### Title

Endoscopic Rhizotomy for Facetogenic Back Pain: A Review of the History, Financial Considerations, Patient Selection Criteria, and Clinical Outcomes




### Authors

Streetman, Daniel
Fricker, Joshua G
Garner, Garrett L
et al.



### Publication Date

2023

### DOI

10.1016/j.wneu.2022.10.020

# Endoscopic Rhizotomy for Facetogenic Back Pain: A Review of the History, Financial Considerations, Patient Selection Criteria, and Clinical Outcomes

Daniel Streetman[1], Joshua G. Fricker[1], Garrett L. Garner[1], Adam L. Webb[1], Noah Pierzchajlo[1], Neal A. Patel[1], Nicholas A. Howard[1], Ellen M. Hardin[1], Triston E. Smith[1], Alana J. Hagley[1], Nolan J. Brown[2], Julian L. Gendreau[3]

**Key words**
- Dorsal medial branch
- Endoscopic rhizotomy
- Facetogenic back pain
- Lumbar facet joint
- Radiofrequency ablation
- Rhizotomy

**Abbreviations and Acronyms**
3DNER: Three-dimensional navigated endoscopic rhizotomy
CBP: Chronic back pain
DMB: Dorsal medial branch
ER: Endoscopic rhizotomy
FJ: Facet joint
LFJP: Lumbar facet joint pain
NSAIDs: Nonsteroidal anti-inflammatory drugs
RFA: Radiofrequency ablation
VR: Virtual reality

*From the [1]Mercer University School of Medicine, Savannah, Georgia; [2]Department of Neurological Surgery, University of California, Irvine, California; and [3]Department of Biomedical Engineering, Johns Hopkins Whiting School of Engineering, Baltimore, Maryland, USA*

*To whom correspondence should be addressed: Daniel Streetman [E-mail: Daniel.ryan.streetman@live.mercer.edu]*

*Citation: World Neurosurg. (2022). https://doi.org/10.1016/j.wneu.2022.10.020*

*Journal homepage: www.journals.elsevier.com/world-neurosurgery*

*Available online: www.sciencedirect.com*



BACKGROUND: **Chronic back pain (CBP) is a condition that places a considerable burden on society, with several million people affected in the United States alone. Treatment options to address this problem and relieve CBP are constantly evolving, and one of the most promising treatment modalities for CBP that is refractory to conservative treatment options is endoscopic rhizotomy (ER).**

METHODS: **A thorough search of the PubMed (MEDLINE) database was conducted with the intent to assess the full progression of ER from its earliest uses to present day in a historical narrative review of ER, with treatment of facetogenic pain as a model pathology.**

RESULTS: **ER allows for direct visualization and ablation of sensory branches of the dorsal ramus to provide pain relief in up to 80% of patients faced with refractory CBP. This technique has been built upon since the early 20th century, and the novel endoscopic approach continues to gain popularity among physicians. Benefits of ER include superior postoperative median pain-free duration compared with traditional percutaneous radiofrequency ablation, as well as direct visualization of regional anatomy. Patient selection criteria for the procedure and a modest list of contraindications allow the use of ER as a viable treatment option for a significant population of patients suffering from CBP. Potential barriers to ER include high cost of the procedure, longer intraoperative time, and expensive proprietary equipment.**

CONCLUSIONS: **ER is an effective treatment for refractory CBP with notable advantages. As the technology and popularity of this procedure progress, improvements in the cost, training, and intraoperative time may make it a favorable alternative to the current standard of care.**

## INTRODUCTION

Chronic back pain (CBP) is one of the most common chief complaints among the adult population. Contributing to high healthcare costs, CBP is defined as pain that lasts 12 weeks or longer.[1,2] The prevalence of CBP among those between 20 and 69 years of age is 13.1%, with one study showing patients in their fifth decade having the highest likelihood of CBP, at 27.4%.[3] Although the prevalence of CBP is high, the ability to accurately diagnose it is relatively low.[4,5] Consequentially, conservative treatment for CBP is typically broad, with the use of nonsteroidal anti-inflammatory drugs (NSAIDs), glucocorticoids,[6] and opioids.[7]

