Inciting Events Associated With Lumbar Facet Joint Pain

Charles A. Odonkor, MD,* Yian Chen, MD,† Peju Adekoya, MD,† Bryan J. Marascalchi, MD,†
Hira Chaudhry-Richter, MD,† Teresa Tang, MD,* Christopher Abruzzese, MD,†
Berklee K. Cohen,‡ and Steven P. Cohen, MD*†§||

BACKGROUND: Low back pain is the leading cause of years lost to disability with approximately 15%–25% of the chronic back pain population suffering from lumbar facet arthropathy. No large-scale study has sought to systematically identify inciting events for lumbar facet arthropathy. The aim of this study is to quantify the proportion of individuals with lumbar facetogenic pain who report a specific precipitating event(s) and to determine if there is a correlation between these events and treatment outcome.

METHODS: Institutional electronic medical records were searched based on the current procedural terminology (CPT) codes representing lumbar facet joint radiofrequency ablation for procedures performed between January 2007 and December 2015. All patients had obtained ≥50% pain relief based on 6-hour pain diaries after 1 or more diagnostic facet blocks. A positive outcome was defined as ≥50% pain relief sustained for longer than 3-month after procedure, without additional procedural interventions.

RESULTS: One thousand sixty-nine people were included in analysis. In the 52% of individuals who described an inciting event, the most commonly reported causes were falls (11%), motor vehicle collisions (11%), sports-related injuries (11%, of which weightlifting accounted for 62%), nonspine postsurgical injuries (2%), and "other" (17%). Six hundred seventeen (57.7%) individuals experienced ≥50% pain relief sustained for >3 months. Patients whose pain was preceded by an inciting event were more likely to have a positive outcome than those who could not recall a specific precipitating factor (odds ratio, 1.5; confidence interval, 1.02–2.1, $P = .01$). Another factor associated with outcome was shorter duration of pain (8.1 ± 9.2 vs 9.7 ± 10.1 years, $P = .02$), with an observed modifier effect of age on outcomes. For a 1-year increase in age, there was a 10% increase in the odds of a positive response.

CONCLUSIONS: Inciting events are common in patients diagnosed with lumbar facetogenic pain and may be associated with a positive outcome. (Anesth Analg 2017;XXX:00–00)

Low back pain (LBP) is the leading cause of years lost to disability,[1] with 1 systematic review reporting a lifetime prevalence rate of 50%–80%.[2] Common causes of LBP include radicular pain secondary to a herniated disc or spinal stenosis, discogenic pain, facet joint pain, and sacroiliac joint pain. Based on studies performed using placebo-controlled or comparative local anesthetic blocks, it is estimated that 15%–25% of individuals with axial LBP suffer from lumbar facet arthropathy,[3,4] with the proportion increasing with age.[5,6]

The etiology of LBP may provide clues to diagnosis. Several studies have examined inciting events associated with sacroiliac joint pain, with about 40%–50% reporting a precipitating factor, with the 3 most common being motor vehicle collisions (MVCs), falls, and cumulative strain from work or sports-related activities.[7–10] For lumbar disc herniation, Suri et al[11] found that 62% of 154 individuals with lumbosacral radicular pain could not cite an inciting event, with the most frequent precipitating incidents being nonlifting activities (26%) and lifting (8.5%). Whereas no large-scale study has sought to systematically identify inciting events for lumbar facet arthropathy, similar to other degenerative arthritic conditions, it is widely assumed to be associated with an insidious onset,[12,13] though facet dislocation may infrequently be associated with trauma.[14]

Pain originating from the facet or zygapophysial joints, which serve to stabilize the cervical and thoracolumbar spine and assist the lumbar discs with load bearing, generally derives from repetitive stress leading to incremental degeneration.[12,15] In animal studies, inflammatory compounds such as phospholipase A2 and interleukins were used to elicit inflammatory responses in dorsal spine tissue, leading to changes in neuronal sensitization.[16,17] This provides evidence in support of a pathophysiological connection between degenerative changes and pain generation. Similar to cervical facet joint pain, in which there is estimated to be a 29%–60% prevalence rate in patients with chronic neck pain after whiplash injuries,[18–20] lumbar facet pain can also occur following MVCs. In a retrospective review, DePalma et al[21] found that 5 of 27 patients who developed LBP after a MVC responded to a set of diagnostic, comparative local

From the Departments of *Physical Medicine and Rehabilitation and †Anesthesiology and Critical Care Medicine, Pain Medicine Division, Johns Hopkins School of Medicine, Baltimore, Maryland; ‡River Hill High School, Clarksville, Maryland; §Department of Neurology, Johns Hopkins School of Medicine, Baltimore, Maryland; and Departments of ||Anesthesiology and ¶Physical Medicine and Rehabilitation, Uniformed Services University of the Health Sciences, Bethesda, Maryland.

Accepted for publication April 24, 2017.

Funding: Funded in part by the Centers for Rehabilitation Sciences Research, Bethesda, MD.

Conflicts of Interest: See Disclosures at the end of the article.

C. A. Odonkor and Y. Chen contributed equally to this work.

Reprints will not be available from the authors.

Address correspondence to Steven P. Cohen, MD, 550 North Broadway, Suite 301, Baltimore, MD 21205. Address e-mail to scohen40@jhmi.edu.

DOI: 10.1213/ANE.0000000000002242

anesthetic medial branch blocks (MBBs). Yet, the function, anatomy, and potential mechanisms of injury of the cervical facet joints, which are vulnerable to hyperextension, flexion, or torsional injuries following rapid deceleration,[22] differ from those in the lumbar spine, which bear increased axial loads and limit rotational movements. Hence, one might surmise that the mechanisms and etiologies of injury may also be different. In a case–control study comparing patients with neck or combined neck and lower back pain to controls with only LBP, Freeman et al[20] found a substantially higher likelihood of MVC-associated neck or combined neck and back pain (45%) compared with LBP alone (24%), with a pooled Mantel–Haenszel exposure odds ratio (OR) of 4.0 for men and 2.1 for women. However, it is important to note that this study did not specify whether these patients suffered from facet pain.

