.002
	N of Valid Cases	451		

[a]1 cells (7.1 %) have expected count less than 5. The minimum expected count is 4.52.
[b]6 cells (42.9 %) have expected count less than 5. The minimum expected count is 0.73.
[c]7 cells (58.3 %) have expected count less than 5. The minimum expected count is 0.45.
[d]2 cells (14.3 %) have expected count less than 5. The minimum expected count is 2.87.
[e]10 cells (100.0 %) have expected count less than 5. The minimum expected count is 0.38.
DRG – Dorsal Root Ganglion.

L4/5 levels [48]. A postoperative inflammatory irritation of the DRG can produce bothersome impairment of proprioception in the affected nerve roots and be accompanied by profound quadriceps weakness; a phenomenon that can be a result of neuropraxia, but just as often may be related to poor effort by the patient who is profoundly bothered by the impaired proprioception contributing to buckling of the lower extremity at the knee. [49]

Compared to the sheer quantity of peer-reviewed literature on spinal endoscopy that has emerged over the last five years alone, there remains a remarkable scarcity of research on the frequency and contributing factors that seemingly make one patient more prone to developing a postoperative DRG irritation than another. In fact, the authors could only find one other article published by Choi et al. in 2013 that was dedicated to the investigation of injury to the exiting nerve root in Korean military servicemen treated for herniated disc. Notably, the age of these patients reportedly ranged from 18 to 51 years with a mean of 23 years. Of these 233 patients who underwent transforaminal discectomy, 15 (6.4 %) developed postoperative dysethesia, and another 5 (2.15 %) were noted to have motor weakness grade 2–4 resulting in a combined exiting nerve root injury rate of 8.58 %. In comparison, our patients' age ranged from 19 to 99 years, with a mean age of 55.77 years (standard deviation [SDV] = 15.6 years) suggesting more advanced degeneration of the lumbar spinal motion segment. Moreover, our patients were not military service men but came from all walks of life with a more diverse occupational backgrounds and were likely more representative of the kinds of patients seen in a typical degenerative spine practice. Hence, the rate of postoperative nerve injury DRG irritation of 21.5 % found regardless of the surgical level found in our multicenter study is likely more realistic. It was higher than in another previously reported single-surgeon study which found a rate of 12.45 %. [17]

