Prospective Study

Pain-Free Survival After Endoscopic Rhizotomy Versus Radiofrequency for Lumbar Facet Joint Pain: A Real-World Comparison Study

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Background: Endoscopic rhizotomy (ER) of the medial branch has been recently developed for the treatment of lumbar facet joint pain (LFJP). However, there are no studies comparing the pain-free duration after ER and radiofrequency (RF).

Objectives: To evaluate the long-term outcomes for pain and physical function in patients who underwent ER versus RF for LFJP and compare their pain-free survival.

Study Design: Open label, prospective, real-world study that includes patients treated with ER or RF at a single center between November 2017 and February 2020.

Setting: The research took place within a single university-based neuro-spine center.

Methods: Patients with a positive diagnostic medial branch block (≥ 80% pain relief) were treated with ER or RF. Numeric rating scale (NRS), Oswestry Disability Index (ODI), and Global Impression of Change (GIoC) were obtained at the baseline, and at 6 months and 12 months postoperatively. The duration of pain-free time was recorded at every follow-up. The final follow-up was conducted in March 2021.

Results: Of 55 patients with LFJP, 19 underwent ER, and 36 underwent RF. Both ER and RF groups showed significant decreases in NRS and ODI scores at 6 months and 12 months compared with baseline ($P < 0.001$). ER had significantly better efficacy than RF in NRS, ODI, and GIoC scores at 6 and 12 months ($P < 0.05$). The pain-free survival curves showed that the median pain-free duration was 20 months and 10 months in ER and RF, respectively.

Limitation: Patients were not randomized to different groups, which may have led to bias.

Conclusions: Both ER and RF can improve the pain and physical function in patients with LFJP. ER is associated with a longer operative duration and medical expenses; however, it provides more sustained efficacy than RF. The surgical choice should depend on the patients' specific conditions.

Key words: Low back pain, facet joint, medial branch, endoscopic, rhizotomy, radiofrequency, pain-free survival, real-world study

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According to a worldwide study in 2019, low back pain (LBP) features among the top 10 conditions in the Global Burden of Disease and is comparable to heart disease, diabetes, and cancer (1). Various anatomical structures such as muscles, ligaments, fascia, nerves, interverbal disc, and joints can be responsible for LBP. About 27% to 41% of chronic LBP is understood to originate from traumatic or degenerative lumbar facet joints (2,3). The nociceptive signals produced by these joints were transmitted by 2 medial branches of the dorsal ramus of the spinal nerve. Based on the anatomy, radiofrequency (RF) denervation of medial branches following a positive diagnostic block is the commonly used procedure for lumbar facet joint pain (LFJP) (2,4).

Health services research reported that the facet joints interventions and their expenditures were significantly increased in the United States, especially in RF (4,5). Traditional medial branch RF had a high recurrence rate within 12 months, which is always required for repeated interventions (6-9). To extend the duration of pain relief, various techniques have emerged for more sufficient coagulation of nerves, such as cooled RF, 2-needle RF technique, and parallel electrode approaches (10-12). In the past 2 decades, the endoscopic technique has shown advantages in minimally invasive spine surgery, which could magnify the tiny spinal structures in aqueous medium. This technique allowed for a new approach for denervation of facet joints, to directly visualize the medial branch under an endoscope and perform a thorough rhizotomy.

Several studies have evaluated the outcomes of endoscopic rhizotomy (ER) for the treatment of LFJP (13-16). Of these, although one study compared the efficacy between ER and RF (16), the duration of pain relief after the 2 procedures was not discussed. To address this lack of data, we conducted a real-world study to compare the pain-free survival after ER and RF measured by the Global Impression of Change (GIoC), as well as to compare the improvement of pain and physical function in individuals with LFJP.

Methods

Study Design

The study was approved by the local institutional ethics committee. All patients provided written informed consent.

Patients were enrolled between November 2017 and February 2020 at a single medical center. The inclusion criteria were: 1) patients referred to our clinic with chronic LBP of more than 6 months' duration, which was unresponsive to conventional treatment including nonsteroidal anti-inflammatory drugs, opioids, muscle relaxants, or physical therapy; 2) suspected LFJP screened by pain pattern, physical exams, and imaging studies; and 3) positive response to single diagnostic medial branch block with ≥ 80% reduction in LBP with local anesthetic (0.5-1 mL of 0.5% lidocaine). The exclusion criteria were: 1) symptomatic lumbar disc herniation, 2) untreated coagulopathy, 3) inability to complete rating scales, 4) cognitive dysfunction, and 5) psychiatric illness.