Whereas most cases of symptomatic degenerative joint disease are attributable to cumulative stress[23,24] and traumatic dislocations are unusual, it is possible that a high-impact collision or torsional incident could represent the specific event required for cumulative degenerative processes to reach the threshold required for nociception—the proverbial "straw that broke that camel's back." Studies have documented that a substantial percentage of patients diagnosed with lumbar facet pain report an inciting event.[21,25] Manchikanti et al[25] found that 46% of 48 patients diagnosed with lumbar facet joint pain based on comparative blocks reported an antecedent traumatic event. The fact that patients attribute their pain to a specific cause does not establish actual causation. For example, Al-Allaf et al[26] reported that 39% of fibromyalgia sufferers reported physical trauma prior to symptom onset compared to 24% of non-fibromyalgia outpatients with nonrheumatological conditions. Fybromyalgia is widely considered to be a disorder characterized by abnormal central pain processing rather than a disease associated with discrete pathetiology.

Identifying purported precipitating events for lumbar facet joint pain is important for several reasons. First, it may enhance our understanding regarding the mechanisms of lumbar facet joint pain, which may help guide therapy and improve treatment outcomes.[27] Second, from a medicolegal perspective, it can affect remuneration after work-related injuries, MVCs, and other traumatic injuries, which could have broad societal ramifications. As discussed earlier, whereas there have been several small retrospective and prospective studies that examined the association of injection-diagnosed lumbar facet joint pain and injury, there are no published large-scale studies evaluating causation or any that have sought to determine whether the presence of a discrete inciting event influences outcome. The objectives of this study are to quantify the proportion of individuals with a putative diagnosis of lumbar facetogenic pain diagnosed based on positive blocks who cited a precipitating event, to categorize those inciting events, and to determine whether any specific event(s) correlated with the treatment outcome. Based on the extant literature, we surmised that a sizable percentage of individuals would attribute their LBP to a specific event and tested the hypothesis that those who did would be more likely to fail treatment based on literature suggesting that there is an association between causal beliefs and pain prognosis.[28]

METHODS

Selection Criteria

Permission to conduct this retrospective study was granted by the Institutional Review Board of Johns Hopkins Medical Institutions, who deemed it an exempt protocol. Seven different board-certified pain medicine physicians performed all procedures between January 2007 and December 2015. Included in this study were patients with mechanical LBP and paraspinal tenderness who obtained ≥50% pain relief after 1 or more diagnostic facet blocks and proceeded to RF denervation. Exclusion criteria were focal neurologic deficit(s), <50% pain relief or lack of documentation thereof on any diagnostic block, presence of radicular signs and symptoms, and absence of 3-month follow-up data. In the absence of any pathognomonic test or reference standard for the diagnosis of lumbar facet joint pain, facet blocks, either of the medial branch nerves innervating the targeted joints or the joints themselves, are considered to be the best means for identifying a painful joint, though without another diagnostic comparator the accuracy of the blocks remains unknown. Individuals were identified by a search of institutional electronic medical records based on the CPT codes 64622 and 64623 for procedures done between 2007 and 2011 and 64635 and 64636 thereafter, which replaced the former designations in 2012. These refer to "destruction by neurolytic agent, paravertebral facet joint nerve(s), with imaging guidance (fluoroscopy or computed tomography), lumbar or sacral levels."

Diagnostic Medial Branch and L5 Dorsal Ramus Blocks

Diagnostic MBB were performed without sedation using fluoroscopic guidance in accordance with previous published techniques.[29] The levels targeted were based on physical examination, documented facet joint pain referral patterns,[12] and in some cases palpation performed using fluoroscopic guidance. Individuals with primarily 1-sided pain underwent unilateral blocks with 22-gauge spinal needles, whereas those with midline or bilateral symptoms received bilateral blocks. Superficial anesthesia was provided using 1% lidocaine. Once correct needle position was confirmed using oblique, anteroposterior, and lateral fluoroscopic imaging at the junction of the superior articular and transverse processes for MBB, and the groove between the sacral ala and articular process for L5 dorsal rami, 0.5 mL of 0.5% bupivacaine was administered after either negative aspiration or real-time injection of radiopaque contrast. Following the injection, all patients were given instructions regarding the proper use of a 6-hour paper pain diary, which included pain scores recorded every 30 minutes on a 0–10 numerical rating scale and a section for activities. The pain diary was then filled out and faxed or e-mailed to the office. In order to control for the presence of concomitant spinal pathology, a putative diagnosis of facet-mediated pain was made if the individual obtained ≥50% relief without an increase in rescue medications, as previous studies found little utility in using higher cutoff thresholds.[30]

Intraarticular Injections

Intraarticular (IA) injections were performed by one practitioner preferentially and a second practitioner in about 10% of cases. Fluoroscopic guidance was employed using ipsilateral oblique angles ranging from 30° to 60°, and sometimes cephalad angulation, to facilitate visualization of the facet joint(s). These injections constituted approximately 28% of the diagnostic blocks performed. The targeted levels were identified, and superficial anesthesia was provided in a manner similar to those utilized for MBB. Once 22-gauge spinal needles were properly positioned using in oblique, anteroposterior, and lateral images, 0.1–0.25 mL of radiopaque contrast was administered to confirm IA placement, which was estimated to occur in about 70% of cases based on an ongoing randomized, controlled trial.[31] When optimal needle position was ascertained, 0.5–1.0 mL solution containing 0.5% bupivacaine and 5–10 mg of depomethylprednisolone was injected into each joint. In individuals who experienced prolonged relief from at least 1 IA injection and received subsequent procedures, the same pain diaries and postdischarge instructions were given only after the first block, similar to those people who underwent MBB.

Radiofrequency Denervation

All RF procedures were performed in patients who experienced positive diagnostic MBB or IA injections following return of their pain to baseline, using superficial anesthesia and intravenous sedation as needed. RF denervation was not performed in those who experienced long-term relief from their blocks. There were subtle interpractitioner differences between denervation techniques, though the most common involved positioning the C-arm intensifier in an ipsilateral oblique and caudad–cephalad direction to maximize contact of the convex surface of the electrode with bone in an orientation parallel to the course of the target nerve. An 18- or 21-gauge curved radiofrequency cannula with a 10-mm active tip was then inserted in a coaxial view until bone was contacted between the superomedial border of the transverse process, and the inferior lateral neck of the superior articular process for levels above L5, and in the groove just lateral to the upper border of the sacral articular process for lesions targeting the L5 dorsal ramus.[29,32] At each targeted nerve, the electrodes were adjusted to optimize sensory stimulation at a frequency of 50 Hz and maximize paraspinal muscle contraction at 2 Hz. Generally, most physicians performed a second lesion after minor electrode refinements for levels in which concordant sensory stimulation could not be appreciated at <0.6 V. After optimal positioning was noted, up to 1 mL of 2% lidocaine was injected through each cannula to reduce procedure-related pain and amplify lesion parameters.[33] The RF probe was then reinserted, and a 105- to 135-second, 80°C–90°C lesion was created using a RF generator, with the longer lesion cycles and higher temperatures being introduced division wide in 2013 to improve lesioning parameters (Kimberly Clark Pain Management Generator 115V, Kimberly Clark Health Care, Roswell, GA).[3] Once ablation was completed, 0.5–1.0 mL of a solution containing 5–10 mg depomethylprednisolone diluted in normal saline was injected at each level to prevent neuritis, and the cannulas were removed.[34]