To the surprise of this team of authors and contrary to the common

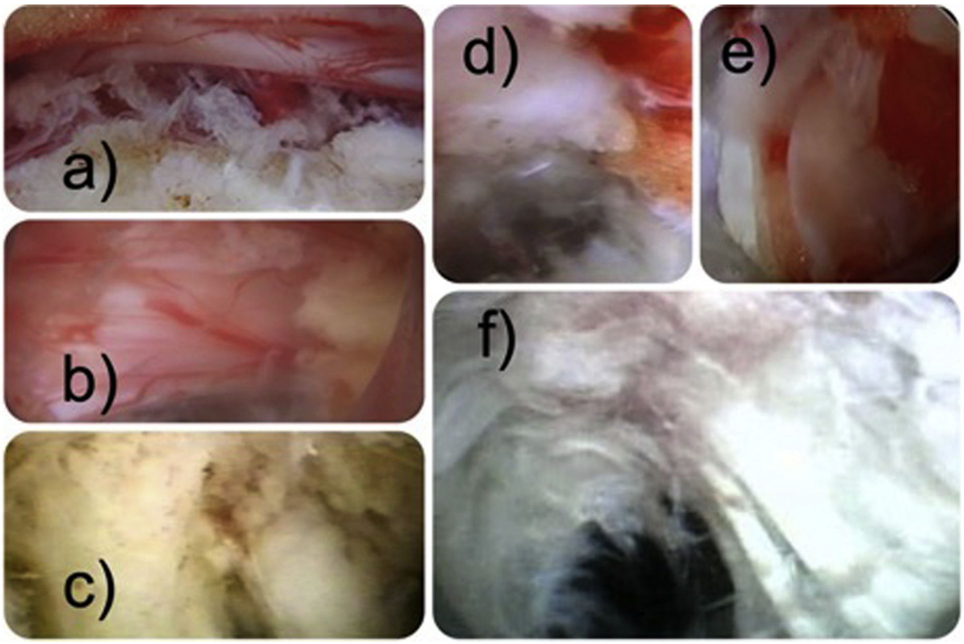

Fig. 3. Intraoperative endoscopic views of painful pathology the authors thought were associated with a higher risk for postoperative development of dysesthetic leg pain: a-b) inflamed traversing nerve roots, c) furcal nerve, D-e) adhesions of the DRG to the tip of the superior articular process with a facet cyst, and inflamed annular tear with adhesive granulation tissue adherent to the nerve. Statistically, the authors were not able to demonstrate any significant correlation to these directly visualized intraoperative findings.

belief amongst endoscopic spine surgeons, the results of this study showed that there was no particular predilection to one or two specific surgical level(s) for postoperative DRG irritation to occur following the transforaminal endoscopic decompression for a herniated disc or spinal stenosis. DRG irritation occurred nearly at the same frequency in approximately one fifth of patients (mean 21.5 %), regardless of whether it was performed at L5/S1 or L2/3 or any other of the surgical levels included in this study. It is conceivable that our study was limited by surgeons' affective (unconscious emotional reaction), [50,51] cognitive (distortions of thinking) [52], or notoriously unavoidable hindsight bias [52,53] common to retrospective studies by thinking that the former two levels are more problematic than others because these patients with postoperative inflammation of the DRG tend to have more disability from impaired ambulation than at the other levels and require more frequent follow-up management. In contrast, decompression at the L4/5 level is by far the most commonly performed endoscopic spinal surgery, and many of those patients often exit the practice even if they had a DRG irritation without requiring much additional management because it is better tolerated than DRG irritation symptoms stemming from the L2/3, or L5/S1 level. Likewise, patients may fall victim to similar recall bias – a well-recognized phenomenon [54–56] – by readjusting their expectations to the "normal" functioning of peers, friends and family members rather than to their own preoperative impaired functional status [57]. This forward-looking recall bias may adversely impact the patients' interpretation of their clinical outcome with endoscopic surgery and lead to worse clinical outcome ratings and higher utilization postoperatively, particularly when the acute onset of sharp burning leg pain occurs unexpectedly.

The analysis of variance of the frequency distribution of the patients with DRG irritation by the number of levels, surgeon, and outcome brought a few interesting facts to light that are worth discussing. The authors were concerned that operating at more than one level during the transforaminal decompression could be correlated with a higher rate of DRG irritation. In other words, more surgery equals more irritation. Again, this turned out not to be the case in the study of 451 patients with sufficient statistical power. The DRG irritation rates remained relatively stable regardless of whether the patient had a single (21.8 %), or a two-level (20.2 %) transforaminal endoscopic decompression. Only patients with multilevel endoscopic transforaminal surgery had the highest risk of DRG irritation rate of 40 %. The latter was a very uncommon scenario and only took place in two of the five patients who underwent an L3 to S1 unilateral endoscopic decompression.

Table 5
Frequency distribution of postoperative DRG irritation by preoperative diagnosis of spinal endoscopy patients (n = 451).

Recovery		Preoperative Diagnosis					Total
DRG		Deformity	HNP	Recurrent HNP	Spondylolisthesis	Stenosis	
Uneventful Recovery	Count	12	223	10	6	103	354
	% Diagnosis	85.7 %	81.7 %	58.8 %	100.0 %	73.0 %	78.5 %
Postop DRG Irritation	Count	2	50	7	0	38	97
	% Diagnosis	14.3 %	18.3 %	41.2 %	0.0 %	27.0 %	21.5 %
Total	Count	14	273	17	6	141	451
	% Diagnosis	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %

Chi-Square Tests	Value	df	Asymptotic Significance (2-sided)
Pearson Chi-Square	10.095a	4	.039
Likelihood Ratio	10.759	4	.029
N of Valid Cases	451		

[a] 4 cells (40.0 %) have expected count less than 5. The minimum expected count is 1.29.
DRG – Dorsal Root Ganglion.

