Original Experimental

Ángeles Canós-Verdecho, Ruth Robledo, Rosa Izquierdo, Ara Bermejo, Elisa Gallach, David Abejón, Pilar Argente, Isabel Peraita-Costa, María Morales-Suárez-Varela*

Confirmatory study of the usefulness of quantum molecular resonance and microdissectomy for the treatment of lumbar radiculopathy in a prospective cohort at 6 months follow-up

https://doi.org/10.1515/sjpain-2023-0077
received June 12, 2023; accepted December 7, 2023

Abstract

Objectives – Low back pain is a common musculoskeletal complaint and while prognosis is usually favorable, some patients experience persistent pain despite conservative treatment and invasive treatment to target the root cause of the pain may be necessary. The aim of this study is to evaluate patient outcomes after treatment of lumbar radiculopathy (LR) with quantum molecular resonance radiofrequency coblation disc decompression and percutaneous microdiscectomy with grasper forceps (QMRG).

Methods – This prospective cohort study was carried out in two Spanish hospitals on 58 patients with LR secondary to a contained hydrated lumbar disc hernia or lumbar disc protrusion of more than 6 months of evolution, which persisted despite conservative treatment with analgesia, rehabilitation, and physiotherapy, and/or epidural block, in the previous 2 years. Patients were treated with QMRG and the outcomes were measured mainly using the Douleur Neuropathique en 4 Questions, Numeric Rating Scale, Oswestry Disability Index, SF12: Short Form 12 Health Survey, Patient Global Impression of Improvement, Clinical Global Impression of Improvement, and Medical Outcomes Study Sleep Scale.

Results – Patients who received QMRG showed significant improvement in their baseline scores at 6 months post-treatment. The minimal clinically important difference (MCID) threshold was met by 26–98% of patients, depending on the outcome measure, for non-sleep-related outcomes, and between 17 and 62% for sleep-related outcome measures. Of

*** Corresponding author: María Morales-Suárez-Varela**, Unit of Preventive Medicine and Public Health, Department of Preventive Medicine and Public Health, Food Sciencs, Toxicology and Forensic Medicine, Universitat de València, Av. Vicent Andrés Estellés s/n, 46100 Burjassot, Valencia, Spain; CIBER Epidemiology and Public Health (CIBERESP), The Institute of Health Carlos III (ISCIII), Av. Monforte de Lemos, 3-5, Pabellón 11, Planta 0, 28029 Madrid, Spain, e-mail: maria.m.morales@uv.es

Ángeles Canós-Verdecho: Multidisciplinary Pain Management Unit, Hospital Universitari i Politècnic La Fe, Av. de Fernando Abril Martorell, 106, 46026 Valencia, Spain; Anaesthesiology Department, Hospital Universitari i Politècnic La Fe, Av. de Fernando Abril Martorell, 106, 46026 Valencia, Spain, e-mail: mangelescanos10@gmail.com

Ruth Robledo: Multidisciplinary Pain Management Unit, Hospital Universitari i Politècnic La Fe, Av. de Fernando Abril Martorell, 106, 46026 Valencia, Spain; Anaesthesiology Department, Hospital Universitari i Politècnic La Fe, Av. de Fernando Abril Martorell, 106, 46026 Valencia, Spain, e-mail: laruthi@hotmail.com

Rosa Izquierdo: Multidisciplinary Pain Management Unit, Hospital Universitari i Politècnic La Fe. Av. de Fernando Abril Martorell, 106, 46026 Valencia, Spain; Anaesthesiology Department, Hospital Universitari i Politècnic La Fe, Av. de Fernando Abril Martorell, 106, 46026 Valencia, Spain, e-mail: rosizaguirre@hotmail.es

Ara Bermejo: Multidisciplinary Pain Management Unit, Hospital Universitari i Politècnic La Fe, Av. de Fernando Abril Martorell, 106, 46026 Valencia, Spain, e-mail: arabermejo@hotmail.com

Elisa Gallach: Multidisciplinary Pain Management Unit, Hospital Universitari i Politècnic La Fe, Av. de Fernando Abril Martorell, 106, 46026 Valencia, Spain; Psychiatry Department, Hospital Universitari i Politècnic La Fe, Av. de Fernando Abril Martorell, 106, 46026 Valencia, Spain, e-mail: gallach.eli@gmail.com

David Abejón: Multidisciplinary Pain Management Unit, Hospital Universitario Quirónsalud, Calle Diego de Velázquez, 1, 28223 Pozuelo de Alarcón, Madrid, Spain, e-mail: dabejongonzalez@gmail.com

