Lumbar Zygapophysial Joint Radiofrequency Denervation: a Long-Term Clinical Outcome Study

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Abstract Zygapophysial joint (z-joint) pain has long been suggested to be one of the sources of low back pain. Radiofrequency denervation of the medial branches of the dorsal rami to treat z-joint pain is an outpatient minimally invasive treatment option. There have been many short-term studies to determine the outcome of the procedure, but few long-term studies have been conducted. Our goal is to clarify whether radiofrequency denervation has any long-term clinical benefit. In this retrospective cohort study, a total of 42 patients (25 women and 17 men), with an average follow-up of 3.5 years, with clinical signs of zygapophysial joint involvement who had failed conservative treatment (pre-procedure symptom duration mean 6.03 years; range 5 months to 48 years) and had a favorable response to a diagnostic medial branch block or zygapophysial joint injection, were identified. The identified subjects underwent radiofrequency denervation at the Hospital for Special Surgery Physiatry Department from 1998 to 2006. Patient's records were reviewed, and a questionnaire was provided, completed on phone call follow-up, or mailed by the patient. The success of this intervention in providing improvement in pain and function was analyzed using the Numerical Rating Scale (NRS)—11, North American Spine Society (NASS) four-point satisfaction index, and a modified Roland–Morris Disability Questionnaire (RMDQ). Fifty-two percent of patients reported a successful outcome with improved function at a minimum follow-up period of 2 years (mean 3.5 years, range 2–8.8 years). Patients in the failure group were more

likely to be older and have moderate to severe neuroforaminal stenosis (77.8%) compared to patients in the success group (24.2%). Radiofrequency denervation in selected patients with chronic zygapophysial joint-mediated low back pain provides long-term reduction in pain and improved function with minimum morbidity.

Keywords radiofrequency denervation · facet joint · lumbar zygapophysial joint · back pain · neurotomy · diagnostic block

Introduction

Low back pain is the second most common reason for primary care visits annually [1]. Zygapophysial (z) joints have long been suggested to be one of the sources of low back pain [2–5]. In accordance with the criteria established by the International Association for the Study of Pain (IASP) [6], z-joints have been implicated as the source of lumbar pain in 15% to 45% of patients [7–11].

The medial branch of the primary dorsal rami of the spinal nerves is shown to be the primary innervation of z-joints [4, 12]. Giles and Harvey [13] also found that nerves within the z-joint contain substance P, which is considered to play a role in the nociceptive transmission of nerve impulses. Given that z-joints have proven to be a source of pain with definitive innervations, various methods have been used to treat patients presenting with this condition. Nonsurgical approaches to z-joint pain include relative rest, physical therapy, chiropractic care, acupuncture, oral analgesics, and fluoroscopic intra-articular z-joint steroid injections [14]. If pain relief is not produced by conservative measures, surgical techniques including pedicle screw fixation, z-joint translaminar fixation, and trans z-joint fixation are some of the more aggressive methods for treating this form of low back pain [14–16]. As with all invasive surgeries, these procedures carry the risk of

Level of Evidence: Level IV Retrospective Review

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infection, hemorrhage, long-term adverse effects, and complications associated with general anesthesia.

Intra-articular injections, medial branch blocks, and medial branch neurotomy are generally accepted as less invasive management options for z-joint pain [6]. The use of radiofrequency denervation of the medial branches of the dorsal rami to treat z-joint pain has been employed for over 30 years [17]. Over this time period, the technique and the guidelines have been fine-tuned to improve the outcomes of the procedure [18], and treatment algorithms have been designed to pinpoint specific patients who may benefit. Comparative diagnostic injections, when used with the appropriate guidelines, are the best method of diagnosing z-joint pain [18, 19]. Selective branch blocks at the medial branches of the dorsal rami and/or z-joint steroid with anesthetic injections are initially used to determine whether pain relief is produced. These diagnostic and therapeutic treatments preclude the use of the alternative, safer treatment of radiofrequency denervation (RFD).

In addition to diagnosis, these injections also improve the success rate of RFD by reducing the number of false-positive patients [20, 21]. These diagnostic injections have emerged because common imaging techniques [i.e., plain radiographs, magnetic resonance imaging (MRI), computed tomography (CT) and bone single-photon emission computed tomography (SPECT)] are unable to reliably predict patients with z-joint pain [22–24]. Although findings of z-joint involvement are common, radiologic studies demonstrate little correlation between abnormalities of z-joints on imaging and z-joint-mediated pain [22]. Multiple studies place doubt on the ability to diagnosis z-joint pain based on clinical features, further supporting the use of diagnostic blocks [8, 25, 26].