In cases of conservative therapy-refractory pain, surgical options become the standard of care.[4] Traditional measures, such as spinal fusion surgery for the treatment of chronic low back pain, lead to significant morbidity and involve a surgeon treating a symptom without a clearly defined anatomic defect.[4] Traditional percutaneous radiofrequency ablation (RFA) is a much less invasive option but does not allow direct visualization of the dorsal medial branch (DMB).[8] Moreover, the pain relief provided for these patients is often short-lived, with studies showing a considerable number of patients with pain at 1-year follow up.[9,10] For this reason, escalating therapy in the form of multiple percutaneous RFAs is necessary for some patients, such as patients with anatomic variations.[10]

Endoscopic rhizotomy (ER) is now a viable treatment option for patients with chronic low back pain lacking a radiographically defined anatomic defect.[11] Using this technique, surgeons insert an endoscope to view the DMB of the affected zygapophyseal joint and can achieve DMB denervation using RFA. One benefit of this technique is direct visualization of the spinal anatomy, allowing for more precision when





REV 5.6.0 DTD ■ WNEU19611_proof ■ 27 October 2022 ■ 2:56 pm ■ ce

severing small branches of the DMB as well as identifying anatomic variants.[10] A literature review on this novel surgical technique, including data on patient outcomes, has yet to be provided. The objective of this review was to outline, in a narrative format, the most recent developments of ER for chronic low back pain by providing data on clinical trials, case series, and technical reviews. We also provide an overview of the history of rhizotomy, patient selection, and financial considerations.

## METHODS

We reviewed current and historical literature pertaining to ER through a search of the PubMed (MEDLINE) database. References were also screened for notable information relevant to the review. Recent developments are outlined and evidenced by clinical trials, case series, and technical reviews. In addition, financial considerations, patient selection, and patient outcomes are discussed. Although modern ER is used to treat a multitude of chronic pain pathologies, including disc-mediated low back pain, facetogenic CBP was chosen as a model pathology because of its role in the genesis of ER.

### History of Rhizolysis

The technique of ER to ablate the sensory branches of the dorsal ramus has evolved with improvements in imaging, pathophysiological understanding, and surgical technology from the primitive description of events derived more than 100 years ago. According to Russo et al,[12] the first account of interventional rhizolysis for CBP was developed and performed by Vincent Nesfield in 1918. Nesfield believed that the cause was a sensory nerve "trapped" in muscle or tendon, a condition termed "trench back," alluding to the large number of soldiers from World War I who presented with unrelenting back pain.[13] In 1918, he developed a procedure using an ophthalmic scalpel that was inserted into the spine and propelled vertically to "cut" the trapped nerve.[12] Nesfield performed this procedure for more than 40 years, and in 1959, urologic surgeon William Rees became enamored of this work.[14] Rees began to specialize in treating CBP in rural Australia and later developed the multiple bilateral percutaneous rhizolysis procedure.[15] Numerous surgeons trained under Rees until his retirement in 1993.[14]

One of Rees's trainees was famous neurosurgeon C. Norman Shealy.[16] Shealy's career focused on providing resolutions to patients with chronic pain using alternative methods and holistic medicine that are both safe and effective.[16] Instead of using surgical scalpels to sever nerves, Shealy used his experience with fluoroscopic-guided RFA of the gasserian ganglion and applied this knowledge to rhizotomy.[17,18] Thus, he became the first to use fluoroscopy and RFA, severing what he deemed to be the articular nerve supply to the lumbar facet joints (FJs). He referred to his technique as "percutaneous denervation of the facet joints."[17,18]

Nikolai Bogduk is the next pioneer in the history of modern-day rhizolysis. Bogduk was a physician with a special interest in spinal pain and spinal musculoskeletal medicine.[19] Studying spinal anatomy, Bogduk separated himself from many of the innovators before him by performing dissections on human and other mammalian cadavers.[20-22] He studied the cadavers of former patients of Dr Shealy and determined Shealy was targeting not the articular nerve supply of the FJs, but rather the medial branch of the dorsal ramus.[23-25] With this knowledge, he and colleague Don Long tweaked Shealy's technique, calling their procedure "percutaneous medial branch neurotomy," a technique still used today.[26] The foregoing is not intended to be an all-encompassing history of the surgical technique, as many others who are unnamed here have contributed to the surgical technique used in operating rooms around the world today.

