

Sensory Mapping of Lumbar Facet Joint Pain: A feasibility study

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Keywords:	Low Back Pain, Zygapophyseal joint, Denervation, Electric Stimulation, Sensory Threshold
Abstract:	<p>Objective: To evaluate the feasibility of sensory mapping of lumbar facet joint pain in patients scheduled to undergo radiofrequency denervation</p> <p>Design: Prospective cohort study</p> <p>Setting: University teaching hospital</p> <p>Subjects: 15 participants listed for radiofrequency denervation of lumbar facet joint</p> <p>Method: After written informed consent, participants were recruited to the study. Participants completed a pain diagram prior to their procedure. After successful image-guided placement of radiofrequency (RF) cannulas, the sensory detection threshold using 50 Hz stimulation was obtained, followed by application of suprathreshold stimulation. Participants mapped the stimulated area in comparison to their pre-procedure pain diagram.</p> <p>Results: All 15 participants had previously undergone diagnostic blocks. All participants were able to report either pain or paraesthesia during suprathreshold stimulation. Fourteen out of 15 participants reported complete coverage of their usual pain area with suprathreshold stimulation of nerves scheduled for RF denervation. In one of the participants, an area of upper lumbar pain was not covered during suprathreshold stimulation. Nearly two-thirds of the participants (n=9), reported either pain or paraesthesia, outside their normal painful area during suprathreshold stimulation. A total of 71 nerves were scheduled for RF denervation. Sensory electrical stimulation was successfully achieved in 68 out of 71 nerves (96%). The average sensory detection threshold was found to be 0.3 V while the suprathreshold stimulation was 0.6 V.</p> <p>Conclusion: Lumbar facet joint pain can be mapped using suprathreshold sensory stimulation, which has the potential to introduce objectivity during RF denervation.</p>

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25 stimulation, which has the potential to introduce objectivity during RF denervation.
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31 **Key Words:** Low back pain, Electrical Stimulation, Facet joint, Radiofrequency Neurotomy,
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Introduction:

Low back pain is a very common chronic pain condition subjected to different treatment modalities including somatic and psychological approaches. The somatic approach seeks to establish a diagnosis. A variety of structures such as facet joints, intervertebral discs, sacro-iliac joints and muscles are known to be involved in low back pain. The well-established pathoanatomical approach employs precision diagnostic blocks to identify these anatomical structures as source of nociception. Of them, facet joints have been found to be one of the most common structure contributing significantly to back pain [1]. In clinical practice, the medial branches from posterior primary rami or dorsal rami itself are anaesthetised to establish the diagnosis of facet joint pain. Radiofrequency (RF) denervation of these nerves are usually offered as evidence based interventional pain management option to the sufferers [2].

The validity and reliability of the medial branch blocks have been well established. However, their clinical utility has been a subject of discussion due to the false positive rates, post-procedure evaluation and cost-effectiveness [3]. As the false positive rates of single diagnostic blocks are high at around 30%, controlled diagnostic blocks with a stringent post-procedure evaluation with 75% improvement in the index pain are recommended by the Spine Intervention Society [4]. However, pragmatic trials highlight that such strict criteria are not often followed [5]. A survey of pain physicians in the United Kingdom also revealed significant variation in practice including the number of diagnostic blocks [6]. Due to low morbidity associated with the procedure, RF denervation has also been carried out without prior diagnostic blocks [7]. In addition, the currently accepted diagnostic paradigm follows a

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3 standardised approach of blocking 2 nerves for each lumbar facet joint but this approach
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5 does not account for any anatomical variations. Thus, if we develop a strategy for
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7 identifying the culpable nerves – medial branches and/ or dorsal rami, it would account for
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9 any anatomical variation and introduce objectivity. Hence, we investigated the feasibility of
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11 sensory mapping of the medial branches using suprathreshold sensory stimulation during
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13 RF denervation.
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20 **Methods:**

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24 The study was prospectively registered on the ClinicalTrials.Gov database: Identifier:

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30 *Participants:*

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34 Following prospective ethical approval from the ***** Research Ethics
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36 Committee, consecutive male and female patients aged 18 to 80 years who were
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38 scheduled for RF denervation at ***** were invited to participate in the study.
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40 Participants who were deemed able to complete a pain diagram as well as understand and
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42 comprehend instructions given in English were recruited. Participants who had requested or
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44 required sedation during the procedure were excluded. This was a pilot feasibility study
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46 which aimed to recruit 15 patients.
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53 *Procedure:*

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56 The standard local practice is to carry out a single diagnostic block with lidocaine before
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58 being considered RF denervation. The target joints are identified based on the presence of
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3 paraspinal tenderness under imaging. Two nerves are blocked for each facet joint as
4 advocated by the Spine Intervention Society guidelines. For denervation, RF cannulas are
5 placed parallel to the nerve in the groove between superior articular and transverse
6 processes using fluoroscopic pillar views as advocated by the Spine Intervention Society
7 [4]. Our local practice is to use 50 Hz stimulation for sensory detection and 2 Hz motor
8 stimulation up to 2 Volts as safety check before anaesthetising the medial branches and / or
9 dorsal ramus for RF denervation.
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23 After written informed consent, participants completed a pre-procedure pain diagram - a
24 body map of their usual back pain and rated their pain on a visual analog scale of 0 to 10.
25 The standard procedure for RF denervation was undertaken. After adequate fluoroscopic
26 confirmation of the RF cannula placement, lumbar medial branches and dorsal rami were
27 stimulated using 50 Hz electrical stimulation. The voltage at which participants felt any new
28 sensation (tingling, pressure or back pain) was considered as the sensory detection
29 threshold. The voltage was deliberately increased to a maximum of threefold of the sensory
30 detection threshold, considered as the suprathreshold stimulation. After suprathreshold
31 stimulation of each nerve, participants were asked to describe the area where they were
32 feeling pain in a body map, considered as sensory mapping. They were asked to compare
33 this against the pain diagram completed prior to the procedure. For each stimulated nerve,
34 the collected data included sensory detection threshold voltage, suprathreshold stimulation
35 voltage, whether the stimulation was within the pain area or extended beyond the pain area,
36 as well as the percentage of usual pain area covered. The standard procedure for RF
37 denervation was then completed in accordance with local practice.
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3 Other participant data collected included age, sex, occupation, duration of pain, pain co-
4 morbidity, the number of nerves scheduled for lesioning and total coverage of pain after
5 stimulation.
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10 11 12 13 *Data analysis*

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16 Anonymised data was entered into case record forms prior to transfer to a spreadsheet.

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19 Descriptive analysis was undertaken.
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25 **Results**

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28 Twenty four potential participants were invited to take part in the study and 18 were
29 recruited. The CONSORT diagram is shown in Figure 1. Three participants were excluded
30 due to the requirement for sedation and data from 15 participants are presented. Baseline
31 participant data are presented in Table 1. Eleven participants stated that they had other
32 pain comorbidities, such as chronic widespread pain or other neuropathic pain, in addition
33 to their lower back pain. The median [range] duration of low back pain was 7 [2 -30] years.
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35 **The median pain score on the day of RF procedure was 7.5 [3 to 8.5].** Two participants had
36 previous RF denervation.
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50 A total of 71 nerves were scheduled for RF denervation. Sensory stimulation was
51 successfully achieved in 68 out of 71 nerves (95.8%) using 50 Hz electrical stimuli. All 15
52 participants reported either pain or paraesthesia during suprathreshold stimulation and 14
53 of 15 participants (93.3%) reported complete coverage of their usual painful area with
54 suprathreshold stimulation. The median coverage of pain areas for L3, L4 medial branches
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3 and L5 dorsal rami was found to be 50%. In 5 participants, suprathreshold stimulation of
4 one nerve reproduced all their pain, thereby providing 100% coverage of the pain area. In
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6 only one of the participants, an area of upper lumbar pain was not covered with
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10 suprathreshold stimulation.