The application of radiofrequency to the medial branches supplying the z-joint has been suggested to relieve pain and discomfort [4, 27]. The denervation procedure involves the passage of RF current along the length of the cannula's active tip to generate heat into the surrounding tissues, effectively coagulating the targeted medial branch nerve [14, 28]. RFD in the lumbar spine is a safe procedure with rare associated complications (i.e., painful cutaneous dysesthesias, painful neuritis) [20] when applied to well-selected patients with lumbar z-joint pain, and can alleviate pain and improve function [20–29]. A review of the world's literature concludes that there is only moderate evidence that RFD is effective [20, 30]. Techniques and inclusion criteria have evolved over time. While there have been some retrospective as well as prospective studies [17, 19, 31–33, 34–36], few studied long-term outcome effects greater than 2 years. Gofeld et al., in a prospective study followed patients who underwent radiofrequency denervation for up to 24 months, reporting 42.8% with pain relief for 12–24 months and 2.4% with pain relief greater than 24 months. [37]. A retrospective controlled case series by North et al. [36] at a mean follow-up interval of 3.2 years reported 45% of patients with at least 50% pain relief.

In this study, we include 42 patients over a period of 8 years who have undergone RFD of the z-joint, with a follow-up period of at least 2 years. The aim of this study is

to gain long-term clinical information regarding the success of RFD and document clinical improvements using the Numerical Rating Scale (NRS)—11 [38], North American Spine Society (NASS) four-point satisfaction index [39], and the modified Roland–Morris Disability Questionnaire (RMDQ) [40]. We hope to further clarify whether RFD has any long-term beneficial clinical effect in patients with chronic low back pain.

Materials and methods

This retrospective chart review was performed in an outpatient physical medicine and rehabilitation center providing interventional spine care at Hospital for Special Surgery. Patients treated with RFD between 1998 and 2006 with at least 2 years between treatment and follow-up were identified from the database of procedures kept in our offices related to billing. Informed consent was obtained, and strict patient confidentiality was preserved under approval from the Institutional Review Board. Chronic low back pain patients (>3 months) who did not exhibit sustained relief from their moderate to severe pain with conservative treatment including oral analgesics, physical therapy, with or without epidural steroid injections were initially selected for medial branch blocks (MBB) and/or z-joint injections. Patients were asked for their pain level after 30 min following the MBB or z-joint injection. Patients with at least 50% pain reduction based on NRS scores were eligible candidates for RFD. Exclusion criteria included patients with (1) less than 2 years follow-up time, (2) radicular type pain below their knees, (3) radiologic evidence of a moderate to severe disc protrusion, and (4) a positive discogram. Patients with previous surgery were not excluded from the study. Charts were reviewed for demographic information and pre-procedure NRS scores.

Patients, 101, were identified by billing codes obtained from chart review as having undergone radiofrequency denervation of the medial branch of the dorsal rami for z-joint pain between 1998 and 2006. Thirty-four of the

Fig. 1. RFD AP radiograph with proper needle position. Needle tip is at the junction of the superior articular process and the transverse process

Table 1 Patient satisfaction index (North American Spine Society)

Score	
1	The treatment met my expectations.
2	I did not improve as much as I had hoped, but I would undergo the same treatment for the same outcome.
3	I did not improve as much as I had hoped, and I would not undergo the same treatment for the same outcome.
4	I am the same or worse than before treatment.

patients could not be contacted because their information was inaccurate, or they could not be reached. Ten subjects did not meet the inclusion criteria. The results of four subjects were excluded because they were poor historians and were not able to comprehend and answer the survey questions accurately. Seven subjects refused to participate in the study. Three subjects' charts were archived and unattainable. One subject's chart was incomplete and could not be used. In total, we enrolled 42 subjects with completed surveys and charts that were used for this study. There were 25 women (59.5%) and 17 men (40.5%).