The patients were divided into 2 groups: ER and RF. For patients with recurrent pain from previous medial branch RF and those with a history of pedicle screw fixation, ER was recommended. For patients < 60 years of age, RF was suggested (Fig. 1).

Procedure

Patients were positioned prone on a radiolucent fluoroscopy table. Pillows were placed under the upper abdomen to allow the lumbar spine to be moderately flexed. Under the C-arm radiographic guidance, the entry points and target points were marked on the skin. For L1-L4 medial branches, the puncture route was 15-30-degree lateral to the target point to avoid blocking by the superior articular process (SAP). For the L5 dorsal ramus, the puncture route was vertical to the target to avoid blocking by the posterior superior iliac spine. After disinfection by iodophor, the skin was anesthetized by 2-3 mL of 1.0% lidocaine.

For patients who were treated by ER, a puncture needle was introduced at the junction of the transverse process (TP) and the SAP. Once a satisfactory needle position was confirmed, the guidewire was inserted, and a skin incision measuring about 8-mm wide was made. The soft tissue was dilated by soft tissue dilators step by step, and the working cannula was inserted. After placing in the endoscope, the soft tissue covering the bone surface was cleared by endoscopic bipolar radiofrequency and grasper. The medial branches were identified based on 2 aspects: the morphology and direction of the nerves and the stimulus response by bipolar radiofrequency. Then, the medial branch was thoroughly dissected using a bipolar radiofrequency or scissors (Fig. 2). After retracting the endoscopy and cannula, the skin incision was stitched using an endothelial suture.

For patients treated with RF, the 20-gauge introducer needle was placed at the same position as the ER. Sensory (100 Hz) and motor (2 Hz) testing was performed at each target site, and the stimulus threshold generally did not exceed 2V. Then, the RF lesions were performed for 120 s at 80°C at each site.

Clinical Evaluation

Clinical evaluation was administrated by an independent interviewer who was blind to the patients' assigned treatment group. Demographic data and procedure characteristics, including age, gender, pain duration, surgical history, fluoroscopy time, operative duration, and medical expenses were collected. The

Numeric Rating Scales (NRS) and Oswestry Disability Index (ODI) scores were obtained before diagnostic block. During the follow-up, NRS, ODI, and GIoC scores were obtained at the intervals of 6 and 12 months after the procedure. GIoC included 7 ranks ranging from 1 to 7 (1 = very much improved; 2 = moderately improved; 3 = slightly improved; 4 = no change; 5 = slightly worsened; 6 = moderately worsened; 7 = very much worsened). If a patient underwent reoperation because of recurrence of pain within the 6- or 12-month follow-up, the surveys were obtained before the reoperation and were accounted for in 6- and 12-month follow-up, respectively. To evaluate long-term clinical outcomes and plot pain-free survival curves, every follow-up also recorded the pain-free duration, which was described as "very much improved" or "moderately improved" in the GIoC. The final follow-up was conducted in March 2021 (Fig. 1). The annual medical expense was defined as medical expenses per procedure (in USD)/median pain-free duration (year).