Standing on the shoulders of the giants who preceded him, Anthony Yeung provided the first description of ER in a 2007 presentation of a pilot study at the International 25th Jubilee Course in Zurich, Switzerland.[27] Through detailed cadaveric dissection and years of experience with endoscopic foraminal spine surgery, Yeung was armed with the skills to develop this novel technique. In this presentation, he described a nonrandomized study assessing the efficacy of using a specially designed spinal cannula and endoscope to directly visualize and confirm the ablation or transection of nervous tissue. One crucial benefit of the endoscopic approach, Yeung claimed, is that a larger area of tissue can be ablated over the transverse process where the medial branch crosses the FJ. The inclusion criterion for the original pilot study was a 50% improvement in back pain on medial branch block.[27] The initial 50 patients enrolled in the pilot study showed excellent clinical results, and the study was continued with a stricter inclusion criterion of 70% improvement of back pain from injection/block.[11] Even with the more stringent guidelines for surgical recommendation, the study rapidly grew to 450 participants. Still, exceptional clinical results were achieved, with no patients reporting disappointment or dissatisfaction when the ≥70% pain relief from medial branch block was used for endoscopic surgical recommendation. From this study, the investigators concluded that the endoscopic approach offered more consistent and longer-lasting clinical results than the gold standard fluoroscopically guided approach through its ability to overcome technical and anatomic limitations.[11]

Along with Yeung's original publication on ER in 2014 came the debut of the Richard Wolff YESS rhizotomy set developed by Elliquence (Baldwin, New York, USA).[11] This original kit was composed of cannulas, the Bi-Tip, surgical bipolar radiofrequency probes, and an endoscope designed to provide excellent images that remain in focus while resting on the cannula. The probe uses a low-temperature, ultra-high-frequency (1.7–4.0 MHz) bipolar energy radio frequency energy to ablate small nerves of ≤1 mm.[11] With this first public appearance, Elliquence became the leader in the private sector of ER kits. Joimax (Irvine, California, USA), RIWOspine (Knittlingen, Germany), and MaxMoreSpine (Frankfurt, Germany) were quick to follow with their own kits, all of which provide surgeons with direct visualization and RFA of the DMB of the affected FJ.[28-30] Although Yeung's original procedure is still widely used, these manufacturers' kits, equipment, and protocols vary, and there is not yet a standard protocol for ER.

**Table 1.** Summary Table of Direct Comparative Studies Evaluating Endoscopic Rhizotomy and Comparison Treatment

| Variable | Li et al.[9] | | Du et al.[33] | | Xue et al.[10] | |
|---|---|---|---|---|---|---|
| Year(s) | 2011 | | 2017–2020 | | 2020 | |
| Country | China | | China | | China | |
| Design | Randomized prospective cohort | | Open-label prospective cohort | | Randomized prospective cohort | |
| Maximum follow-up (months) | 12 | | 12 | | 12 | |
| Inclusion criteria | >80% relief after 2 medial branch blocks | | >80% relief after 1 medial branch block | | >80% relief after 1 medial branch block | |
| Allocation method | Random | | Open label | | Random | |
| Outcome measures | VAS score, % pain relief, McNab score | | NRS, ODI, PGIC | | VAS, McNab score, postoperative complications | |
| Total number (ER only number) | 58 (45) | | 55 (19) | | 60 (30) | |
| Cohorts | Treatment | Comparison | Treatment | Comparison | Treatment | Comparison |
| | ER | Conservative (NSAID, PT, CBT) | ER | RF ablation | ER | RF ablation |
| Duration of preoperative pain, (months), mean ± SD | 137.13 ± 135.77 | 48.23 ± 71.40 | 100.8 ± 51.6 | 68.4 ± 37.2 | 46.83 ± 11.43 | 46.71 ± 11.21 |
| Age (years), mean ± SD | 61.84 ± 11.77 | 62.62 ± 19.83 | 75.5 ± 8.3 | 68.9 ± 12.3 | 65.73 ± 7.62 | 64.78 ± 6.62 |

VAS, visual analog scale; NRS, numeric pain rating scale; ODI, Oswestry Disability Index; PGIC, Patient Global Impression of Change; ER, endoscopic rhizotomy; NSAID, nonsteroidal anti-inflammatory drug; PT, physical therapy; CBT, cognitive behavioral therapy; RF, radiofrequency.

## Financial Considerations

The financial implications of real-world ER represent an important consideration. Nearly 10% of individuals worldwide are affected by CBP, and the prevalence is increasing. A significant source of CBP is the lumbar FJs, especially in the elderly.[31,32]

A real-world study comparing ER to RFA for lumbar FJ pain (LFJP) found a mean operative duration of 61.9 ± 12.9 minutes for ER, compared with 35.4 ± 7.6 minutes for RFA ($P < 0.001$).[33] This represents a statistically significant greater operation time for ER, nearly twice as long on average. An increase in operative time increases the time spent in the operating room, which adds to the cost of the procedure.