Although there are various techniques described in the literature [41], RFD is an established technique with recommended guidelines established by the International Spine Intervention Society (ISIS) [18, 42]. The following procedure was performed after the patient met the inclusion criteria. No sedation was used during this procedure. In the prone position, under fluoroscopic guidance, a 20-gauge curved radiofrequency needle (Radionics, Burlington, MA, USA), with a 10-mm exposed tip, was advanced from a lateral inferior approach parallel to the target nerve at involved levels confirmed by MBB or z-joint injections. At each level, motor stimulation was carried out to obtain a motor response of the multifidus muscle equal to or less than one volt of energy. Patients were monitored for leg pain and lower limb muscle contractions during the radiofrequency stimulation to verify absence of contractions. Once the proper needle placement was obtained with anterior-posterior, lateral, and oblique fluoroscopic guidance and after the administration of local anesthesia, a radiofrequency current was administered at each level at 80° centigrade for 90 s (Fig. 1). Post-procedure, patients

Table 2 NRS and RMDQ pre-procedure vs. at follow-up (mean change of score)

Characteristic	Success outcome ^a (n=33)	Failure outcome ^b (n=9)	p-value
Mean change of score (post-pre)			
NRS Pain (NOW)	-1.73 (3.26)	0.333 (3.16)	0.099
NRS Pain (BEST)	-1.55 (2.76)	-1.67 (1.80)	0.902
NRS Pain (WORST)	-2.33 (3.21)	-1.22 (2.49)	0.343
Roland-Morris Questionnaire	-6.79 (5.74)	-0.44 (6.27)	<0.001

Significant at $p < 0.05$

^a Score of 1 or 2 on NASS-4

^b Score of 3 or 4 on NASS-4

Table 3 Patient demographics

Characteristic	Success outcome ^b (n=33) Mean (SD) or N (%)	Failure outcome ^c (n=9)	p-value ^a
Age (years) [Range]	58.8 (13.5) [27,81]	71.6 (14.2) [47,88]	0.017
Sex			
Male	11 (33.3%)	6 (66.7%)	0.071
Female	22 (66.7%)	3 (33.3%)	
Race			
White	31 (93.9%)	9 (100%)	0.751
Non-Hispanic Black	1 (3.0%)	0 (0%)	
Hispanic	1 (3.0%)	0 (0%)	
Pre-procedure duration of symptoms (years)	5.8 (7.5)	10.9 (17.7)	0.415
Duration of pain relief (days) [Range]	347.5 (403.2) ^d [0,1,764]	70.0 (125.7) [0,365]	0.056
Previous pain returned			
Yes	19 (57.6%)	9 (100%)	0.019 ^e
No	14 (42.4%)	0 (0%)	
Follow up time (years) [Range]	3.5 (1.8) [2.0,8.8]	3.4 (1.5) [2.2,6.6]	0.881

^a Significant at $p < 0.05$

^b Score of 1 or 2 on NASS-4

^c Score of 3 or 4 on NASS-4

^d n=19

^e Fisher's exact test used

were observed for any adverse effects and followed with a neurological examination.

Patients included in the study were presented with a questionnaire completed on phone call follow-up by an independent examiner or mailed by the patient. Patients were asked to complete the NRS from 0 (no pain) to 10 (worst pain), a NASS patient satisfaction index (Table 1), and a modified RMDQ to compare the amount of perceived pain and change in function pre-procedure to post-procedure at the time of follow-up. A score of 1 or 2 on the NASS patient satisfaction index was considered a successful response to the procedure. Patients also reported whether their previous pain returned and the duration of pain relief.

Table 4 Pre-procedure NRS and RMDQ

Characteristic	Success outcome ^a (n=33)	Failure outcome ^b (n=9)	p-value
Pre-procedure			
NRS Pain (NOW) [Range]	5.09 (2.17) [1,8]	4.67 (2.96) [0,8]	0.634
NRS Pain (BEST) [Range]	3.52 (2.55) [0,8]	3.78 (2.22) [0,6]	0.780
NRS Pain (WORST) [Range]	8.73 (0.94) [7,10]	8.89 (1.54) [6,10]	0.770
Roland-Morris Questionnaire (pre) [Range]	12.18 (5.74) [1,22]	9.56 (6.27) [3,20]	0.240

Significant at $p < 0.05$

^a Score of 1 or 2 on NASS-4

^b Score of 3 or 4 on NASS-4

Table 5 Degree of central and neuroforaminal stenosis

Characteristic	Success Outcome ^a (<i>n</i> =33)	Failure Outcome ^b (<i>n</i> =9)	p-value	OR	95% Confidence interval
Neuroforaminal stenosis					
None to mild	25 (75.8%)	2 (22.2%)	0.005	10.9	(1.88, 63.68)
Moderate to severe	8 (24.2%)	7 (77.8%)			
Central stenosis					
None to mild	24 (72.7%)	5 (55.6%)	0.323	2.1	(0.46, 9.77)
Moderate to severe	9 (27.3%)	4 (44.4%)			

Significant at $\alpha=0.05$ ^a Score of 1 or 2 on NASS—4^b Score of 3 or 4 on NASS—4

A two-point reduction on the NRS and a 30% improvement in the RMDQ score were considered significant. On review of the patient's MRI reports prior to RFD, the degree of central and neuroforaminal stenosis was recorded as mild, moderate, or severe.