Study Size

Power analysis was performed using the Power Analysis and Sample Size software (2008, Kaysville, UT). By using a 2-sided hypothesis, a total sample size of 500 was deemed adequate for 80% power to detect an effect size of 1.23, $\alpha = .05$, and $\beta = .2$. With regard to predictor variables, this sample size was estimated to provide 80% power to detect a 40% difference in the proportion of individuals reporting no inciting event versus those reporting an inciting event, and for detecting a 1.8-year difference in mean duration of chronic pain for groups with a successful versus unsuccessful treatment response. To offset potential missing data and the small decrease in power that will result from performing an interim analysis, the sample size was adjusted upward to 700.

Outcome Measures

The variables recorded from the electronic medical records consisted of age, gender, duration of pain, baseline average and worst pain scores with activity, disability status, smoking, obesity, opioid dose, laterality and levels targeted, percent pain relief from the diagnostic block, and treatment outcome, which was predefined as ≥50% pain relief sustained for longer than 3-months after the procedure, without additional procedural interventions. The 3-month criterion was used in a previous randomized, controlled trial by Cohen et al,[29] which was based on a review of patient records, as well as interviews with patients and pain medicine physicians. In individuals who underwent repeat procedures, the result of only the first intervention was recorded. For the variable of interest, inciting event, data were retrieved from an extensive medical review that included pain medicine, primary care, and referring physician notes. This category was subsequently subclassified into different etiologies based on a pilot review of 100 records to include major events such as MVC, sports-related, work-related, pregnancy-related, and "other" (classified as minor events). The "other" group was then reexamined to determine whether those events classified as such fit better into one of the other categories.

Statistical Analysis

Data are summarized with descriptive statistics. Group means (positive versus negative outcome) for continuous and categorical variables were compared using Student *t* tests, and χ^2 and Fisher exact tests, respectively. The percent distribution of reported etiologies of lumbar facet pain is shown using a pie chart. Correlation effects were analyzed by Spearman rank correlation coefficient. Candidate variables for logistic regression were identified by univariate analysis (pain duration, number of levels targeted, baseline pain score, and reported inciting event for lumbar facet pain). Hypotheses-based models were generated using a priori defined explanatory variables (age, gender, obesity, and smoking status) and covariates previously identified by univariate analysis. Multivariable logistic regression models were developed using a manual backward elimination approach (PROC Logistic, SAS Statistical package version 9.3; SAS Institute Inc, Cary, NC) to identify factors associated with successful pain relief from RF denervation. Model fitness was assessed using the Hosmer–Lemeshow goodness-of-fit test. Stratified analysis was performed using Breslow–Day test for homogeneity of odd ratios and Cochran–Mantel–Haenszel test to assess for effect modifiers on positive RF outcomes. All statistical analyses were performed with SAS software, version 9.3, using a 2-sided hypothesis test with the probability of a type 1 error set at .05.

RESULTS

Baseline Characteristics

The medical records of 1981 patient visits for radiofrequency ablation were obtained from our database search. After exclusions for repeated procedure (ie, duplicate), nonlumbar facet denervation (n = 8), and absence of follow-up data (n = 89), 1069 individuals were included in the analysis. Of these 1069 individuals, 617 reported ≥50% pain relief sustained for longer than 3-months after the procedure without additional procedural interventions, for a success rate of 57.7%. Table 1 presents the characteristics of individuals stratified by outcome. Compared to subjects with a negative outcome, those with a positive outcome had a statistically significant shorter duration of pain (8.1 ± 9.2 vs 9.7 ± 10.1 years, P = .02). For individuals who experienced a successful denervation procedure, over half (54.9%) reported an inciting event preceding their symptoms. This was higher than the proportion of individuals reporting an antecedent event who had a negative outcome (47.3%, P = .01). No significant differences were found between individuals with positive versus negative outcomes when stratified by gender, opioid use, laterality, pain scores, and mean number of treated levels. However, there was a correlation effect between age and duration of pain (Spearman r = 0.2, P = .001), age and sports-related injury (Spearman r = −0.15, P = .01), and age and work-related injury (r = −0.16, P = .004).

Figure 1 shows the patient-reported etiologies of lumbar facetogenic pain broken down into categories. In the 52% of individuals who described an inciting event preceding their injection-diagnosed lumbar facet joint pain, 11% attributed their condition to falls, 11% to MVCs, 2% to nonspine postsurgical injury, 11% related to sports, and 17% to "other" etiologies. Among specific sports-related precipitating events, 62% were attributed to weightlifting, with the remaining 38% being nearly equally divided between repetitive trauma and a single, sports-related occurrence. There were 185 "other"

Table 1. Baseline Demographic and Clinical Variables Stratified by Treatment Outcome (N = 1069)[a]

Variable	Positive Outcome, N = 617 (57.7%)	Negative Outcome, N = 452 (42.3%)	*P*
Age (y), mean ± SD	54.3 ± 14.0	55.8 ± 15.0	.10
Age (y), n (%)			
<65	461 (74.7)	312 (69.0)	.049
≥65	156 (25.3)	140 (31.0)	
Duration of pain (y), mean ± SD	8.1 ± 9.2	9.7 ± 10.1	.02
Gender, n (%)			
Male	269 (43.6)	188 (43.6)	.54
Female	348 (56.4)	263 (56.4)	
Baseline average pain score, mean ± SD	6.1 ± 2.2	6.3 ± 2.1	.10
Baseline worst pain score, mean ± SD	8.9 ± 9.7	9.1 ± 10.4	.18
Opioid use, n (%)			
Yes (≤90 mg of morphine sulfate equivalent)	293 (47.5)	205 (45.4)	.59
Yes (>90 mg of morphine sulfate equivalent)	53 (8.6)	35 (7.7)	
No	271 (43.9)	212 (46.9)	
Disability/worker's compensation, n (%)			
Yes (disability)	125 (20.3)	101 (22.4)	.76
Yes (worker's compensation)	12 (1.9)	6 (1.3)	
No	480 (77.8)	345 (76.3)	
Obesity, n (%)			
Yes	267 (43.3)	172 (38.1)	.08
No	350 (56.7)	280 (61.9)	
Smoking, n (%)			
Yes	171 (27.7)	130 (28.8)	.52
No	446 (72.3)	322 (71.2)	
Laterality, n (%)			
Unilateral	278 (45.1)	213 (47.1)	.27
Bilateral	339 (54.9)	239 (52.9)	
Levels, mean ± SD	2.3 ± 0.7	2.4 ± 0.6	.10
Levels			
1	30 (4.9)	30 (6.6)	.40
2	319 (51.7)	235 (52.0)	
3	268 (43.4)	187 (41.4)	
Etiology			
Inciting event	339 (54.9)	214 (47.3)	.01
None	278 (45.1)	238 (52.7)	
Worked-related injury			
Single event	75 (12.2)	46 (10.2)	.47
Multiple events	25 (4.1)	15 (3.3)	
None	517 (83.7)	391 (86.5)	