The study comparing ER and RFA for LFJP also reported the medical expenses associated with each procedure, with a mean cost of cost 3964 ± 154.9 (USD) for ER and 979.1 ± 99.0 (USD) for RFA ($P < 0.001$). Annual medical expense was also evaluated as medical expenses per procedure (in USD)/median pain-free duration (year), which showed 2378.4 for ER and 1174.9 for RFA.[33] This represents a statistically significant difference in the cost of the 2 procedures, with ER costing nearly 4 times more than RFA. Medical cost represents a major barrier when considering the financial burden for patients. However, it is very important to consider long-term medical costs; for example, a real-world study found that ER had double the median pain-free duration of RFA.[33] Although it may be difficult to determine, preventing repeated RFA procedures may lead to a different cost analysis for long-term care, considering that RFA is known to have a high recurrence rate within 12 months that requires repeat interventions.[34-37]

The financial costs associated with appropriate training indicated for endoscopic lumbar spine surgery also should be considered. Important elements of surgical training for endoscopic lumbar spinal surgery are didactic lectures, cadaveric training, and surgical mentorship. Surgeons must have a complete understanding of spinal anatomy and surgical approach, along with mastery of minimally invasive surgery techniques. Completion of multiple sessions where the surgical technique is performed on cadavers is recommended. Additionally, surgeons should perform numerous endoscopic spinal surgeries with an attending preceptor before engaging in these surgeries alone.[38] Specifically, ER is known to have a significant learning curve even with proficient skills.[33] A potential training method that could reduce financial costs associated with appropriate training for ER is a virtual reality (VR) training simulator. VR is increasingly being integrated into surgical training based on a number of key advantages: low cost, no risk to patients, no time limit, and unlimited practice opportunities. This can allow for a better spatial understanding of desired anatomy. All of this can be done using an internet-connected personal computer and a VR headset. VR-based surgical simulations with collision detection have been used for shoulder arthroscopy simulation, endovascular training, ventricular catheterization, pedicle screw insertion, lumbar puncture, and percutaneous rhizotomy.[39-41] Although VR-based surgical simulations are not at the forefront of training for ER, they represent a potential future training method that could help reduce costs and should be considered as surgical training methods evolve.





REV 5.6.0 DTD ■ WNEU19611_proof ■ 27 October 2022 ■ 2:56 pm ■ ce

**Table 2.** Outcome Data for the Included Studies at 12-Month Follow-Up

| | Li et al.[9] | | | Du et al.[33] | | | Xue et al.[10] | | |
|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **ER** | **Comparison** | ***P*** | **ER** | **Comparison** | ***P*** | **ER** | **Comparison** | ***P*** |
| VAS | 0.69 ± 1.00 | 5.38 ± 1.26 | <0.011 | - | - | - | 3.69 ± 1.13 | 5.36 ± 1.38 | <0.001 |
| McNab score ("excellent" and "good" rate) | 97.80% | 0% | | - | - | - | 96.70% | 70% | 0.006 |
| Relief of pain (%) | 90.82 ± 13.05 | 22.25 ± 11.96 | <0.01 | - | - | - | - | - | - |
| NRS | - | - | - | 3.7 ± 1.3 | 5.5 ±1.7 | <0.001 | - | - | - |
| ODI | - | - | - | 40.5 ± 9.9 | 58.1 ± 10.6 | <0.001 | - | - | - |
| PGIC | - | - | - | 2.1 ± 0.9 | 2.9 ± 1.0 | <0.05 | | | |
| Postoperative complications | - | - | - | - | - | - | 2* | 9† | 0.002 |

*P* values represent the difference between ER and comparison outcomes, not compared with initial baseline.
ER, endoscopic rhizotomy; VAS, visual analog scale; NRS, numeric pain rating scale; ODI, Oswestry Disability Index; PGIG, Patient Global Impression of Change.
*One case of analgesia and 1 case of total loss of skin sensation.
†Six cases of analgesia and 3 cases of total loss of skin sensation.