Comparisons were made between the groups of failures and successes for differences in age, sex, race, pre-procedure duration of symptoms, duration of pain relief, location and severity of stenosis (neuroforaminal vs. central), pre-procedure and post-procedure NRS pain score and RMDQ. Data were analyzed using the software SPSS version 14.0 for Windows operating system. For dichotomous variables a Pearson chi-square test was conducted, and for continuous measures, an independent sample *t* test was conducted. Subsequent *p* values or Fisher's exact tests were recorded. Statistical significance was set at $p=0.05$.

Results

Seventy-eight percent of the subjects reported a successful outcome with a NASS of 1 or 2 at an average of 3.5 years follow-up (range 2–8.8 years). Of the subjects, 52% reported a NASS of 1 or 2 and demonstrated a 30% decrease in the

RMDQ. Thirty-eight percent reported a NASS of 1 or 2 and demonstrated a two-point reduction in the NRS pain score. There appears to be a very high association between a 30% reduction in the RMDQ and successful outcome ($\chi^2=8.810$, $p=0.003$). Subjects who had a 30% reduction in RMDQ score were 93.7% less likely to have a failure outcome compared to those who did not have a 30% reduction (OR=0.063, 95% CI=0.007, 0.565). There does not appear to be an association between any two-point reduction of NRS score (now, best, and worst) and success outcome. The change in NRS (Table 2) score decreased on an average of 1.73 [standard deviation (SD) of 3.26] in the success group compared to an increase by 0.33 (SD of 3.16) in the failure group ($p=0.099$). With respect to the RMDQ, the average decrease in scores of the success outcome group was 6.79 (SD of 5.74) compared to 0.44 (SD of 6.27) in the failure group ($p=0.001$).

When the demographic description of the patient population is sorted into success and failure, (Table 3) younger patients demonstrated a greater rate of success than older patients ($p=0.017$). The average age of the success outcome is 58.8, whereas the average age of the failure outcome is 71.6. In the success group, the average number of days of pain relief is 347.5 compared to 70 days in the

Table 6 Time to return of previous pain

Parameter			Success vs. failure		Total
			Success	Failure	
When pain returned (categorized) recoded	No pain returned	Count	14	0	14
		Percent within success vs. failure	42.4%	.0%	33.3%
	immediate to 3 months	Count	2	7	9
		Percent within success vs. failure	6.1%	77.8%	21.4%
	3 to 6 months	Count	6	1	7
		% within success vs. failure	12.1%	11.1%	11.9%
	12 to 24 months	Count	4	1	5
		Percent within success vs. failure	12.1%	11.1%	16.7%
	Greater than 24 months	Count	3	0	3
		Percent within success vs. failure	9.1%	.0%	7.1%
Total		Count	33	9	42
		Percent within success vs. failure	100%	100%	100%

Success vs. failure (cross-tabulation)

Table 7 Change in RMDQ (pre–post)

Parameter	Test value=0					
	<i>T</i>	<i>df</i>	Sig. (2-tailed)	Mean difference	95% Confidence interval of the difference	
					Lower	Upper
Percent change in RMDQ Score (pre–post)	5.324	16	0.000	0.62059	0.3735	0.8677
RMDQ change in score (pre–post)	5.247	16	0.000	9.47059	5.6440	13.2971

failure group ($p=0.056$). There were no differences between groups when looking at days to follow-up, pre-procedure duration of symptoms, gender, or ethnic background. There were no differences between success and failure groups in their pre-procedure RMDQ score or their pre-procedure NRS pain scales for now, best, and worst (Table 4). There were no reported complications following the procedure.

