Asymmetrical atrophy of the paraspinal muscles in patients undergoing unilateral lumbar medial branch radiofrequency neurotomy

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Abstract

Lumbar medial branch radiofrequency neurotomy (RFN), a common treatment for chronic low back pain due to facet joint osteoarthritis (FJOA), may amplify paraspinal muscle atrophy due to denervation. This study aimed to investigate the asymmetry of paraspinal muscle morphology change in patients undergoing unilateral lumbar medial branch RFN. Data from patients who underwent RFN between March 2016 and October 2021 were retrospectively analyzed. Lumbar foramina stenosis (LFS), FJOA, and fatty infiltration (FI) functional cross-sectional area (fCSA) of the paraspinal muscles were assessed on preinterventional and minimum 2-year postinterventional MRI. Wilcoxon signed-rank tests compared measurements between sides. A total of 51 levels of 24 patients were included in the analysis, with 102 sides compared. Baseline MRI measurements did not differ significantly between the RFN side and the contralateral side. The RFN side had a higher increase in multifidus FI ($+4.2\%$ [0.3-7.8] vs $+2.0\%$ [-2.2 to 6.2], $P = 0.005$) and a higher decrease in multifidus fCSA (-60.9 mm^2 [-116.0 to 10.8] vs -19.6 mm^2 [-80.3 to 44.8], $P = 0.003$) compared with the contralateral side. The change in erector spinae FI and fCSA did not differ between sides. The RFN side had a higher increase in multifidus muscle atrophy compared with the contralateral side. The absence of significant preinterventional degenerative asymmetry and the specificity of the effect to the multifidus muscle suggest a link to RFN. These findings highlight the importance of considering the long-term effects of lumbar medial branch RFN on paraspinal muscle health.

Keywords: Back pain, Radiofrequency neurotomy, Medial branch, Multifidus, Facet joint

1. Introduction

Lumbar facet interventions rank as the second most performed procedures in interventional pain management in the United States, while utilization of lumbar medial branch radiofrequency neurotomy (RFN) had an annual increase of 9.7% between 2007 and 2016, with an overall increase of 130.6%, and an accompanying growth in cost.[12,18] The indication for lumbar medial branch RFN is typically chronic low back pain that is resistant to conservative treatment and confirmed to be caused by facet joint osteoarthritis (FJOA) by a positive response to a facet joint block.

Radiofrequency neurotomy is typically achieved through percutaneous insertion of an electrode, which induces a thermal lesion along the medial branch of the dorsal ramus. Ablation of this nerve branch can successfully provide pain relief as it contains afferent pain fibers originating from the facet joint.[3,22] However, as this nerve branch also contains efferent fibers that innervate the surrounding multifidus muscle (**Fig. 1**), the procedure causes a denervation of the muscle, as evident in altered EMG activity following RFN.[5,20] While reporting on acute loss of muscle function following RFN is limited to a single case report of an acute head-drop following cervical RFN,[21] localized lumbar multifidus muscle dysfunction was reported in patients who have undergone RFN.[15] However, whether this denervation has any long-term effects on muscle morphology and function is a concern and presently disputed.[9] In the literature, there is increasing evidence showing a positive correlation between atrophy of the lumbar paraspinal musculature, comprising the multifidus and erector spinae muscles, and degenerative parameters of the spine such as facet joint arthropathy,[25] and disk degeneration,[7] indicating an involvement of the muscular envelope in the degeneration of the spinal motion segment.[2,25]

Therefore, the question of whether RFN procedures may be achieving temporary symptomatic improvement while inadvertently accelerating the degenerative cascade of the spine is justified and requires attention in the literature. Expanding our knowledge on the long-term implications of iatrogenic damage to the medial branch of the dorsal ramus will have implications in spine surgery as well, as screw-based techniques are shown to lead to transection of the medial branch.[14] Therefore, in this study, we aim to analyze whether the paraspinal muscles

Figure 1. Shared innervation of the multifidus muscle and the facet joints by the medial branch of the dorsal ramus. Illustrative representation of the branches of the dorsal ramus at an exemplary lumbar level, based on cadaveric studies.[1,20] The dorsal ramus gives rise to the medial branch which innervates the facet joints and the multifidus muscle and also to the intermediate and the lateral branches which innervate the erector spinae muscle. *Site of medial branch radio-frequency ablation. AB, articular branches; DR, dorsal ramus; ES, erector spinae muscle; IB, intermediate branch; LB, lateral branch; M, multifidus muscle; MD, medial branch; SA, sagittal axis; SN, spinal nerve; VR, ventral ramus.

undergo asymmetrical degeneration in patients who receive unilateral lumbar medial branch RFN. We hypothesized that the multifidus muscle will undergo greater atrophy on the RFN side, compared with the contralateral side.