[a]No outcome data were available for 1 patient who was deceased at the time of follow-up. The cause of death was undocumented. Data of 1069 of 1070 were included for analysis.

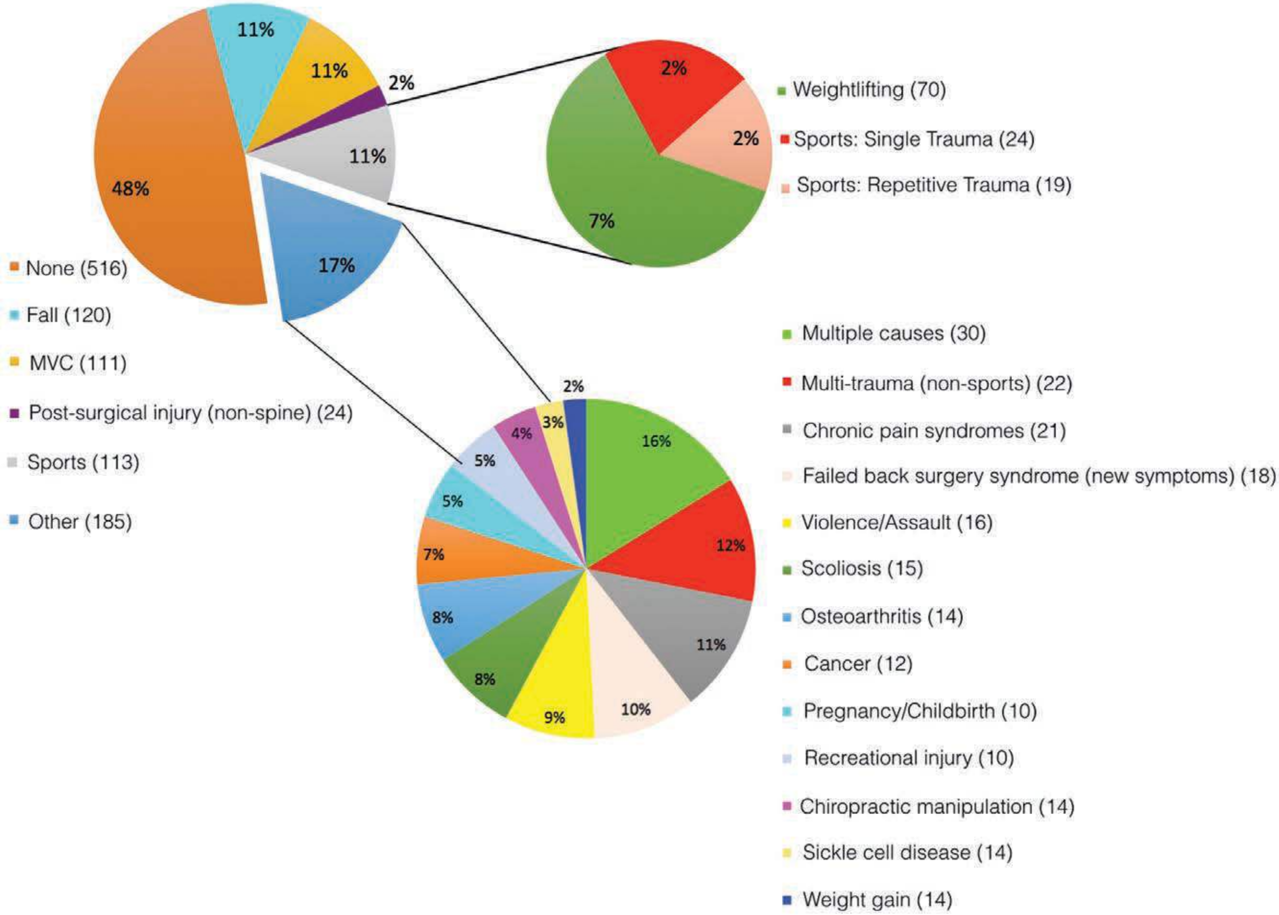

Figure 1. Pie chart highlighting patient-reported etiologies for patients with confirmed diagnosis of lumbar facet joint pain (N = 1069). MVC indicates motor vehicle collision.

reported etiologies, with 22 people attributing their symptoms to nonsports multitrauma and 18 individuals reporting "new" symptoms after lumbar spine surgery (failed back surgery). Among the 161 cases attributed to work-related injuries, patients reported that 121 followed a single, traumatic event, with 40 being ascribed to repetitive injuries (Table 1).

Figure 2 illustrates the percent success rates of RF denervation for each reported etiology of lumbar facet joint pain. Among those subjects who reported a precipitating event, 61% of individuals obtained a positive outcome, which favorably compared to the 54% success rate in those who did not cite a precipitating incident (Table 1; Figure 2). The highest success rates were observed among subjects reporting repetitive trauma due to sports (68.4%) and weightlifting (67%). The following variables were identified as significant by univariate analysis: pain duration ($P < .001$), number of levels targeted ($P = .01$), baseline pain score ($P = .04$), and reported inciting event for lumbar facet pain ($P = .035$). The logistic model was built with these identified variables in addition to explanatory variables deemed clinically relevant (age, gender, obesity, and smoking status) even if not statistically significant by univariate analysis alone. The final model was adjusted for the following variables: age, gender, obesity, duration of pain, number of nerves and levels of treatment, and reported etiology of pain.