A unique consideration to include in our discussion is the difference between 2 types of ER, conventional ER and 3D navigated ER (3DNER). According to Jentzsch et al., "in contrast to conventional rhizotomy, 3DNER enables the surgeon to ablate more precisely and extensively, which is especially useful if scar tissue is present from previous injuries or surgeries." [42] 3DNER is presumed to be a safer procedure with longer-lasting pain relief, which could lessen the financial burden on patients through decreased morbidity and decreased repeated medical interventions.[43] However, 3DNER has a far higher equipment cost with minimally increased operating time compared with conventional ER. Morbidity-related costs are believed to be decreased with 3DNER, so determining long-term cost differences between these 2 surgical approaches has proven difficult.[42]

Private companies who manufacture endoscopic surgical kits often provide educational programs and training simulations for clients. RIWOspine offers full-endoscopic spine surgery training modules including basic training, intensive training, or master class training to provide physicians with different levels of simulation in endoscopic spinal surgery.[44] Elliquence provides ER educational webinars to assist physicians in building their endoscopic skill set.[45] MaxMoreSpine hosts conferences and workshops with hands-on cadaveric training and provide educational videos and preceptorships that involve individualized training that can be conducted at the client's home institution.[46] Joimax offers a 3-step training program including (1) visitation, where the client participates in surgical operations; (2) a hands-on workshop providing step-by-step training in the surgical techniques; and (3) first surgery: operating on a patient. Joimax also offers the "EndoTrainer Plus," a simulator for endoscopic procedures with virtual fluoroscopic imaging and realistic feedback.[47]

## Patient Selection Criteria

Determining which patients would benefit from ER and what specific contraindications exist with this procedure remain to be fully elucidated. However, drawing on previous research on endoscopic minimally invasive spinal procedures, case reports of ER, and literature reviews, certain factors should be considered for each patient. Chronic low back pain continues to be a very difficult condition to treat; many different pathologies lend themselves to the clinical presentation of chronic low back pain. When deciding whether to treat CBP with ER, pain control should be managed medically at first. If adequate pain control is not achieved medically, then surgical intervention should be considered.[8] Guidelines on the duration of medical treatment before surgical intervention are not strict, but some studies have based inclusion criteria on refractory lower back pain that has been resistant to physical therapy and NSAID treatment for longer than 2 months.[10] Other studies have suggested more rigorous nonsurgical treatment, such as opioids and even neurobehavioral and biopsychosocial rehabilitation, before operative intervention.[48] Clinical judgment should be used to determine how well-controlled an individual's pain is medically, as well as the likelihood that continued medical treatment will result in improved pain control.

Once it has been determined that a patient's current medical regimen is not providing adequate relief, careful consideration needs to be taken in the approach to anatomic pathology of the CBP.[8,38] Patients who have structural changes to the FJ have been shown to respond to ER.[8] Some of these pathologies include FJ hypertrophy, FJ arthritis, osteophytes, the intra-articular vacuum phenomenon, and spinal trauma.[8,10,49] Other studies have reported the successful use of rhizotomy in patients with a clear neurovascular insult in cranial nerve diseases such as glossopharyngeal neuralgia and vagoglossopharyngeal neuralgia.[50] However, the benefit of rhizotomy has been studied more frequently in patients with chronic low back pain due to pathologies resulting from FJ structural changes.

A patient with FJ structural changes causing CBP or believed to be a significant contributor to pain should be assessed for response to spinal nerve blockade.[8,49] FJ





REV 5.6.0 DTD ■ WNEU19611_proof ■ 27 October 2022 ■ 2:56 pm ■ ce

infiltration has not been shown to be an adequate standalone treatment option (blockade, steroids) but can serve as a diagnostic tool to explore the etiology of CBP. FJ infiltration also can be used as a tool to predict pain control from ER intervention.[8] To be considered a good candidate for ER, a patient should receive adequate control of pain within 3 hours of anesthetic blocking agent administration.[8] If FJ structural changes are the suspected etiology of CBP and FJ infiltration with blockade provides adequate pain relief, the patient should be considered a potential candidate for ER.

Specific contradictions toe ER that have been described include anticoagulation and negative preoperative infiltrating testing.[8] Other pathologies, such as disc herniation, tumor, metastatic disease, or evidence of active osteomyelitis, are contraindications as well.[8] Patients should not describe lower limb paresthesia or numbness, or saddle paresthesia or incontinence, which suggest further pathologies other than joint structural changes.[10] Previous surgical intervention on the spine is not a contraindication for ER to treat CBP. In addition, patients who underwent prior percutaneous rhizotomy are still eligible for and can benefit from an endoscopic approach.[48] In fact, previous percutaneous rhizotomy was found to have no bearing on the success or complication rates of future ER for low back pain.[48] As well as not being a contraindication for ER, prior spine surgery has no impact on the outcome of future ERs; furthermore, a prior ER is not a contraindication for a future ER. Prior endoscopic transforaminal foraminoplasty for lumbar stenosis and previous spinal fusion also are not considered contraindications to ER, although the data are limited.[38]

Benefits and potential harms must be weighed in each patient individually. Additional nerve injury and blood vessel injury can occur with this operation; sensorimotor deficits and ultimate exacerbation of the CBP are also possible.[8] Proper patient selection is crucial for favorable outcomes. If a patient has failed medical management, shows FJ structural changes, has good response to FJ infiltration, and otherwise has no other contradictions, ER could be effective in treating their chronic low back pain.