2. Materials and methods

2.1. Patient population

This is a single-center, retrospective longitudinal analysis. Patients who underwent unilateral lumbar medial branch RFN from March 2016 to October 2021 had both a lumbar MRI scan within 6 months before and over 2 years after the RFN procedure and had no history of lumbar spinal surgery were queried from our institution's electronic medical records system. Patients were excluded if they had a degenerative scoliosis of over 20°, underwent RFN on the contralateral side before or within the examined timeframe, reported no improvement of lower back pain symptoms following RFN, and those with MRIs not performed at our institution. All patients underwent RFN under fluoroscopy guidance. Radiofrequency neurotomy success was assessed by significant pain improvement as reported by the patient in the follow-up visit. Recorded demographic and procedural data included age, sex, body mass index (BMI), duration of chronic

low back pain, side of RFN procedure, ablated levels, and the number of repeated ablations within the study timeframe. Approval of the hospital's institutional review board (IRB) was obtained before patient query and data collection (#2019-2137).

2.2. MRI assessment

All MRI scans were performed on a 1.5 or 3.0 T MRI system (GE Healthcare, Chicago, IL) using standardized imaging protocols at our institution. Facet joint osteoarthritis was graded at all lumbar levels (L1 to S1) on pre-RFN axial T2-weighted MRI scans, according to the Weishaupt classification, which grades the facet joints from 0 to 3, taking into account degenerative changes such as joint space narrowing, osteophytes, hypertrophy, subarticular sclerosis, and subchondral cysts with a substantial intrarater agreement and a moderate interrater agreement.[23] Lumbar foraminal stenosis (LFS) was graded on pre-RFN sagittal T2-weighted MRI scans according to the Lee classification, which was reported to have a nearly perfect intrarater and interrater agreement.[11] The gradings were performed by a physician researcher (A.G.), who was blinded to the side of RFN. The erector spinae and multifidus muscles were segmented bilaterally on T2-weighted MRI scans using dedicated software (ITK SNAP version 3.8.0; www.itksnap.org). The segmentations were performed at the axial mid-disk plane at all lumbar levels caudal to the uppermost ablated level (eg, in a patient who underwent RFN of the L3, L4, and L5 nerves, the L4-L5 and L5-S1 levels were segmented). This methodology was previously reported[17] and is in accordance with the innervation pattern of the multifidus muscle.[1]

Using a previously published method, the fat area of the segmented muscle was calculated using custom software (MATLAB version R2019a, The MathWorks, Inc, Natick, MA) which uses pixel intensity threshold automation and classifying pixels above and below the threshold as fat and muscle, respectively.[13] The fatty infiltration (FI) was calculated by dividing the fat area by total muscle area (ie, cross-sectional area) for each muscle and reported in percentage. The functional cross-sectional area (fCSA) was calculated by subtracting the fat area from the cross-sectional area and reported in mm^2.

2.3. Statistical analyses

Statistical analyses were performed using R-Studio version 2022.12.0 (Posit Software, Boston, MA). The Shapiro–Wilk test was used for assessing normality of all continuous parameters. Non-normally distributed parameters were reported as median and interquartile range (IQR), and normally distributed parameters were reported as mean ± standard deviation. All paraspinal muscle parameters were reported as median (IQR), regardless of distribution, to achieve comparability. The Wilcoxon signed-rank test was used to compare the MRI gradings and measurements between the RFN and contralateral sides. The Wilcoxon signed-rank test was also used for comparing muscle measurements between the 2 time points. Statistical significance was defined as $P < 0.05$ for all analyses.

3. Results

3.1. Demographics and degenerative asymmetry

A total of 79 patients were identified by the query. Of these 31 patients who received RFN on the contralateral side, 19 patients who had a lumbar scoliosis over 20 degrees Cobb angle were excluded. Among the remaining patients, 4 who had no pain

Table 1

Demographic data in patients who underwent unilateral lumbar medial branch radiofrequency neurotomy.