Factors Associated With Radiofrequency Success Rates

Table 2 demonstrates the results of the multivariable logistic regression model predicting the likelihood of successful radiofrequency denervation for injection-confirmed lumbar facet pain. The final model was adjusted for the following variables: age, gender, obesity, duration of pain, number of nerves and levels of treatment, and reported etiology of pain. Age was treated as a continuous variable with unit change set at 1 year. For every 1-year increase in age, there was a 10% increase in the odds of a positive response. For the same model, pain was treated as a continuous variable and set up such that a unit change corresponded to pain duration of 10 years. For every 10-year increase in the duration of pain, there was a 20% decrease in the odds of successful radiofrequency denervation for lumbar facet pain. In a separate analysis, when age was dichotomized using younger adults (<65 years) as a reference, there was no clear difference between the 2 groups; for older adults, OR = 1.2, 95% confidence interval (CI), 0.94–1.4, $P = .09$. The area under the curve for the model was 0.65 (95% CI, 0.60–0.71), indicating good model discrimination, and the Hosmer–Lemeshow goodness-of-fit test was $P = .24$. The test is basically used to determine that poor predictions (lack of fit) are not significant, ie, $P > .05$. If the poor predictions significantly lack model fit, ie, $P < .05$, it means there

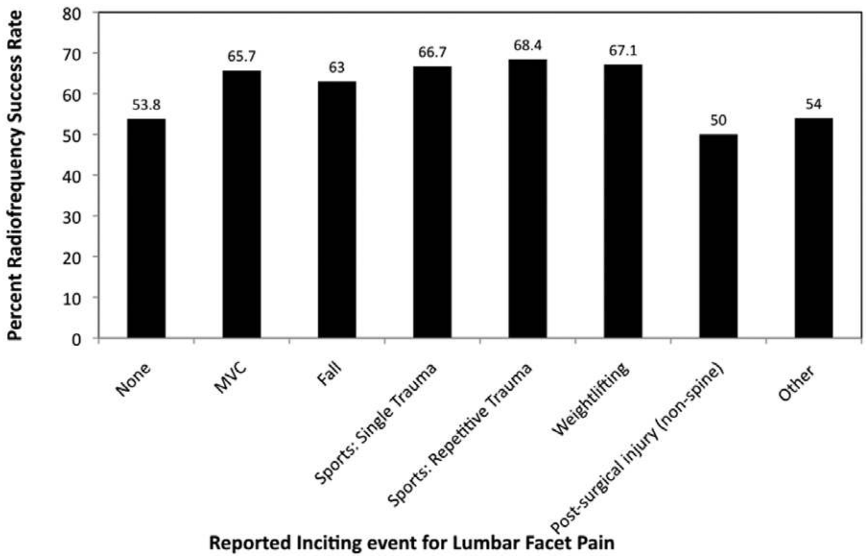

Figure 2. Radiofrequency denervation success rate by reported etiology of lumbar facet joint pain. MVC indicates motor vehicle collision.

Table 2. Multivariable Logistic Regression Model Showing Likelihood of Success for Lumbar Facet Joint Radiofrequency Denervation (N = 1069)[a]

Variable	OR (99% CI)	*P*
Patient characteristics		
Age[b]	1.1 (1.02–1.9)	.049
Males[c]	1.1 (0.7–1.5)	.30
Obesity[d]	1.2 (0.9–1.6)	.15
Pain duration[e]	0.8 (0.6–0.9)	.004
Levels[f]		
2 levels = 3 nerves	1.2 (0.7–1.7)	.20
3 levels = 4 nerves	1.4 (0.8–3.1)	.10
Inciting event[g]		
Motor vehicle collision	1.4 (0.9–2.3)	.20
Falls	1.5 (1.0–2.4)	.17
Sports trauma	1.6 (0.5–5.1)	.45
Weightlifting	1.7 (0.9–3.2)	.08
Postsurgical injury (nonspine)	2.2 (0.5–9.1)	.49
Other	0.9 (0.6–1.4)	.52

Model AUC = 0.65.

Abbreviations: AUC, area under the curve; CI, confidence interval; OR, odds ratio.

[a]Total sample size excludes 1 patient who was deceased, as there were no outcome data available; cause of death was undocumented but was deemed to be unrelated to the procedure.

[b]Age was treated as a continuous variable with unit change set at 1 y. For every 1-y increase in age, there is a 10% increase in the odds of a positive response. However, in a separate analysis, using younger adults (<65 y) as a reference, there was no clear difference between the 2 groups; for older adults, OR = 1.2, CI, 0.94–1.4, *P* = .09.

[c]Reference point: females.

[d]Reference point: normal weight.

[e]Model was set up with unit change in pain duration of 10 y. For every 10-y increase in the duration of pain, there is a 20% decrease in odds of successful radiofrequency denervation for lumbar facet pain. In separate models, with unit change in duration of 2.5 and 5 y, there was a 9% (OR = 0.91, CI, 0.8–0.99, *P* = .01) and 12% (OR = 0.88, CI, 0.7–0.95, *P* = .02) decrease in the odds of successful treatment response.

[f]Reference point: 1 level = 2 nerves. OR for 1 level = 1.2 (95% CI, 0.9–1.5, *P* = .07).

[g]Reference point: no inciting event.

are problems with the model. Therefore, the *P* = .24 reflects good statistical fit of our regression model. At a cutoff threshold of 55% probability of a positive outcome, model sensitivity and specificity were 71% and 49%, respectively, with 61% prediction accuracy. Duration of pain was significantly associated with successful treatment outcomes (OR, 0.8; 95% CI, 0.6–0.9; *P* = .004). No significant difference was found between treating 4 nerves (ie, 3 levels) or 3 nerves versus 2 nerves (single level). Individuals who reported that their pain onset was consequent to weightlifting showed a trend toward treatment benefit when compared to subjects who reported no index injury (OR, 1.7; 95% CI, 0.9–3.2; *P* = .08). Adjusting for age as a continuous variable in the logistic model suggested that age was associated with a positive outcome (OR, 1.1; 95% CI, 1.02–1.9; *P* = .049).

Stratified Analysis

Due to observed correlations and interaction effects of age with reported inciting event, obesity, pain duration, and work-related injury, data analysis was stratified by age (<65 vs ≥65 years) to identify effect modifiers across different strata of associated factors (Table 3). Adjusting for the effect of age, there was an association between single versus multiple injuries and positive treatment outcome (OR, 1.5; 95% CI, 1.02–2.1; *P* = .003). The Breslow–Day statistic was 8.4 with df = 1 (*P* = .004), suggesting that there is strong evidence that the association of reported multiple versus single inciting injury with a categorical positive RF response varied by age. Individuals who were younger than 65 years and reported a single inciting event were more likely to experience a positive RF outcome compared to their peers who reported multiple injuries (OR, 2.0; 95% CI, 1.3–3.1; *P* = .003). Conversely, there was no difference in outcomes among adults aged 65 years or older who reported a single versus multiple inciting injuries (OR, 0.6; 95% CI, 0.3–1.2; *P* = .22).