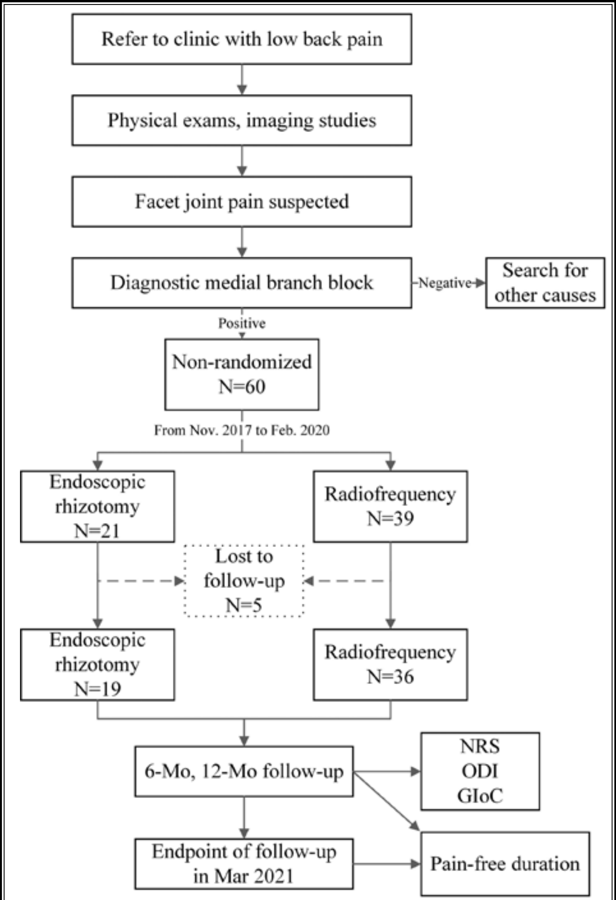

Fig. 1. *Study flowchart.*
NRS = numeric rating scales; ODI = Oswestry Disability Index; GIoC = Global Impression of Change.

Statistical Analysis

Demographic data were compared between groups using t-test, Pearson's chi-squared test, Yates' correction test, or Fisher's exact test. Changes in NRS and ODI within and between groups were analyzed by independent t-tests. The GIoC between groups was analyzed by Mann-Whitney U test. Kaplan-Meier analysis was used for comparison of pain-free survival between groups, and the difference was analyzed by the Mantel-Cox test.

Results

Of the 60 patients enrolled in this study, 5 were lost to follow-up. The remaining 19 patients who underwent ER and 36 patients who underwent RF were administered complete clinical evaluation.

The descriptive statistics of demographic data and procedure characteristics are summarized in Table 1. The ER group was significantly older, had a longer duration of pain, and a more frequent surgical history than the RF group ($P < 0.05$). With no significant difference in denervated joints, ER required less fluoroscopy time but more operative duration and medical expenses than RF ($P < 0.05$).

No serious adverse events (infection, hemorrhage, lower limb dysfunction) were reported in either group. Table 2 shows the changes in NRS, ODI, and GIoC scores in the 12-month follow-up. Both ER and RF groups showed significant decreases in NRS and ODI scores at 6 months and 12 months compared with the baseline scores ($P < 0.001$). Based on the NRS and ODI scores, ER showed significantly better effectiveness than RF at 6 months ($P < 0.05$); this difference was more dramatic at 12 months ($P < 0.001$). The GIoC scores also showed better benefits after ER than RF at 6 months and 12 months ($P < 0.05$).

Figure 3 shows the individual responses in NRS and ODI scores at 6 months and 12 months after intervention, quantified by percent change from the baseline values. A ≥ 50% NRS reduction was observed in 89.5% and 30.6% of patients at 6 months ($P < 0.001$), and 52.6% and 16.7% of patients at 12 months ($P < 0.05$) in the ER and RF groups, respectively. A ≥ 30% ODI reduction was observed in 89.5% and 55.6% of patients at 6 months ($P < 0.05$), and 78.9% and 13.9% of patients at 12 months ($P < 0.001$), in ER and RF, respectively.