### Clinical Outcomes

Owing to the recency of this surgical technique, the body of evidence directly comparing ER and RFA is limited. Nevertheless, through a literature search, we identified 3 studies that directly compared ER to comparison interventions (Table 1).[9,10,33] All 3 studies were cohort studies conducted in China and featured a maximum follow-up of 12 months. Each study required >80% symptom relief with DMB blockage prior to inclusion. Various outcome measures related to pain and disability were recorded; however, retreatment rate was not, likely because of the maximum follow-up duration. Overall patient populations ranged from 55 to 60 in the 3 studies. Visual analog scale scores were measured in 2 studies (Table 2), both of which showed a significant decrease with ER relative to the comparison interventions at 12 months. McNab scores at 12 months were also measured in 2 studies, and pooled "excellent" and "good" rates of 97.8% and 96.7% were achieved in the ER cohort. In one of these studies, the comparison intervention consisted of conservative therapy (NSAIDs, physical therapy, etc.), which achieved a pooled "excellent" and "good" rate of 0%, and in the other study, the comparison intervention was RFA, which achieved a rate of 70%. Twelve-month relief of pain (%), numeric pain rating scale, Oswestry Disability Index, Patient Global Impression of Change, and postoperative complications were recorded in one study. All these outcome measures showed a significant improvement with ER relative to the comparison treatment (Table 2). In the study that recorded postoperative outcomes,[10] the 2 complications that resulted from ER were lack of skin sensation in the surrounding surgical site and analgesia. These same complications were experienced in the RFA cohort; however, more complications were observed in the latter cohort, in both number and percentage of the overall cohort. Overall, these studies provide an optimistic view of patient outcomes with ER that may improve with continued adoption and refined techniques; however, there remains a lack of data to definitively predict patient outcomes compared with alternative treatments.

## LIMITATIONS

The main limitation of the present study is the lack of primary literature on ER and its place in neurosurgical pain management. Owing to the recency of this technique, only 3 control trials have been reported to date, and these trials lack the granular detail needed to accurately assess all facets of patient outcomes. The lack of comparisons with other rhizotomy techniques is also a limitation, owing to the dearth of primary data on the topic. Head-to-head comparisons of traditional percutaneous RFA, ER with VR, and 3DNER are not possible without more research.

## CONCLUSIONS

ER is an increasingly used minimally invasive procedure for the treatment of CBP refractive to conservative therapies. Recent advancements are rapidly improving the efficacy and outcomes of this procedure owing to its unique ability to directly visualize regional anatomy. ER costs approximately 4 times more than traditional RFA for the treatment of LFJP, due to the cost of training, longer intraoperative time (almost twice that of RFA), and special equipment used during the procedure (especially for 3DNER). However, long-term outcomes appear superior to those of RFA, with a median pain-free duration twice that of RFA. Owing to the recency of this technique, there is still a paucity of literature detailing patient outcomes compared with traditional treatments; therefore, future clinical trials are required for a thorough assessment of this novel treatment and its place in surgical pain management.

## REFERENCES

1. Deyo RA, Tsui-Wu YJ. Descriptive epidemiology of low-back pain and its related medical care in the United States. *Spine (Phila Pa 1976)*. 1987;12:264-268.

2. Violante FS, Mattioli S, Bonfiglioli R. Low-back pain. *Handb Clin Neurol*. 2015;131:397-410.

3. Shmagel A, Foley R, Ibrahim H. Epidemiology of chronic low back pain in US adults: data from the 2009-2010 National Health and Nutrition Examination Survey. *Arthritis Care Res (Hoboken)*. 2016;68:1688-1694.

4. Dhillon KS. Spinal fusion for chronic low back pain: a "magic bullet" or wishful thinking? *Malays Orthop J*. 2016;10:61-68.