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16 Nearly two-thirds of the participants (n=9, 60%), reported pain / paraesthesia outside their
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18 normal painful area during suprathreshold stimulation. This was particularly evident in 4 out
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20 5 patients who had 100% coverage with a single nerve stimulation. Of the stimulated 68
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22 nerves, five (7.4%), produced pain / paraesthesia completely outwith the participant's
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24 painful region while the pain / paraesthesia extended beyond the normal pain region in
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26 another 11 nerves (16%). The most common nerve, not contributing to pain, was found to
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28 be L5 dorsal ramus (n= 9).
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36 The details of painful area covered by individual nerves, sensory detection threshold and
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38 suprathreshold stimulation can be found in Table 2. The sensory detection threshold ranged
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40 from 0.1 V to 0.8 V with an average of 0.3 V. The suprathreshold stimulation voltage
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42 ranged from 0.3 V to 1.5 V with an average of 0.6 V. In 60% (n=41), a 3-fold increase in
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44 sensory detection voltage was needed while a 2-fold increase was needed in 19% (n = 13)
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46 to achieve an adequate clinical response. For a further 13% (n=9) the voltage increase lay
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48 between 2 and 3 times the sensory detection threshold and in 7% (n=5), adequate clinical
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50 response was achieved with increasing the voltage up to twice the sensory detection
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52 threshold. No adverse events were noted during this study.
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Discussion:

In our study, we chose to electrically stimulate the nerves which have been scheduled for RF denervation to explore acceptability of suprathreshold stimulation, feasibility of sensory mapping of lumbar facet joint pain and to evaluate whether there is concurrence with the nerve blocks. We showed that it is feasible to reproduce the pain in patients with chronic back pain using 50 Hz electrical stimulation in all participants.

Ninety three percent of participants had complete coverage of the back pain with suprathreshold stimulation implying concurrence with the diagnostic nerve blocks and introducing objectivity during RF denervation. However, suprathreshold stimulation produced pain / paraesthesia outside the normally painful area in 60% of the participants. Non-painful region mapping was noted more with participants who had full coverage with single nerve stimulation alone. Thus, it can be inferred that all the stimulated nerves were not involved in pain transmission. In addition, one participant's area was not fully covered, implying that all the appropriate nerves were not included for RF denervation. In our study population, 7.5% of the denervated nerves did not contribute to pain transmission as detected by suprathreshold stimulation.

Electrical stimulation of lumbar medial branches and dorsal rami was carried out in chronic low back pain patients as early as 1997. A study conducted by Fukui et al. is very similar to the present study, as they electrically stimulated the medial branches of the dorsal rami and mapped out the 'geographical' distribution of each single nerve before RF denervation [8]. However, it is unclear to what extent they related this back to the patient's original pain.

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3 Windsor et al. demonstrated that a reproducible perceptible stimulation of all lumbar (L1 to
4 L4) medial branches and L5 dorsal ramus can be obtained between 0.05 to 0.25 V using 50
5 Hz stimulation in healthy volunteers [9]. Recently, O'Neill et al. demonstrated that
6 increasing the sensory detection threshold by a factor of three, on average, induces local
7 pain of the stimulated lumbar facet joint [10]. So, we used up to a 3-fold increase in the
8 sensory detection threshold and successfully induced / reproduced the back pain. The
9 average suprathreshold stimulation in our study, was 0.6V.
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23 Initial selection of the lumbar facet joints for diagnostic blocks is subjective. Lower lumbar
24 facet joints are commonly affected and tenderness of these joints under imaging is
25 conventionally used in clinical practice to choose the joints. This dictates the number of
26 nerves to target diagnostic blocks. For a given facet joint (L4/5), the medial branch from the
27 same level (L4) and one level above (L3) are anaesthetised. If the patients responds
28 positively by 50 or 80% relief, RF denervation of these nerves is carried out. In the event of
29 inadequate relief from blocking nerves of the selected joints, other joints may subsequently
30 be targeted for blocks, thereby exposing patients to further invasive treatments with
31 inherent risks.
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The diagnostic blocks have shortcomings in terms of high-false positive rates, post-procedural evaluation and cost-effectiveness [3, 11, 12]. In addition, anaesthetising 2 nerves for a given lumbar facet joint ignores the well-established anatomical variations or aberrant medial branch innervation [13 -15]. All of these have the potential to negatively influence the success rate of RF treatment [16].