Age modified the effect of obesity on positive RF outcome. Older adults with normal weight versus those with an obese habitus had a higher likelihood of a positive outcome (OR, 1.7; 95% CI, 1.02–2.7; *P* = .001; Table 3). Ignoring age, no association was found between obesity and RF response (OR, 1.2; 95% CI, 0.96–1.6; *P* = .11). Adults younger than 65 years with less than a decade's duration of chronic pain versus those with greater than a 10-year pain history had a higher likelihood of benefit from RF treatment (OR, 2.0; 95%

Table 3. Stratified Analysis Evaluating the Modifying Effect of Age on Factors Associated With RF Outcomes for Lumbar Facet Joint Pain

Variable	Age < 65 y, OR (95% CI), *P* Value	Age ≥ 65 y, OR (95% CI), *P* Value	Combined, OR (95% CI), *P* Value
Single versus multiple inciting events	2.0 (1.3–3.1), .002	0.6 (0.3–1.2), .14	1.5 (1.02–2.1), .04
Normal weight versus obese habitus	1.1 (0.8–1.5), .11	1.7 (1.02–2.7), .03	1.2 (0.96–1.6), .21
Pain duration <10 y versus pain duration ≥10 y	2.0 (1.4–2.8), <.001	1.4 (0.8–2.2), .18	1.7 (1.3–2.3), <.001
Work versus nonwork injury	1.1 (0.6–1.6), .15	1.7 (0.6–4.6), .40	1.2 (0.8–1.6), .20
Male versus female	1.01 (0.8–1.4), .20	0.7 (0.5–1.2), .25	0.94 (0.7–1.2), .19

Abbreviations: CI, confidence interval; OR, odds ratio; RF, radiofrequency denervation.

CI, 1.4–2.8; *P* = .001). In contrast, no significant difference in outcomes was found for older adults regardless of whether pain duration was less or greater than 10 years (OR, 1.4; 95% CI, 0.8–2.2; *P* = .41). Stratified by age, there was no significant association for work versus nonwork-related injury or gender with positive RF treatment response (Table 3).

DISCUSSION

In this retrospective analysis of patients undergoing radiofrequency ablation for lumbar facetogenic pain, we found several factors associated with positive outcome, including shorter duration of symptoms and attribution of an inciting etiology. Some of these have been reflected by prior studies. For instance, duration of symptoms has been previously reported to correlate negatively with a positive treatment outcome for both radiofrequency ablation and other procedures for degenerative pain syndromes.[35,36] We had hypothesized that people who identified an antecedent event prior to their LBP would be more likely to fail RF ablation treatment than those who did not. More specifically, we believed that people who had filed worker's compensation or disability claims, indicative of secondary gain, would have a higher failure rate than those without ongoing litigation. This is similar to past studies showing that individuals with outstanding legal action for back pain were more likely to have a negative outcome after epidural steroid injections[37] and surgery.[38] However, we found that the opposite was true—people who reported a specific inciting event had a higher success rate than those who did not. Moreover, neither disability nor worker's compensation claims were associated with treatment outcome. These findings are similar to a small (n = 46) prospective study by Sapir and Gorup[39] that found no difference in cervical facet joint RF ablation outcomes between whiplash patients actively involved in litigation and nonlitigant subjects.

The association between attributed etiological factors and RF outcomes merits discussion. Presumably, subjects who attributed their diagnostically confirmed lumbar facet pain to weightlifting injuries may have higher physical function at baseline due to their fitness training. In χ^2 analysis, we found that although patients reporting weightlifting injuries had a similar duration of pain as those reporting nonsports etiologies (7.8 ± 5.2 vs 7.7 ± 4.9 years, *P* = .21), weightlifters tended to be younger and nonobese. A literature review shows that exercise therapy including strengthening and stretching improves pain and function in people with chronic LBP.[40] Weightlifters, who frequently engage in such exercises, may have a higher functional reserve than nonweightlifters, which could explain their propensity to experience a positive RF outcome. Studies exploring the augmented role of exercise in RF treatment outcomes might yield additional information regarding this possible association.

Our finding that patients who attributed LBP to a putative inciting event had a more positive prognosis raises interesting questions regarding what role patients' certainty about pain precipitants versus anxiety (arising from uncertainty about the cause of pain) may play in their expectations of recovery and eventual treatment response. Future research exploring this psychosocial aspect of patients' perceptions may deepen our understanding of determinants of RF treatment response for lumbar facet pain.

Prior studies have identified other characteristics associated with successful lumbar facet RF ablation.[35,41,42] Similar to our findings, a previous study by Cohen et al[35] found obesity and longer duration of pain to be associated with negative outcome. A small, retrospective review by North et al[41] found bilateral symptoms to be associated with poorer outcomes, in contrast to our findings that demonstrated no effect of laterality on treatment results. A previous prospective study identified a lower rate of successful treatment in patients with depression, as defined by a Beck Depression Inventory score >16[42]; however, in contrast to our study, duration of pain was not predictive of denervation outcome. The differences in findings between our study and those of Streitberger et al[42] could be explained by our larger sample size and our analysis accounting for subtle latent interaction and modifier effects.

Traditionally, predictive models utilize one-to-one linear associations of predictors with outcomes without stratified assessments. This results in nonnuanced models, which fail to capture latent interactions or modifier effects between predictive variables. As an illustration, adjusting for obesity without stratifying by age seemed to indicate that obesity had no significant association with RF outcomes for lumbar facet pain (*P* = .15; Table 2). However, when stratified by age (Table 3), being obese significantly decreased the likelihood of RF ablation success among older adults (*P* = .01). Similarly, though pain duration was associated with RF outcome (Table 2, *P* = .004), the stratified analysis illustrates that age has an important modifying effect on how pain chronicity influences RF treatment outcomes. In younger adults, treatment benefit was likely if chronic pain had lasted <10 years (OR, 2.0; 95% CI, 1.4–2.8; *P* = .001). In older adults, duration of pain was not as relevant. As people age, load-bearing shifts posteriorly, increasing stress on the paired, zygapophysial joints,[43] and clinical studies have found that older patients may be more likely than younger ones to have the facet joints as their primary source of LBP.[5,6] But our results suggest the relationship between age and pain generators is not so simple. Such subtle and nuanced analyses may prove instructive for clinicians seeking to understand the determinants of treatment outcome and may help guide tailored interventions (ie, precision medicine).