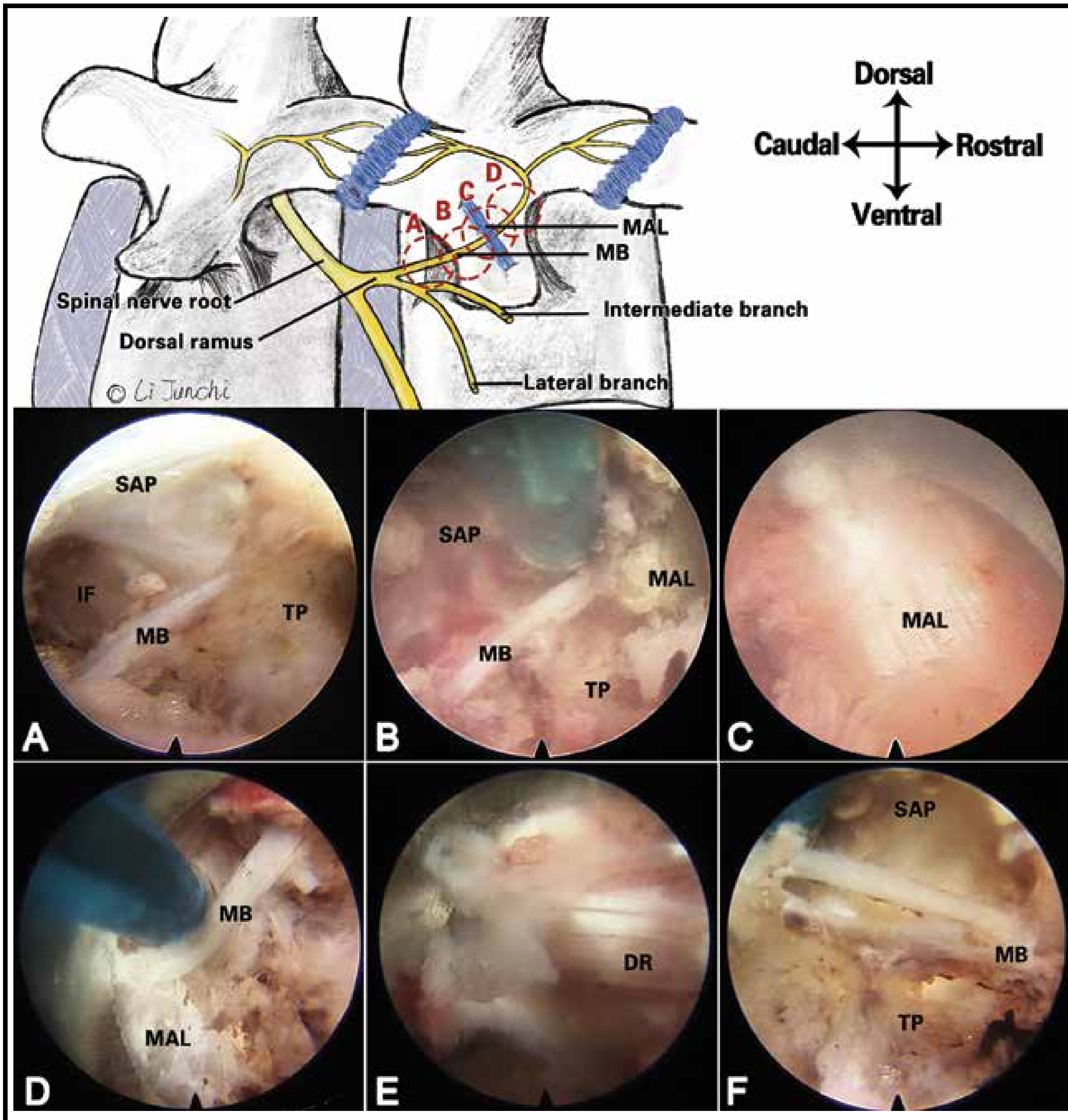

Fig. 2. *Atlas and endoscopic picture of left-sided MB. A) MB exiting from the intervertebral foramen. B) MB entering MAL. C) MAL. D) MB exiting from MAL. E) Dorsal ramus from L5, which is not further divided into MB, is generally thicker than MB from L1-L4. F) Anatomy variations: twin MB.*
MB: medial branch, IF: intervertebral foramen. SAP: superior articular process. TP: transverse process. MAL: mamillo-accessory ligament. DR: dorsal ramus.

With a mean 25.8 (12-39) months of follow-up duration, the Kaplan-Meier plot shows the pain-free survival of ER and RF (Fig. 4). The initial success was absolute (100%) in both groups. However, the pain-free rate declined as the follow-up time increased. The survival curves indicate a more sustained treatment effect in the ER group than the RF group, with a median pain-free duration of 20 months and 10 months, respectively. The Cox-Mantel test revealed statistically significant differences between groups ($P < 0.001$). The annual medical expenses calculated by pain-free duration were USD 2,378.4 and USD 1,174.9 for ER and RF, respectively.

Discussion

In this real-world study involving 55 patients with LFJP, both ER and RF notably improved the pain and physical function. ER showed a more sustained treatment effect than RF, with a median pain-free duration of 20 months and 10 months.