Variable	(n = 24)
Age	61.7 ± 12.2
Sex (female/male)	12/12
BMI	29.5 ± 6.5
Duration of pain (y)	3.0 (2.0-8.5)
Side of RFN (right/left)	14 (58.3%)/10 (41.7%)
Branches ablated	
L1	0 (0.0%)
L2	5 (20.8%)
L3	22 (91.7%)
L4	24 (100%)
L5	24 (100%)
S1	1 (4.2%)
No. of ablations within timeframe	
1	14 (58.3%)
2	6 (25.0%)
3	4 (16.7%)

RFN, radiofrequency neurotomy.

improvement following RFN and 1 who had an external pre-RFN MRI were excluded. The demographic data for the 24 remaining patients are presented in **Table 1**. The median time between the preinterventional MRI and the RFN procedure was 1 month (IQR: 0-5). The mean time between RFN and postinterventional MRI was 37.8 ± 8.4 months. Preinterventional and follow-up MRIs were defined as time points 1 and 2, respectively. The total number of examined L3-L4, L4-L5, and L5-S1 levels were 5, 22, and 24, respectively, corresponding to a total of 51 analyzed levels and 102 sides compared. **Table 2** lists the FJOA and LFS grades of all lumbar levels for the RFN and contralateral sides. The highest FJOA and LFS grades were observed at the L4-L5 level bilaterally. The RFN and contralateral sides did not differ significantly in any of the degenerative parameters at time point 1.

3.2. Change in paraspinal muscle morphology

Table 3 presents the fCSA and FI of the erector spinae and multifidus muscles on preinterventional MRI and the change at the 2-year follow-up MRI. Baseline paraspinal muscle measurements did not differ significantly between sides. The change in the erector spinae fCSA and FI until time point 2 did not differ significantly between the sides. The RFN side had a significantly greater decrease in multifidus fCSA of $-$60.9 mm^2 (IQR: $-$116.0 to 10.8), compared with the contralateral side with $-$19.6 mm^2 (IQR: $-$80.3 to 44.8) ($P = 0.003$). The RFN side had a greater increase in multifidus FI of 4.2% (IQR: 0.3-7.8), compared with the contralateral side with 2.0% (IQR: $-$2.2 to 6.2) ($P = 0.005$).

Compared with the contralateral side at time point 2, the RFN side had a significantly higher FI of the multifidus (55.4% [IQR: 43.2-63.3] vs 50.0% [IQR: 39.8-58.7], $P < 0.001$) and erector spinae muscles (45.1% [IQR: 36.9-51.5] vs 41.9% [IQR: 34.7-48.0], $P = 0.005$), as well as a lower multifidus fCSA (527 mm^2 [IQR: 359.0-709.6] vs 533.1 mm^2 [IQR: 440.1-768.6], $P = 0.004$). Erector spine fCSA did not differ between sides at time point 2 with 765.4 mm^2 (IQR: 491.75-978.9) and 775.7 mm^2 (IQR: 549.1-1179.7) on the RFN and contralateral sides, respectively.

Comparisons between time points 1 and 2 revealed a significantly higher multifidus FI at time point 2 on both the RFN side (55.4% [IQR: 43.2-63.3] vs 50.9% [IQR: 39.5-60.1], $P < 0.001$) and on the contralateral side (50.0% [IQR: 39.8-58.7] vs 47.9% [IQR: 36.6-58.2], $P = 0.047$). Compared with time point 1, at time point 2, the RFN side had a lower multifidus fCSA (527 mm^2 [IQR: 359.0-709.6] vs 609.5 mm^2 [IQR: 403.5-801.9], $P < 0.001$) and a higher erector spinae FI (45.1% [IQR: 36.9-51.5] vs 40.8% [IQR: 33.7-50.2], $P = 0.003$). Erector spinae fCSA did not differ between time points on the RFN side ($P = 0.236$). There was no difference in the contralateral side multifidus fCSA ($P = 0.097$), erector spinae fCSA ($P = 0.491$), or erector spinae FI ($P = 0.130$) between the 2 time points.

4. Discussion

Paraspinal muscle denervation following lumbar medial branch RFN was previously reported in the literature,[20] but the long-term changes in paraspinal muscle morphology in patients undergoing this procedure have not been fully explored. Our findings show a significantly higher increase in multifidus atrophy on the RFN side compared with the contralateral side with a greater increase in FI and a greater decrease in fCSA. Moreover, the sides did not differ significantly in the net change of their erector spinae muscle parameters, although the RFN side had a significant increase in erector spinae FI unlike the contralateral side.