Evaluation of our findings should be interpreted in view of the fact that large sample sizes increase propensity to detect small statistically significant differences. In contrast to standardized clinical measures such as blood pressure wherein it is easier to judge what changes may be deemed as clinically meaningful, it is more difficult to do so for nonstandard measures, such as chronic pain duration. In contexts where no clinical preambles exist, it is instructive to translate results into clinically measurable terms. As most practitioners may intuit, longer pain duration correlates with worse outcomes. Our analysis showing that a 10-year increase in pain corresponds with a decreased likelihood of successful response to treatment provides contextual relevance, which clinicians might appreciate. Although not the focus of this study, the findings (a statistically significant mean difference of 1.6 years between positive and negative outcomes) provide preliminary data that may help determine minimal clinical differences in pain duration in future studies.

There are several limitations to our study that warrant attention. First, retrospective studies contain inherent inaccuracies and missing data. Second, we did not routinely use control blocks. Uncontrolled facet blocks are associated with a high false-positive rate ranging between 20% and 40%[44]; so some of our patients likely had other primary pain generators. Despite our findings, back injuries sustained during lifting might be more likely to result in stress and tears in the disc than injury to the facet joints,[45] which again augurs for more research into this relationship. Third, not all patients returned their pain diaries, and pain scores recorded in the recovery area may not be indicative of actual benefit during activities of daily living, representing a source of misdiagnosis. Fourth, our data were obtained by CPT codes for lumbar facet RF ablation, so that individuals with positive diagnostic blocks who obtained prolonged pain relief obviating the need for denervation or who were otherwise lost to follow-up were systematically excluded. Our data are also limited by its retrospective nature, whereby other functional measures such as Oswestry disability index or Roland Morris scores, or predictor variables such as psychiatric comorbidity, were not documented, hence not available for review, but may have influenced the observed outcomes. Finally, our facet block and radiofrequency ablation protocols were standardized in 2013, leading to greater variability in the treatment of patients who were treated before that time.

In conclusion, we found that over half of the people diagnosed with lumbar facet joint pain reported a preceding, precipitating event, and paradoxically, these individuals were more likely to experience a positive RF ablation treatment outcome. Future directions for research could include prospective studies, which stratify patients based on the factors identified in this study. Randomization and blinding of treatment could be employed to further verify factors that contribute to successful outcomes in patients with lumbar facet pain. Ultimately, determination of predictive factors could lead to better outcomes for patients, as well as conservation of resources in a value-based and outcome-focused health care economy.

DISCLOSURES

Name: Charles A. Odonkor, MD.
Contribution: This author helped write the manuscript, collect the data, analyze the data, create figures, respond to reviewers, and critically review the manuscript.
Conflicts of Interest: None.
Name: Yian Chen, MD.
Contribution: This author helped write the manuscript, collect the data, respond to reviewers, and critically review the manuscript.
Conflicts of Interest: None.
Name: Peju Adekoya, MD.
Contribution: This author helped collect the data and critically review the manuscript.
Conflicts of Interest: None.
Name: Bryan J. Marascalchi, MD.
Contribution: This author helped collect the data and critically review the manuscript.
Conflicts of Interest: None.
Name: Hira Chaudhry-Richter, MD.
Contribution: This author helped collect the data and critically review the manuscript.
Conflicts of Interest: None.
Name: Teresa Tang, MD.
Contribution: This author helped collect the data and critically review the manuscript.
Conflicts of Interest: None.
Name: Christopher Abruzzese, MD.
Contribution: This author helped collect the data and critically review the manuscript.
Conflicts of Interest: None.
Name: Berklee K. Cohen.
Contribution: This author helped collect the data and critically review the manuscript.
Conflicts of Interest: None.
Name: Steven P. Cohen, MD.
Contribution: This author helped originate the concept and submit to the institutional review board, write the manuscript, create the table and figure, response to the reviewer, and critically review the manuscript.
Conflicts of Interest: Steven P. Cohen serves on the advisory boards of Halyard and Boston Scientific.
This manuscript was handled by: Honorio T. Benzon, MD.

REFERENCES

1. US Burden of Disease Collaborators. The state of US health, 1990–2010: burden of diseases, injuries and risk factors. *JAMA*. 2013:591–608.
2. Rubin DI. Epidemiology and risk factors for spine pain. *Neurol Clin*. 2007;25:353–371.
3. Cohen SP, Huang JH, Brummett C. Facet joint pain—advances in patient selection and treatment. *Nat Rev Rheumatol*. 2013;9:101–116.
4. 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.
5. DePalma MJ, Ketchum JM, Saullo T. What is the source of chronic low back pain and does age play a role? *Pain Med*. 2011;12:224–233.
6. DePalma MJ, Ketchum JM, Saullo TR. Multivariable analyses of the relationships between age, gender, and body mass index and the source of chronic low back pain. *Pain Med*. 2012;13:498–506.