RF is a thermal ablative technique that has been used for several decades to treat LFJP with good effect in carefully selected patients. The pain-relief duration is significant related to the selection threshold of diagnostic block and the number of denervated facet joints: strictly threshold or multiple lesions may provide better efficacy (3). However, studies have reported high recurrence rates within the 1-year follow-up (2,6,7,9,17,18), which was consistent with our results. Gofeld reported a 9-month median pain-relief duration among 174 patients treated with RF (18). A systematic review based on 16 articles found that the pain relief after initial RF generally ends after 7-9 months (19). The success of repeated RF suggests that the regeneration of MB contributes to the recurrence of low back pain (8,20,21). In recent years, although more RF techniques have been developed to cope with insufficient coagulation of MB, they still cannot avoid regeneration of these nociceptive nerve fibers (10-12,22).

Endoscopic technique provides a magnified view of spine structures, such as intervertebral foramen, TP, SAP, and mamillo-accessory ligaments, which help locate the target (Fig. 2). The MB can be identified by combining the fluoroscopy image, nerve visualization, and bipolar radiofrequency stimuli response. Thus, ER can provide precise and complete rhizotomy of MB, which largely prevents insufficient coagulation or regeneration of the nerve.

Table 1. ***Demographic data and procedure characteristics.***

	Endoscopic rhizotomy (n = 19)	Radiofrequency (n = 36)	*P* value
Demographic data			
Age (years)	75.5 ± 8.3	68.9 ± 12.3	< 0.05
Men/Women	8/11	18/18	0.577†
Duration of pain (years)	8.4 ± 4.3	5.7 ± 3.1	< 0.05
Follow-up duration (months)	25.6 ± 10.0	25.9 ± 9.2	0.916
MB radiofrequency history (%)	8 (42.1)	5 (13.9)	< 0.05‡
Pedicle screw fixation history (%)	5 (26.3)	1 (2.8)	< 0.05‡
Procedure characteristics			
Denervated joints (No.)	2.1 ± 0.5	2.3 ± 1.0	0.366
No. (%)			
1 (unilateral)	1 (5.3)	6 (16.7)	0.435‡
1 (bilateral)	8 (42.1)	7 (19.4)	0.072†
2 (unilateral)	9 (47.4)	15 (41.7)	0.685†
2 (bilateral)	1 (5.3)	8 (22.2)	0.217‡
Fluoroscopy time (s)	19.2 ± 5.8	27.8 ± 10.6	< 0.05
Operative duration (min)	61.9 ± 12.9	35.4 ± 7.6	< 0.001
Medical expenses (USD)	3964.0 ± 154.9	979.1 ± 99.0	< 0.001
Underwent reoperation within 6-month follow-up (%)	0 (0)	2 (5.6)	0.539§
Underwent reoperation from 6- to 12-month follow-up (%)	1 (5.3)	10 (27.8)	0.103§

Values represent mean ± SD or No. (%); Statistics were based on independent t-test unless†‡§; †From Pearson's chi-squared test; ‡From Yates' correction test; §From Fisher's exact test; MB, medial branch.

Table 2. ***Baseline and postoperative NRS, ODI, and GIoC scores.***

	Endoscopic rhizotomy	Radiofrequency	*P* value
NRS			
Baseline	7.6 ± 1.1	7.4 ± 1.0	0.461
6 months	2.9 ± 1.4*	4.6 ± 2.2*	< 0.05
12 months	3.7 ± 1.3*	5.5 ± 1.7*	< 0.001
ODI			
Baseline	71.5 ± 7.7	67.9 ± 6.6	0.077
6 months	35.8 ± 9.8*	46.9 ± 13.0*	< 0.05
12 months	40.5 ± 9.9*	58.1 ± 10.6*	< 0.001
GIoC			
6 months	1.6 ± 0.7	2.3 ± 0.8	< 0.05†
12 months	2.1 ± 0.9	2.9 ± 1.0	< 0.05†

Values are mean ± SD; *Compared with baseline, the difference was significant ($P < 0.001$); The statistics were based on an independent t-test unless†; †From Mann-Whitney test; NRS, Numeric Rating Scales; ODI, Oswestry Disability Index; GIoC, Global Impression of Change.