Table 2

Baseline degenerative asymmetry in patients who underwent unilateral radiofrequency neurotomy.

Variable	RFN side (N= 51)	Contralateral side (N= 51)	P
Facet joint osteoarthritis grade			
L1-L2	0 (0-1)	0 (0-1)	0.233
L2-L3	1 (0-1)	1 (0-1)	0.424
L3-L4	1 (0-1.3)	1 (0-1)	0.374
L4-L5	2 (1-2.3)	2 (1-2.3)	0.766
L5-S1	1 (1-2)	1 (1-2)	0.073
Total	5 (4-7)	5.5 (3-7.3)	0.798
Lumbar foraminal stenosis grade			
L1-L2	0 (0-0)	0 (0-0)	1
L2-L3	0 (0-0)	0 (0-0)	0.773
L3-L4	0 (0-1)	0 (0-1)	0.233
L4-L5	1 (0.8-2)	1 (0.8-2)	0.299
L5-S1	0.5 (0-1)	1 (0-2)	0.067
Total	2.5 (1-4)	3 (2-4)	0.159

RFN, radiofrequency neurotomy.

Table 3

Radiographic paraspinal muscle measurement changes in patients undergoing unilateral radiofrequency neurotomy.

Muscle measurements	RFN (N = 51)	CONT (N = 51)	P*
Erector spinae fCSA (mm^2)	731.4 (549 to 1017.05)	852.6 (518.4 to 1102.05)	0.539
Change	−11.2 (−133.4 to 67.6)	−14.2 (−137.5 to 83.5)	0.663
Erector spinae FI (%)	40.8 (33.7 to 50.2)	40.6 (32.6 to 48.7)	0.232
Change	+3.7 (−1.0 to 6.3)	+2.0 (−3.2 to 5.5)	0.279
Multifidus fCSA (mm^2)	609.5 (403.5 to 801.9)	619.2 (423.95 to 842.8)	0.133
Change	−60.9 (−116.0 to 10.8)	−19.6 (−80.3 to 44.8)	0.003†
Multifidus FI (%)	50.9 (39.5 to 60.1)	47.9 (36.6 to 58.2)	0.085
Change	+4.2 (0.3 to 7.8)	+2.0 (−2.2 to 6.2)	0.005†

* Wilcoxon signed-rank test.
† Significant.
CONT, contralateral side; fCSA, functional cross-sectional area; FI, fatty infiltration; RFN, radiofrequency neurotomy side.

The fact that the difference in muscle atrophy change between the sides is muscle-specific indicates that the cause may lie in compromised innervation, given the distinct innervation pattern of the paraspinal muscles. The multifidus muscle receives segmental innervation from the medial branch of the dorsal ramus, with all fascicles of the muscle that originate from the spinous process and lamina of a vertebra receiving innervation exclusively from the level of that specific vertebra. By contrast, the iliocostalis and longissimus muscles, which constitute the erector spinae muscle group, receive innervation from the lateral and intermediate branches of the dorsal ramus, respectively, with the latter forming plexus-like communicating loops between branches, allowing for multisegmental innervation.[1,16] Although there is no information in the literature on whether the intermediate and lateral branches are spared by the RFN procedure despite their proximity to the medial branch because RFN specifically targets the medial branch, the erector spinae muscle is not expected to be denervated by the procedure (**Fig. 1**). Cohen et al. challenge this anatomical inference in their consensus guidelines for facet joint pain, pointing out that strong contractions of the erector spinae muscle are observed in some patients during motor testing during the RFN procedure and that the erector spinae may therefore also be denervated during RFN.[3] However, a recent electromyography (EMG) study reports co-contraction of the erector spinae and multifidus muscles on motor testing with intramuscular electrodes,[10] which may explain the observation by Cohen et al.

Even in case of segmental denervation of the erector spinae, the multisegmental innervation pattern would be expected to render this muscle less susceptible to segment-specific compromise of innervation, as in the case of RFN. Therefore, the muscle-specific difference between the sides makes it more likely that RFN is the cause of the observed atrophy. One might argue that since all included patients had unilateral RFN to address predominantly unilateral symptoms, they must also have a degenerative correlate on the side of RFN which would cause the pain and also accelerate muscle degeneration. This notion is challenged by the fact that neither the paraspinal muscle measurements nor the degenerative parameters (FJOA and LFS) had a significant asymmetry in the preinterventional MRI assessment. Nevertheless, a definitive causal relationship between the RFN procedure and muscle atrophy cannot be concluded.