7. Cohen SP, Chen Y, Neufeld NJ. Sacroiliac joint pain: a comprehensive review of epidemiology, diagnosis and treatment. *Expert Rev Neurother*. 2013;13:99–116.
8. Schwarzer AC, Aprill CN, Bogduk N. The sacroiliac joint in chronic low back pain. *Spine (Phila Pa 1976)*. 1995;20:31–37.
9. Chou LH, Slipman CW, Bhagia SM, et al. Inciting events initiating injection-proven sacroiliac joint syndrome. *Pain Med*. 2004;5:26–32.
10. Cohen SP, Strassels SA, Kurihara C, et al. Outcome predictors for sacroiliac joint (lateral branch) radiofrequency denervation. *Reg Anesth Pain Med*. 2009;34:206–214.
11. Suri P, Hunter DJ, Jouve C, et al. Inciting events associated with lumbar disc herniation. *Spine J*. 2010;10:388–395.
12. Cohen SP, Raja SN. Pathogenesis, diagnosis, and treatment of lumbar zygapophysial (facet) joint pain. *Anesthesiology*. 2007;106:591–614.
13. Abhishek A, Doherty M. Diagnosis and clinical presentation of osteoarthritis. *Rheum Dis Clin North Am*. 2013;39:45–66.
14. Levine AM, Bosse M, Edwards CC. Bilateral facet dislocations in the thoracolumbar spine. *Spine (Phila Pa 1976)*. 1988;13:630–640.
15. van Kleef M, Vanelderen P, Cohen SP, Lataster A, Van Zundert J, Mekhail N. 12. Pain originating from the lumbar facet joints. *Pain Pract*. 2010;10:459–469.
16. Chen C, Cavanaugh JM, Ozaktay AC, Kallakuri S, King AI. Effects of phospholipase A2 on lumbar nerve root structure and function. *Spine (Phila Pa 1976)*. 1997;22:1057–1064.
17. Ozaktay AC, Cavanaugh JM, Asik I, DeLeo JA, Weinstein JN. Dorsal root sensitivity to interleukin-1 beta, interleukin-6 and tumor necrosis factor in rats. *Eur Spine J*. 2002;11:467–475.
18. Barnsley L, Lord S, Bogduk N. Comparative local anaesthetic blocks in the diagnosis of cervical zygapophysial joint pain. *Pain*. 1993;55:99–106.
19. Barnsley L, Lord SM, Wallis BJ, Bogduk N. The prevalence of chronic cervical zygapophysial joint pain after whiplash. *Spine (Phila Pa 1976)*. 1995;20:20–25.
20. Freeman MD, Croft AC, Rossignol AM, Centeno CJ, Elkins WL. Chronic neck pain and whiplash: a case-control study of the relationship between acute whiplash injuries and chronic neck pain. *Pain Res Manag*. 2006;11:79–83.
21. DePalma M, Ketchum J, Saullo T, Schofferman J. Structural etiology of chronic low back pain due to motor vehicle collision. *Pain Med*. 2011;12:1622–1627.
22. Bogduk N, Yoganandan N. Biomechanics of the cervical spine Part 3: minor injuries. *Clin Biomech (Bristol, Avon)*. 2001;16:267–275.
23. Murphy NJ, Eyles JP, Hunter DJ. Hip osteoarthritis: etiopathogenesis and implications for management. *Adv Ther*. 2016;33:1921–1946.
24. Manninen P, Heliövaara M, Riihimäki H, Suoma-Iainen O. Physical workload and the risk of severe knee osteoarthritis. *Scand J Work Environ Health*. 2002;28:25–32.
25. Manchikanti L, Singh V, Pampati V, et al. Evaluation of the relative contributions of various structures in chronic low back pain. *Pain Physician*. 2001;4:308–316.
26. Al-Allaf AW, Dunbar KL, Hallum NS, Nosratzadeh B, Templeton KD, Pullar T. A case-control study examining the role of physical trauma in the onset of fibromyalgia syndrome. *Rheumatology (Oxford)*. 2002;41:450–453.
27. Woolf CJ, Max MB. Mechanism-based pain diagnosis: issues for analgesic drug development. *Anesthesiology*. 2001;95:241–249.
28. Buitenhuis J, de Jong PJ, Jaspers JP, Groothoff JW. Catastrophizing and causal beliefs in whiplash. *Spine (Phila Pa 1976)*. 2008;33:2427–2433.
29. Cohen SP, Williams KA, Kurihara C, et al. Multicenter, randomized, comparative cost-effectiveness study comparing 0, 1, and 2 diagnostic medial branch (facet joint nerve) block treatment paradigms before lumbar facet radiofrequency denervation. *Anesthesiology*. 2010;113:395–405.
30. Cohen SP, Strassels SA, Kurihara C, et al. Establishing an optimal "cutoff" threshold for diagnostic lumbar facet blocks: a prospective correlational study. *Clin J Pain*. 2013;29:382–391.
31. Cohen SP; Johns Hopkins University; Uniformed Services University of the Health Sciences; Walter Reed National Military Medical Center. Medial branch blocks vs. intra-articular injections: randomized, controlled study. Available at: https://clinicaltrials.gov/ct2/show/NCT02002429. NLM identifier: NCT02002429. Accessed December 5, 2016.
32. Gofeld M, Faclier G. Radiofrequency denervation of the lumbar zygapophysial joints—targeting the best practice. *Pain Med*. 2008;9:204–211.
33. Provenzano DA, Lassila HC, Somers D. The effect of fluid injection on lesion size during radiofrequency treatment. *Reg Anesth Pain Med*. 2010;35:338–342.
34. Dobrogowski J, Wrzosek A, Wordliczek J. Radiofrequency denervation with or without addition of pentoxifylline or methylprednisolone for chronic lumbar zygapophysial joint pain. *Pharmacol Rep*. 2005;57:475–480.
35. Cohen SP, Hurley RW, Christo PJ, Winkley J, Mohiuddin MM, Stojanovic MP. Clinical predictors of success and failure for lumbar facet radiofrequency denervation. *Clin J Pain*. 2007;23:45–52.
36. Tanaka N, Sakahashi H, Sato E, Hirose K, Ishima T, Ishii S. Intra-articular injection of high molecular weight hyaluronan after arthrocentesis as treatment for rheumatoid knees with joint effusion. *Rheumatol Int*. 2002;22:151–154.
37. Tong HC, Williams JC, Haig AJ, Geisser ME, Chiodo A. Predicting outcomes of transforaminal epidural injections for sciatica. *Spine J*. 2003;3:430–434.
38. Taylor VM, Deyo RA, Ciol M, et al. Patient-oriented outcomes from low back surgery: a community-based study. *Spine (Phila Pa 1976)*. 2000;25:2445–2452.
39. Sapir DA, Gorup JM. Radiofrequency medial branch neurotomy in litigant and nonlitigant patients with cervical whiplash: a prospective study. *Spine (Phila Pa 1976)*. 2001;26:268–273.
40. Hayden JA, van Tulder MW, Tomlinson G. Systematic review: strategies for using exercise therapy to improve outcomes in chronic low back pain. *Ann Intern Med*. 2005;142:776–785.
41. North RB, Han M, Zahurak M, Kidd DH. Radiofrequency lumbar facet denervation: analysis of prognostic factors. *Pain*. 1994;57:77–83.
42. Streitberger K, Müller T, Eichenberger U, Trelle S, Curatolo M. Factors determining the success of radiofrequency denervation in lumbar facet joint pain: a prospective study. *Eur Spine J*. 2011;20:2160–2165.
43. Pollintine P, Przybyla AS, Dolan P, Adams MA. Neural arch load-bearing in old and degenerated spines. *J Biomech*. 2004;37:197–204.
44. Boswell MV, Manchikanti L, Kaye AD, et al. A best-evidence systematic appraisal of the diagnostic accuracy and utility of facet (zygapophysial) joint injections in chronic spinal pain. *Pain Physician*. 2015;18:E497–E533.
45. Nachemson A. Towards a better understanding of low-back pain: a review of the mechanics of the lumbar disc. *Rheumatol Rehabil*. 1975;14:129–143.