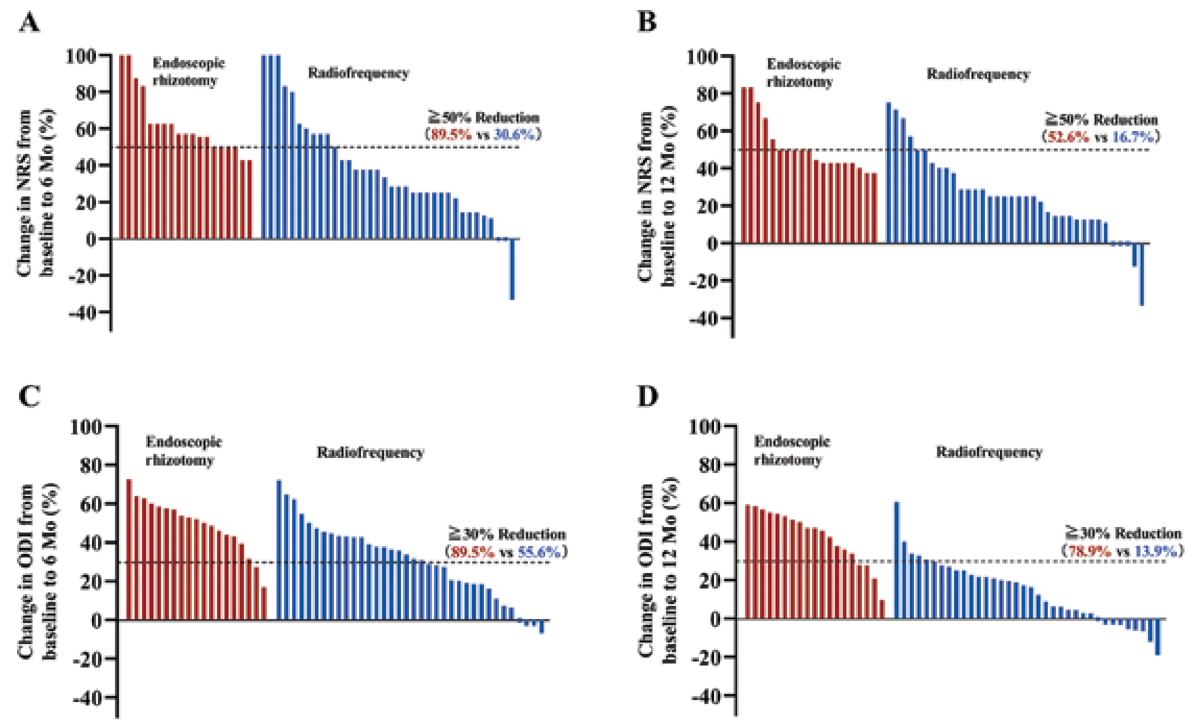

Fig. 3. *The waterfall plot presents individual responses in the Numeric Rating Scale (NRS) and Oswestry Disability Index (ODI) scores at the 6-month and 12-month follow-up after intervention, quantified by percent change from the baseline values. The percentage of patients who experienced ≥ 50% reduction in NRS or ≥ 30% reduction in ODI between groups were significantly different at both the 6- and 12-month follow-up ($P < 0.05$).*

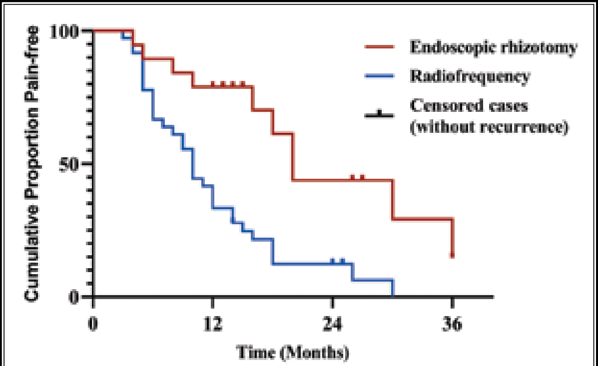

Fig. 4. *Kaplan-Meier plot presents pain-free survival of endoscopic rhizotomy and radiofrequency. The median pain-free duration is 20 months and 10 months, respectively. The difference between the 2 survival curves is obvious ($P < 0.001$).*

Previous studies have demonstrated the feasibility and efficacy of ER for the treatment of LFJP (13-16,23,24). Our study showed that the median pain-free duration for ER was twice that for RF. The functional improvement was also more sustained in ER than RF, with 78.9% of patients in ER experiencing a ≥ 30% reduction in ODI at 12 months (vs. 13.9% of patients in RF). Although MB is thoroughly dissected during ER, there were still several patients who had pain recurrence in the long-term follow-up, wherein the pain must have likely originated from degenerated lumbar discs, muscles, ligaments, or other undenervated facet joints.