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3 Thus suprathreshold electrical stimulation of medial branches has the potential to offer
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5 objectivity by reproducing patients' back pain and improving safety by limiting RF
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7 denervation to nerves involved in pain transmission.
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13 This was a pilot study to explore the feasibility and acceptability of suprathreshold electrical
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15 stimulation in a small number of participants. Further studies are needed to explore the
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17 utility of sensory mapping using suprathreshold stimulation during RF denervation and the
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19 clinical outcomes.
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26 **Conclusion:**

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29 Electrical sensory stimulation was able to recreate lumbar pain in almost all patients
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31 indicating that it may complement the diagnostic anaesthetic blocks by introducing
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33 objectivity in identifying nerves during RF denervation, improved patient safety, and a better
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35 patient experience.
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42 **Acknowledgements:** We would like to thank ***** for his statistical advice on
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44 this paper.
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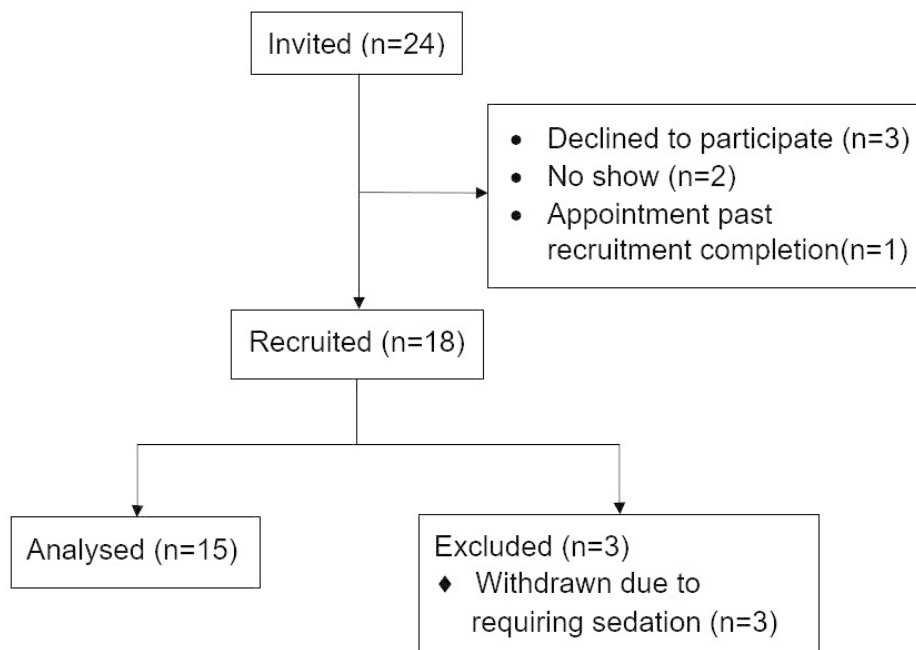


Figure 1. Study flow diagram

238x158mm (96 x 96 DPI)

Table 1: Baseline demographics

Demographics	
Patients (M=7, F=8)	15
Age (Years)	62 (30-80)*
BMI (kg/m ²)	26.8 (21.9-39.1)*
Pain duration (Years)	7 (2-30)*
Pain Score Average (0-10)	7.5 (3-8.5)*
Previous RF denervations	2/15

* data presented as median (range)

Table 2: Individual nerve characteristics

Nerve	Number <i>n</i>	Sensory detection threshold in volts	Suprathreshold Stimulation in volts	Contribution to painful area
L2	2	0.16 (0.15-0.18)	0.44 (0.42-0.45)	65% (50-80%)
L3 *	20	0.3 (0.15-0.8)	0.8 (0.3-1.4V)	50% (0-100%)
L4 *	24	0.3 (0.1-0.7)	0.8V (0.3-1.5V)	50% (10-100%)
L5	23	0.3 (0.12-0.6)	0.9V (0.3-1.5V)	50% (0-100%)

*excluding nerves that were not stimulated (one L3 and two L4 medial branches)

data expressed as median (range)