5. Waddell G. Subgroups within "nonspecific" low back pain. *J Rheumatol*. 2005;32:395-396.

6. Patrick N, Emanski E, Knaub MA. Acute and chronic low back pain. *Med Clin North Am*. 2014;98: 777-789.

7. Dowell D, Haegerich TM, Chou R. CDC Guideline for prescribing opioids for chronic pain—United States, 2016. *MMWR Recomm Rep*. 2016;65:1-49.

8. Walter SG, Schildberg FA, Rommelspacher Y. Endoscopic sacrolumbar facet joint denervation in osteoarthritic and degenerated zygapophyseal joints. *Arthrosc Tech*. 2018;7:e1275-e1279.

9. Li ZZ, Hou SX, Shang WL, Song KR, Wu WW. Evaluation of endoscopic dorsal ramus rhizotomy in managing facetogenic chronic low back pain. *Clin Neurol Neurosurg*. 2014;126:11-17.

10. Xue Y, Ding T, Wang D, et al. Endoscopic rhizotomy for chronic lumbar zygapophysial joint pain. *J Orthop Surg Res*. 2020;15:4.

11. Yeung A, Gore S. Endoscopically guided foraminal and dorsal rhizotomy for chronic axial back pain based on cadaver and endoscopically visualized anatomic study. *Int J Spine Surg*. 2014;8:23.

12. Russo M, Santarelli D, Wright R, Gilligan C. A history of the development of radiofrequency neurotomy. *J Pain Res*. 2021;14:3897-3907.

13. Sandes JD. "Trench back" treated by sodium salicylate ionization. *Br Med J*. 1915;2:215-216.

14. Stucky R. *Say Goodbye to Back Pain: A Simple, Effective, Safe Procedure for Chronic Back Pain*. Melbourne, Australia: Hill of Content Publishing Company; 1994.

Q5 15. Rees WS. *A Dissertation on the Relief of Pain*. 1990.

16. Shealy CN. *Miracles Do Happen: A Physician's Experience with Alternative Medicine*. London: HarperCollins Publishers Ltd; 1995.

17. Shealy CN. Facets in back and sciatic pain. A new approach to a major pain syndrome. *Minn Med*. 1974;57:199-203.

18. Shealy CN. Percutaneous radiofrequency denervation of spinal facets. Treatment for chronic back pain and sciatica. *J Neurosurg*. 1975;43:448-451.

19. The University of Newcastle, Australia. Emeritus Professor Nikolai Bogduk. Available at: https://www.newcastle.edu.au/profile/nik-bogduk. Accessed March 15, 2022.

20. Bogduk N. Proceedings: the lumbosacral dorsal rami of the monkey and dog. *J Anat*. 1974;118(Pt 2):393-394.

21. Bogduk N. The lumbosacral dorsal rami of the cat. *J Anat*. 1976;122(Pt 3):653-662.

22. Bogduk N. The clinical anatomy of the cervical dorsal rami. *Spine (Phila Pa 1976)*. 1982;7:319-330.

23. Bogduk N. Lumbar dorsal ramus syndrome. *Med J Aust*. 1980;2:537-541.

24. Bogduk N, Wilson AS, Tynan W. The human lumbar dorsal rami. *J Anat*. 1982;134(Pt 2):383-397.

25. Bogduk N, Long DM. The anatomy of the so-called "articular nerves" and their relationship to facet denervation in the treatment of low-back pain. *J Neurosurg*. 1979;51:172-177.

26. Bogduk N, Long DM. Percutaneous lumbar medial branch neurotomy: a modification of facet denervation. *Spine (Phila Pa 1976)*. 1980;5:193-200.

27. Yeung A. *Endoscopic medial branch and dorsal ramus rhizotomy for chronic axial back pain: a pilot study. Presented at: International 25th Jubilee Course on Percutaneous Endoscopic Spine Surgery and Complementary Techniques*. 2007. Zurich, Switzerland.

28. Joimax. MultiZYTE; 2022. Available at: https://www.joimax.com/us/products/pain-therapy/multizyte/; 2022. Accessed February 27, 2022.

29. RIWOspine. Vertebris lumbar; 2022. Available at: https://www.riwospine.com/en/products/full-endoscopic-spine-surgery/vertebris-lumbar/; 2022. Accessed February 27, 2022.

30. MaxMoreSpine. Mini endoscopic system; 2022. Available at: https://www.max-more.com/products/mini-endoscopic-system/; 2022. Accessed March 1, 2022.