In this real-world study, the surgical option was determined according to specific patient conditions. For patients with pedicle screw fixation history, ER was the preferred option for 2 main reasons. First, there are situations where the tip of the RF cannula is overlapped by metallic hardware in the fluoroscopic image, which may affect the accuracy of identifying the target. Second, a cadaver study showed that if an RF cannula is adjacent to or in direct contact with a pedicle screw, there is a risk of transmission of heat through the metallic hardware, causing thermal injury to the surrounding structures (25-27). Meanwhile, the heat dissipation may lead to insufficient coagulation of the target nerve. By comparison, the endoscopic system not only relies on fluoroscopic images but also enables a user to see the surgical field in real-time and maintain distance from the metallic hardware. Besides, the temperature of bipolar radiofrequency is maintained under 42°C, which can avoid thermal injury transmitted by the metallic hardware. ER is also preferred in patients with early recurrence followed by RF owing to the guaranteed efficacy of the former.

There are some limitations of using ER to treat LFJP. It is well-known that MB not only conducts nociception of the facet joints but also innervates the motor function of multifidus muscles. Morphologic studies reveal that the multifidus muscle's segmental architecture enables it to produce intersegmental stabilizing forces of the spine (28). Thus, thorough rhizotomy of MB may permanently reduce the stability of the vertebral column, which is not recommended in younger patients. Besides, there is still a significant learning curve with endoscopic spine surgery that requires more operative duration than RF, even with proficient skills.

Limitations

There were several limitations in this study. First, due to the nature of the real-world study, the patients were not randomized to different groups, which may have led to bias. However, even with older age and longer pain duration of patients who received ER, it still provides more sustained efficacy. Second, the present study used a single set of positive MB diagnostic blocks (≥ 80% pain relief) instead of controlled dual MB blocks to enroll the patients. Although controlled dual blocks tend to decrease the false-positive rate, some data have suggested that increasing the threshold of a positive response to a single MB block not only results in a higher positive predictive value but also reduces the overall cost (29,30). However, this paradigm may prevent some of the patients from undergoing the procedure that could provide treatment benefit. Third, this study did not evaluate the potential effect of ER and RF on spine instability, which merits further investigation in future studies.

Conclusion

Both ER and RF can improve the pain and physical function in patients with LFJP. Although ER is associated with more operative duration and medical expenses, it also provides more sustained efficacy than RF. The surgical option should be determined according to specific patient conditions.

References

1. GBD 2019 Diseases and Injuries Collaborators. Global burden of 369 diseases and injuries in 204 countries and territories, 1990-2019: a systematic analysis for the global burden of disease study 2019. *Lancet* 2020; 396(10258):1204-1222.
2. Manchikanti L, Kaye AD, Soin A, et al. Comprehensive evidence-based guidelines for facet joint interventions in the management of chronic spinal pain: American Society of Interventional Pain Physicians (ASIPP) guidelines facet joint interventions 2020 guidelines. *Pain Physician* 2020; 23(3S):S1-S127.
3. Manchikanti L, Kosanovic R, Pampati V, et al. Low back pain and diagnostic lumbar facet joint nerve blocks: Assessment of prevalence, false-positive rates, and a philosophical paradigm shift from an acute to a chronic pain model. *Pain Physician* 2020; 23:519-530.
4. Manchikanti L, Pampati V, Soin A, et al. Trends of expenditures and utilization of facet joint interventions in fee-for-service (FFS) medicare population from 2009-2018. *Pain Physician* 2020; 23:S129-S147.
5. Manchikanti L, Sanapati MR, Pampati V, et al. Update of utilization patterns of facet joint interventions in managing spinal pain from 2000 to 2018 in the us fee-for-service medicare population. *Pain Physician* 2020; 23:E133-E149.
6. 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.
7. 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.
8. 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.
9. 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.
10. McCormick ZL, Choi H, Reddy R, et al. Randomized prospective trial of cooled versus traditional radiofrequency ablation of the medial branch nerves for the treatment of lumbar facet joint pain. *Reg Anesth Pain Med* 2019; 44:389-397.
11. Chapman KB, Schirripa F, Oud T, Groenen PS, Ramsook RR, van Helmond N. Two-needle technique for lumbar radiofrequency medial branch denervation: A technical note. *Pain Physician* 2020; 23:E507-E516.
12. De Andrés Ares J, Gilsanz F. Randomized pragmatic pilot trial comparing perpendicular thin electrode versus