Patients in the failure group were more likely to have MRI evidence of moderate to severe neuroforaminal stenosis (77.8%; Table 5) compared to patients in the success group (24.2%; $p=0.005$; Table 4). There was not a statistically significant difference between the groups comparing the degree of central stenosis ($p=0.323$). Only 29% of patients (5 out of 17) who reported greater than 2 years pain relief, or no return of their previous pain, had MRI evidence of moderate to severe neuroforaminal stenosis.

Seventeen patients experienced greater than 2 years of pain relief (40.4%). There appears to be an association between successful outcome and delayed return of pain ($\chi^2=22.91$, $p<0.001$) (Table 6). Nine subjects (21.4%) reported pain return in 0–3 months, four subjects (9.5 percent) reported pain return in 3–6 months, seven subjects (16.7%) reported pain return in 6–12 months, five subjects (11.9%) reported pain return in 12–24 months, three subjects (7.1%) reported pain return >24 months, and 14 subjects (33.3%) reported no pain return. This association was also reflected in pre- and post-procedure RMDQ scores. Patients who reported pain relief greater than 2 years had a 30% reduction in RMDQ ($\chi^2=5.43$, $p=0.020$; Table 7). The 17 patients (40.4%) who reported greater than 2 years pain relief were 4.9 times more likely to have a 30% change in RMDQ (OR=4.88, 95% CI: 1.23, 19.32; Table 8). There was a significant association between patients who reported greater than 2 years pain relief and a two-point reduction in NRS-worst ($\chi^2=5.20$, $p=0.02$; Table 9). The 17 patients

were 4.5 times more likely to record at least a two-point reduction in NRS-worst when compared to patients with less than 24 months pain relief (OR=4.52, 95% CI: 1.19, 17.15).

Discussion

This retrospective cohort study analyzed the potential long-term benefits of RFD in patients with chronic low back pain of z-joint etiology. Within the success group, 51% of patients with chronic low back pain (mean time with pain 5.8 years; SD=7.5) at 2-year follow-up (mean 3.5 years, range 2–8.8 years) reported greater than 24 months of pain relief. To gain a more accurate account of successful outcomes, the data was further analyzed looking at what percentage of patients who reported being satisfied with the procedure (78%) demonstrated either a 30% reduction in the RMDQ or a two-point reduction in the NRS pain scale. There appears to be a very high association between a 30% reduction in the RMDQ and success outcome. Patients who had a 30% reduction in RMDQ score were 93.7% less likely to have a failure outcome compared to those who did not have a 30% reduction. When looking at patients who reported a score of 1 or 2 on the NASS scale, 52% of patients reported success in addition to demonstrating a 30% reduction in RMDQ on follow-up. Combining a score of 1 or 2 on NASS and a two-point reduction in NRS pain scale resulted in 38% success rate overall at 2 or more years follow-up. Of patients (out of 42 total), 40.4% reported greater than 2 years pain relief and were 4.9 times more likely to have a 30% change in RMDQ and 4.5 times more likely to record at least a two-point reduction in NRS—worst when compared to patients who reported less than 24 months of pain relief.

Table 8 Is change in RMDQ greater than 30%?

Parameter			<24 months pain relief	>24 months pain relief	Total
Is change in RMDQ greater than 30%?	No	Count	15	4	19
		Percent within no stated pain returned or had greater than 24 months of pain relief	60.0%	23.5%	45.2%
	Yes	Count	10	13	23
		Percent within no stated pain returned or had greater than 24 months of pain relief	40.0%	76.5%	54.8%
Total			25	17	42

Table 9 Is change in NRS—worst at least a two-point reduction?

Parameter			<24 months pain relief	>24 months pain relief	Total
Is change in NRS worst at least a 2 point reduction?	No	Count	19	7	26
		Percent within no stated pain returned or had greater than 24 months of pain relief	76.0%	41.2%	61.9%
	Yes	Count	6	10	16
		Percent within no stated pain returned or had greater than 24 months of pain relief	24.0%	58.8%	38.1%
Total			25	17	42

Partly explaining the discrepancy between patient's perceived satisfaction and reduction of pain on the NRS scale is the elapsed time between the end of therapeutic benefits of the procedure and the time of follow-up. Patients were asked to grade their pain as experienced at the time the questionnaire was completed at 2 or more years follow-up, and not during the time of their maximal period of pain relief. The rate of nerve regeneration and subsequent return of previous lower back pain symptoms following a radiofrequency denervation procedure is thought to be related to the procedure technique and whether correct anatomical placement of the cannula is achieved parallel to the involved nerve. As reported by Bogduk, prior to nerve regeneration following coagulation, repair of the nerve occurs in situ requiring a longer period of time than the 1 mm per month seen in nerve transection injuries. For this reason, contacting a longer area of the nerve coagulates a greater length of segment resulting in longer pain relief [26, 43].