Our findings challenge the results from previous research. In an observational study by Dreyfuss et al.,[4] 3 blinded radiologists analyzed long-term postinterventional MRI scans of 5 patients who had undergone unilateral RFN. Despite documentation of multifidus muscle denervation through EMG and observed diffuse atrophy in these patients, the radiologists were unable to reliably determine the side and level where RFN was performed. Consequently, they concluded that the impact of RFN on muscle morphology is not easily discernible, casting doubt on the clinical significance of RFN-induced multifidus atrophy. However, the robustness of these conclusions is questionable, primarily due to the study's small sample size and the qualitative nature of the muscle assessment. In addition, the lack of preinterventional MRI scans in their analysis is a significant limitation, as it prevents a thorough comparison of muscle quality before and after the RFN procedure.

In a more recent retrospective study, Smuck et al. examined the changes in multifidus fCSA and other lumbar degenerative parameters such as FJOA and disk degeneration in patients who underwent unilateral or bilateral RFN.[17] Multifidus fCSA was assessed using a quantitative methodology involving thresholding, which is similar to our approach. They classified levels and sides as affected or unaffected by the RFN and found a significantly greater increase in disk degeneration at levels affected by RFN. However, despite observing a trend toward greater reduction in multifidus fCSA in the affected levels and sides, this trend did not reach statistical significance. The more pronounced difference in multifidus muscle changes between affected and unaffected sides in our study can be attributed to our stricter exclusion criteria.

We excluded patients with scoliosis exceeding a 20-degree lumbar curve, as scoliosis can cause significant muscle asymmetry, particularly increased multifidus FI on the concave side, and may have interfered with the outcome in the study by Smuck et al.[6,24] Moreover, our study also excluded patients who underwent a repeated RFN on the contralateral side within or before the imaging timeframe. It is common that bilateral RFNs are conducted in a staged fashion such that the ablation on the contralateral side is performed on a separate day, usually within 6 weeks of initial RFN. This is due to insurance plan restrictions or provider preference and was reported to be the case in 33.1% of patients undergoing RFN in the United States.[19] Not accounting for this would have potentially caused misclassification of sides in cases of staged bilateral RFNs. In our opinion, these exclusion criteria represent a significant strength of our study and were instrumental in revealing the reported outcomes. Further strengths were the use of paired statistical analysis which reduces sample variation, blinding of the examiner to side of procedure during measurement and grading of MRI parameters,

as well as the quantitative and validated methodology of paraspinal muscle FI and fCSA measurement.

Certain limitations to our study need to be acknowledged. First, given that only patients were included who had follow-up MRIs, this may have introduced a selection bias toward individuals requiring further diagnostic evaluation due to reasons such as worsening symptoms and progressing degeneration. In addition, although FJOA grading was shown to have better interrater and intrarater reliability on CT,[23] it was conducted on MRI scans, as CT images were not available in this nonoperative patient population. Furthermore, because of the exclusion criteria, the sample size was small, limiting statistical methods. Finally, it is important to note that the clinical implications of the observed increase in muscle atrophy are not known. Despite mounting evidence in the literature, showing the close link between multifidus atrophy and both degeneration of the lumbar spine and low back pain, it remains unclear whether muscle atrophy acts as a triggering factor for lumbar pathology, potentially through reduced stability and impaired proprioceptive feedback.[8] These limitations highlight the need for further prospective, longitudinal studies with broader inclusion criteria to validate and expand on our findings.

5. Conclusion

Patients who underwent unilateral lumbar medial branch RFN had a significantly higher long-term increase in FI and decrease in fCSA of the multifidus muscle, on the side of RFN compared with the contralateral side, despite lack of significant preinterventional degenerative asymmetry. Although direct causality cannot be concluded, long-term effects of lumbar medial branch RFN on paraspinal muscle health should not be ruled out. Larger studies with a prospective approach are needed to confirm our results and improve our understanding on the clinical implications of these findings.

Conflict of interest statement

The authors report no conflicts of interest concerning the materials or methods used in this study or the findings specified in this paper.

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