Pilar Argente: Anaesthesiology Department, Hospital Universitari i Politècnic La Fe, Av. de Fernando Abril Martorell, 106, 46026 Valencia, Spain; Surgical Specialities Department, Hospital Universitari i Politècnic La Fe, Av. de Fernando Abril Martorell, 106, 46026 Valencia, Spain, e-mail: argente_marnav@gva.es

Isabel Peraita-Costa: Unit of Preventive Medicine and Public Health, Department of Preventive Medicine and Public Health, Food Sciencs, Toxicology and Forensic Medicine, Universitat de València, Av. Vicent Andrés Estellés s/n, 46100 Burjassot, Valencia, Spain; CIBER Epidemiology and Public Health (CIBERESP), The Institute of Health Carlos III (ISCIII), Av. Monforte de Lemos, 3-5, Pabellón 11, Planta 0, 28029 Madrid, Spain, e-mail: isabel.peraita@uv.es

the 14 outcome measures studied, at least 50% of the patients met the MCID threshold in 8 of them.
Conclusion – Treatment of LR with QMRG appears to be effective at 6 months post-intervention.

Keywords: lumbar radiculopathy, nucleoplasty, prospective cohort, quantum molecular resonance, radiofrequency coblation

1 Introduction

Disc herniation can occur in any intervertebral disc. However, lumbar discs account for approximately 90–95% of cases [1]. The worldwide prevalence of symptomatic lumbar herniated disc (HD) ranges from 1 to 3%, depending on sex and age [2–11]. The highest prevalence is seen in male patients between the ages of 30 and 50 [12]. In patients under 55 years old, around 95% of the HDs are located at the L4-L5 level, while in those over 55 years old, HDs are more commonly found above the L4-L5 level [13].

Lumbar radiculopathy (LR) is a condition of the nerve roots in the lower back in the area where they leave the spine, which can cause pain, numbness, or weakness in the lower back, buttock, and down the leg [14]. The most common causes of LR are HD with nerve compression, foraminal stenosis, diabetes, nerve root injuries, and scar tissue [14–16]. Posterior degeneration of the annulus fibrosus of the intervertebral disc with the migration of nuclear material through a fissure in the annulus or migration of a nucleus fragment, which protrudes posteriorly with or without compression of neurological structures, such as the spinal cord or the emerging root towards the foramen, may be the cause of secondary LR.

Common treatment options for LR include the use of NSAIDs, corticosteroids or opiates, different physical therapy techniques, epidural or nerve blocks, and radiofrequency. None of the aforementioned options address the root cause of the pain, and they are solely aimed at eliminating or reducing the pain. This is due to the fact that the prognoses for lumbar disc herniation and LR are generally favorable, and in many cases invasive treatment targeting the root cause is not needed. Discectomy can be an effective treatment for lumbar and radicular pain in up to 75–80% of the cases, but pain recurrence has been reported between 3 and 18% after the procedure, and disc height is lost 63% of the time [17].

Among the treatment options available that do address the root cause of the pain are percutaneous discectomy and microdiscectomy. These decompressive techniques, that relieve the pressure in the disc tissue, are a minimally invasive, effective, and safe alternative [18–20].

Quantum molecular resonance (QMR) radiofrequency coblation [1] disc decompression and percutaneous microdiscectomy with Grasper© forceps (QMRG) is an example of a combined treatment option and the subject of this study. The Resadisc® bipolar device (Vertical S.r.l., Spresiano, Italy) used in the intervention bases its operating principle on an innovative high-frequency QMR technology. According to the QMR principle, the energy is transmitted to the tissue packed into quanta, capable of breaking the molecular bonds of the nucleus pulposus in the biological tissue and allows disc decompression, avoiding the development of high temperature. It is combined with a percutaneous microdiscectomy with Grasper© forceps [21].

The aim of this study is to evaluate patient outcomes after treatment of LR with QMRG.

2 Materials and methods

This study is a prospective cohort study that follows an intervention.

2.1 Ethics

Approval (registration number 2021-341-1) for the research described was obtained from the "Comité de Ética de la Investigación con medicamentos del Instituto de Investigación Sanitaria La Fe" presided by Dr. Adela Cañete Nieto in Avenida Fernando Abril Martorell, 106 Torre A 7ª planta, 46026 Valencia (Spain) on the 9th of June 2021. The study adheres to the principles outlined in the Declaration of Helsinki for all human experimental investigations. Verbal and written informed consents were obtained from all patients prior to their inclusion in the study.

2.2 Patients

The initial diagnostic and treatment criteria for inclusion in this study were that the patient must be over 18 years of age and be affected with LR secondary to a L4-L5 contained hydrated lumbar disc hernia or lumbar disc protrusion of more than 6 months of evolution, persistent despite conservative treatment with analgesia (pregabalin, gabapentin, amitriptyline, duloxetine, and minor analgesics such as NSAIDs and paracetamol), rehabilitation and physiotherapy, and/or epidural block (transforaminal epidural blocks of the affected root under

fluoroscopy with levobupivacaine and betamethasone/dexamethasone) in the previous 2 years. Patients that presented discogenic pain in addition to the secondary LR were excluded.