31. Manchikanti L, Boswell MV, Singh V, Pampati V, Damron KS, Beyer CD. Prevalence of facet joint pain in chronic spinal pain of cervical, thoracic, and lumbar regions. *BMC Musculoskelet Disord*. 2004;5:15.

32. Freburger JK, Holmes GM, Agans RP, et al. The rising prevalence of chronic low back pain. *Arch Intern Med*. 2009;169:251-258.

33. Du T, Lu G, Li J, et al. Pain-free survival after endoscopic rhizotomy versus radiofrequency for lumbar facet joint pain: a real-world comparison study. *Pain Physician*. 2022;25:E87-E94.

34. Leclaire R, Fortin L, Lambert R, Bergeron YM, Rossignol M. Radiofrequency facet joint denervation in the treatment of low back pain: a placebo-controlled clinical trial to assess efficacy. *Spine (Phila Pa 1976)*. 2001;26:1411-1417.

35. van Wijk RM, Geurts JW, Wynne HJ, et al. Radiofrequency denervation of lumbar facet joints in the treatment of chronic low back pain: a randomized, double-blind, sham lesion-controlled trial. *Clin J Pain*. 2005;21:335-344.

36. Smuck M, Crisostomo RA, Trivedi K, Agrawal D. Success of initial and repeated medial branch neurotomy for zygapophysial joint pain: a systematic review. *PM R*. 2012;4:686-692.

37. Kim MH, Kim SW, Ju CI, Chae KH, Kim DM. Effectiveness of repeated radiofrequency neurotomy for facet joint syndrome after microscopic discectomy. *Korean J Spine*. 2014;11:232-234.

38. Yue JJ, Long W. Full endoscopic spinal surgery techniques: advancements, indications, and outcomes. *Int J Spine Surg*. 2015;9:17.

39. Li Y, Brodlie K, Phillips N. Web-based VR training simulator for percutaneous rhizotomy. *Stud Health Technol Inform*. 2000;70:175-181.

40. John NW, Phillips NI, Cenydd L, et al. The use of stereoscopy in a neurosurgery training virtual environment. *Presence (Camb)*. 2016;25:289-298.

41. El-Khalili N. Surgical Training on the World Wide Web. April 1999. PhD thesis, University of Leeds. Available at: https://www.academia.edu/56129898/Surgical_Training_on_the_World_Wide_Web. Accessed XXX. Q7

42. Jentzsch T, Sprengel K, Peterer L, Mica L, Werner CM. 3D navigation of endoscopic rhizotomy at the lumbar spine. *J Clin Neurosci*. 2016;23: 101-105.

Q6

43. Skovrlj B, Gilligan J, Cutler HS, Qureshi SA. Minimally invasive procedures on the lumbar spine. *World J Clin Cases*. 2015;3:1-9.

44. RIWOspine. Education and training; 2022. Available at: https://www.riwospine.com/en-us/physicians/education/; 2022. Accessed March 21, 2022.

45. Elliquence. Endoscopic rhizotomy educational webinars; 2022. Available at: https://www.elliquence.com/rhizotomywebinars/; 2022. Accessed March 21, 2022.

46. MaxMoreSpine. Education; 2022. Available at: https://www.max-more.com/education/; 2022. Accessed March 21, 2022.

47. Joimax. Education program; 2022. Available at: https://www.joimax.com/en/education-workshops/; 2022. Accessed March 21, 2022.

48. Meloncelli S, Germani G, Urti I, et al. Endoscopic radiofrequency facet joint treatment in patients with low back pain: technique and long-term results. A prospective cohort study. *Ther Adv Musculoskelet Dis*. 2020;12, 1759720X20958979.

49. Huang SJ, Hsiao MC, Lee JH, Chen CM. How I do it? Full endoscopic lumbar rhizotomy for chronic facet joint pain due to failed back surgery syndrome. *Acta Neurochir (Wien)*. 2022;164:1233-1237.

50. Blue R, Spadola M, McAree M, Kvint S, Lee JY. Endoscopic microvascular decompression for vagoglossopharyngeal neuralgia. *Cureus*. 2020;12: e12353.

*Conflict of interest statement: The authors declare that the article content was composed in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.*

*Received 3 August 2022; accepted 6 October 2022*

*Citation: World Neurosurg. (2022). https://doi.org/10.1016/j.wneu.2022.10.020*

*Journal homepage: **www.journals.elsevier.com/world-neurosurgery***

*Available online: **www.sciencedirect.com***