We analyzed the role of neuroforaminal and central stenosis in predicting outcome in patients with z-joint mediated pain. Patients with moderate to severe neuroforaminal stenosis were more likely to report failure (77.8% versus 24.2% in the success group $p=0.005$). While there was a trend suggesting that patients with moderate to severe central canal stenosis did worse, it was not statistically significant (44.4% of failures with moderate to severe central stenosis versus 27.3% in the success group $p=0.323$). The trend for patients with moderate to severe neuroforaminal stenosis to experience less benefit from the procedure than patients with minimal or no stenosis can be explained anatomically. Severe z-joint arthrosis encroaches upon the neuroforaminal space and the nerve root one level above (Fig. 2). This, in turn, may cause irritation to the nerve root with resulting radiculitis and pain radiating in a dermatomal distribution. Lower back pain is multifactorial, and it may be difficult to quantitate the percentage of pain that is attributed to z-joint pathology alone. Schwarzer et al. estimated that isolated z-joint pain occurs in less than 4% of patients, based on complete relief from diagnostic blocks (average age of 38.4 years) [8]. Medial branch block diagnostic criteria for z-joint-mediated pain can reliably identify those patients who would most benefit from a RFD procedure. It may be presumed that patients who experience at least 50% pain relief after a diagnostic block have the other 50% of their pain attributed to spine pathology such as degenerative disc disease and neuroforaminal stenosis

causing nerve root irritation. Although we excluded patients who demonstrated physical exam findings of radicular pain and pain from degenerative disc disease, this exclusion process may not be definitive and may have included patients with early symptoms of lateral stenosis who have yet to exhibit radicular pain.

Nine out of 33 (27%) patients who reported success with their first radiofrequency procedure underwent a second procedure at an average time of 14.8 months (range 4–37 months) and reported relief of their symptoms for an average of 12.2 months (range 3 months to 3 years) prior to undergoing the second denervation procedure. It is generally accepted in the literature that relief after radiofrequency denervation typically lasts between 6 and 12 months [44], although it has been reported to provide relief for greater than 2 years [36]. Sustained relief of z-joint pain can be maintained by repeat radiofrequency denervation reported up to two and three times [26, 44].

Five patients reported having surgery following the procedure and one patient out of five reported dissatisfaction with the procedure. One patient underwent a lumbar laminectomy and fusion 5 months following radiofrequency denervation but stated that his previous pain did not return and that he was satisfied with the relief of pain obtained from the procedure. Another patient who reported success underwent scoliosis correction surgery with instrumentation from T3 to the sacrum 8 months following the denervation

Fig. 2. Axial T2-weighted MR image at the L4–5 disc level with bilateral z-joint arthrosis with right sided ligamentum flavum thickening causing effacement of the thecal sac

procedure, and another underwent surgery for removal of a z-joint cyst 1-year following surgery. The last patient who reported 3 months pain relief underwent a laminectomy and disectomy for central stenosis 21 months after the denervation procedure. It is difficult to make any definitive conclusions from this data as the sample size is small, but it is reasonable to assume that the radiofrequency procedure provided satisfactory pain relief in individuals who had multifactorial contributions to their chronic lower back pain.

Additional study limitations in this retrospective investigation include a small sample size, recall bias, lack of a control group as in any retrospective study, and selection bias. An additional bias may be introduced by completing telephone-questionnaires. Patients may be reluctant to report poor outcome secondary to their willingness to please members of the medical professional, even though data is analyzed by an independent reviewer. Another weakness lies in our inability to control for other treatments or procedures that could have contributed to the patient's overall improvement in function and pain by the time follow-up was obtained. In addition, some of the improvements seen may be attributable to spontaneous relief and/or placebo effect. These factors are inherent in any noncontrolled, retrospective study.

In conclusion, this retrospective clinical investigation supports the view that radiofrequency denervation in selected patients with chronic z-joint-mediated low back pain provides long-term reduction in pain and improved function with minimal procedural risk. To our knowledge, this is the only investigation reporting the negative predictive value of moderate to severe neuroforaminal stenosis seen on MRI. Future long-term prospective controlled clinical trials are warranted to establish more definitive conclusions.

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