However, a two-level transforaminal endoscopic decompression which was performed in 84 (18.6 %) of the 451 patients did not constitute a risk factor for postoperative DRG irritation. The authors conclude that it is a reasonable strategy to execute a two-level lumbar transforaminal endoscopic decompression surgery since an increased rate of DRG irritation should not be expected.

Another concern was whether the incidence of postoperative DRG irritaton was higher in stenosis cases where there is often a need for a more extensive foraminoplasty and manipulation of the nerve roots than in patients with herniated disc. This was certainly the case in our patient population where patients having surgery for stenosis (27 %) or recurrent disc herniations (21.2 %) had the highest incidence of DRG irritation (Table 10). In patients with soft tissue and bony stenosis, the implication is that they often suffer from more advanced stages of degenerative facet- and disc disease where one would expect more scarring or tethering of the nerve roots by adhesions, facet cysts, thickened ligaments, chronically inflamed annular tears, and generally a more difficult endoscopic dissection requiring more manipulation of the nerve roots (Fig. 3). Likewise, the type of disc herniation could impact the rate of DRG irritation as well. However, this was not statistically significant in our series. Surgeon skill level in more complex stenosis cases with advanced degeneration of the lumbar motion segment or recurrent disc herniation with scar tissue or adhesions are the single most reliable predictor of a higher incidence of postoperative DRG irritation. Additional patient-related factors such as underlying medical, metabolic, neuropathic, or neurological conditions, such as diabetes, renal, thyroid disease, or multiple sclerosis could have exposed the patients in the *Fair* and *Poor* Macnab category to a higher risk of developing a postoperative DRG irritation was beyond the scope of this study. A dedicated study in diabetics is currently underway.

Our study was limited by the inability to determine whether patients with Fair and Poor Macnab outcomes had a higher incidence of DRG irritation because of unrecognized confounding factors that could be entirely unrelated to surgical technique or skill level. Despite 451 study patients, the statistical power was insufficient. Furthermore, no conclusive validated test can be done to determine whether the patient suffers from postoperative dysesthesia or failure to cure. EMG and nerve conduction studies are controversial, and routine postoperative MRI scans were impractical since they are often deemed as medically unnecessary by payers. Therefore, the diagnosis is typically made clinically when the patient returns to the office with a complaint of overwhelming burning leg pain. There is also the possibility that patients with failure to cure unknowingly misrepresented their symptoms during the immediate postoperative recovery. However, the authors were surprised by the association between less favorable long-term clinical outcomes and DRG irritation in the immediate postoperative. It could be coincidental and needs to be further investigated.

5. Conclusions

Acute onset of dysesthetic leg pain after an initial pain-free postoperative interval of 5–10 days is to be expected approximately in one-fifth of patients who underwent single or two-level endoscopic transforaminal surgeries regardless of the lumbar level. The incidence of DRG irritation is higher in patients undergoing endoscopic decompression for spinal stenosis and recurrent disc herniation likely due to a higher rate of scarring, adhesion, and the need for more extensive manipulation and mobilization of the lumbar nerve roots. Unrelenting DRG irritation is associated with less favorable *Fair* and *Poor* long-term clinical outcomes. The surgeon skill level and technique were related to the incidence of postoperative DRG irritation with statistical significance. Most patients' symptoms improve by performing one or two TESI during the early postoperative convalescence.

Disclaimer

The views expressed in this article represent those of the authors and no other entity or organization.

Conflicts of interest

This manuscript is not meant for or intended to push any other agenda other than reporting the clinical outcome data following endoscopic spinal decompression for sciatica-type back and leg pain. The motive for compiling this clinically relevant information is by no means created and/or correlated to directly enrich anyone due to its publication. The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The senior author designed and trademarked his inside-out YESS™ technique and receives royalties from the sale of his inventions. Indirect conflicts of interest (honoraria, consultancies to sponsoring organizations are donated to IITS.org, a 501c 3 organization).

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