parallel thick electrode approaches for lumbar medial branch neurotomy in facetogenic low back pain. *Pain Pract* 2020; 20:889-907.
13. Xue Y, Ding T, Wang D, et al. Endoscopic rhizotomy for chronic lumbar zygapophysial joint pain. *J Orthop Surg Res* 2020; 15:4.
14. Walter SG, Struwe C, Scheidt S, et al. Endoscopic facet joint denervation for treatment of chronic lower back pain. *Clin Neurol Neurosurg* 2020; 195:105904.
15. 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; 12:1759720X-2095897X.
16. Song K, Li Z, Shuang F, et al. Comparison of the effectiveness of radiofrequency neurotomy and endoscopic neurotomy of lumbar medial branch for facetogenic chronic low back pain: A randomized controlled trial. *World Neurosurg* 2019; 126:e109-e115.
17. Royal MA, Bhakta B, Gunyea I, et al. Radiofrequency neurolysis for facet arthropathy: A retrospective case series and review of the literature. *Pain Pract* 2002; 2:47-52.
18. Gofeld M, Jitendra J, Faclier G. Radiofrequency denervation of the lumbar zygapophysial joints: 10-year prospective clinical audit. *Pain Physician* 2007;10:291-300.
19. 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.
20. Schofferman J, Kine G. Effectiveness of repeated radiofrequency neurotomy for lumbar facet pain. *Spine (Phila Pa 1976)* 2004; 29:2471-2473.
21. Rambaransingh B, Stanford G, Burnham R. The effect of repeated zygapophysial joint radiofrequency neurotomy on pain, disability, and improvement duration. *Pain Med* 2010; 11:1343-1347.
22. Sagir A, Bolash R. Combined bipolar and v-shaped lesions for lumbar facet radiofrequency ablation: A technical report. *Pain Med* 2021; pnab136.
23. Jentzsch T, Sprengel K, Peterer L, Mica L, Werner CML. 3d navigation of endoscopic rhizotomy at the lumbar spine. *J Clin Neurosci* 2016; 23:101-105.
24. Woiciechowsky C, Richter LM. Endoscopic 4-mhz radiofrequency treatment of facet joint syndrome is more than just denervation: One incision for three facets. *J Neurol SurgA: Cent Eur Neurosurg* 2020; 81:238-242.
25. Gazelka HM, Welch TL, Nassr A, Lamer TJ. Safety of lumbar spine radiofrequency procedures in the presence of posterior pedicle screws: Technical report of a cadaver study. *Pain Med* 2015; 16:877-880.
26. Ellwood S, Shupper P, Kaufman A. A retrospective review of spinal radiofrequency neurotomy procedures in patients with metallic posterior spinal instrumentation - is it safe? *Pain Physician* 2018; 21:E477-E482.
27. Lamer TJ, Smith J, Hoelzer BC, Mauck WD, Qu W, Gazelka HM. Safety of lumbar spine radiofrequency procedures in patients who have posterior spinal hardware. *Pain Med* 2016; 17:1634-1637.
28. Ward SR, Kim CW, Eng CM, et al. Architectural analysis and intraoperative measurements demonstrate the unique design of the multifidus muscle for lumbar spine stability. *J Bone Joint Surg Am* 2009; 91:176-185.
29. Cohen SP, Stojanovic MP, Crooks M, et al. Lumbar zygapophysial (facet) joint radiofrequency denervation success as a function of pain relief during diagnostic medial branch blocks: A multicenter analysis. *Spine J* 2008; 8:498-504.
30. Schwarzer AC, Aprill CN, Derby R, Fortin J, Kine G, Bogduk N. The false-positive rate of uncontrolled diagnostic blocks of the lumbar zygapophysial joints. *Pain* 1994; 58:195-200.