The next step was the identification of all patients that met the given criteria and could potentially be included in this study in the hospital database. The database search and patient identification process yielded a total of 64 candidate patients. Once identified, these patients were contacted and received detailed information about the study, including the intervention and what data would be collected and how it would be treated. Patients who agreed to participate signed and dated the informed consent before being included in the study. Three patients were unreachable, and two did not consent to participate, leaving the sample with 59 patients. At this point, the sample of 59 patients was considered to meet all the inclusion criteria, which, apart from the aforementioned diagnostic and treatment criteria, included the following:

1. The patient confirmed that they understand the information about the study and expressed their willingness to participate in it by signing the corresponding informed consent form.
2. The patient could and was willing to meet all study requirements.

After informed consent was received, and all the relevant medical data were collected from the patients' medical records, these were reviewed to ensure that none of the patients met any of the exclusion criteria listed below. Patients were excluded if they met any of the following criteria:

1. The patient was immunosuppressed.
2. The patient had a history of cancer and had required active treatment starting from 6 months prior to the intervention to 6 months post-intervention.
3. The patient had a documented history of substance abuse (narcotics, alcohol, etc.) or substance dependence starting from 6 months prior to the intervention to 6 months post-intervention.
4. The patient had a systemic infection at the time of the intervention.
5. The patient was currently pregnant or was pregnant at any point during the study period.
6. The patient was already participating in other clinical research with an active treatment group.
7. The patient had severe neurological or psychiatric pathology.
8. The patient had received prior treatment by discectomy or percutaneous microdiscectomy, with or without a disc prosthesis.
9. The patient was treated with anticoagulant therapy starting from 6 months prior to the intervention to 6 months post-intervention.
10. The patient had an active skin infection in the access area of the technique at the time of intervention.

Of the 59 patients that met the inclusion criteria, one met any of the exclusion criteria, and therefore the final sample consisted of 58 patients. Patients then underwent treatment with QMRG and completed a 6-month follow-up with the Multidisciplinary Pain Management Unit of the La Fe University and Polytechnic Hospital in Valencia (MPMU).

2.3 Device and intervention

The device and intervention have been extensively described in a previous publication. For full details, see Canós-Verdecho et al. [21]. Intervention dates were from 8th July 2021 to 9th December 2021 and final follow-up was completed in June 2022.

2.4 Outcome measures

The intervention protocol for this study, followed at the MPMU, stipulated that the patient's evolution would be evaluated using several questionnaires and scales (listed below) before the day of intervention and at 1 month, 3 months, and 6 emonths post-intervention. The specialists at the MPMU prospectively collected and recorded these data both before and after the intervention. Additionally, any adverse effects were recorded in the patients' medical history if they occurred.

1. DN4: Douleur Neuropathique en 4 Questions
2. NRS: Numeric Rating Scale
3. ODI: Oswestry Disability Index
4. SF-12: Short Form 12 Health Surveys
5. PGI: Patient Global Impression of Improvement
6. CGI: Clinical Global Impression of Improvement
7. MOS: Medical Outcomes Study Sleep Scale

The MOS Sleep Scale is composed of 12 items and results are presented grouped into five subscales (sleep disturbance [SLPD 4], snoring [SLPSNR1], awakening short of breath or with a headache [SLPSOB1], sleep adequacy [SLPA2], and somnolence [SLPS3]) and two indexes (SLP6 and SLP9). Each subscale and index score is generated by averaging specific MOS items: SLPD 4 (1, 3, 7, and 8),

SLPSNR1 [10], SLPSOB1 [5], SLPA2 (4 and 12), SLPS3 (6, 9, and 11), SLP6 (4, 5, 7, 8, 9, and 12), and SLP9 (1, 3, 4, 5, 6, 7, 8, 9, and 12).

The minimal clinically important difference (MCID) is the smallest change considered important or notable by the patient. It is a patient-centered concept that captures the magnitude of change, which can be positive or negative, and the value patients place on this change [22–25]. MCID values vary depending on the patient, clinical context, and estimation method [26]; however, some outcome measures do have previously established and recognized MCIDs.

For outcome measures of chronic pain such as DN4 or NRS, a two-point (ten-point scale) or 30% improvement is considered the MCID [27]. The MCID for the ODI used in previous studies ranges from 4 to 15 points [28–31]. In this study, the ODI MCID has been set at 10 points as a compromise. When it comes to the SF-12 mental and physical component scores, >3.77 in MCS and >3.29 in PCS (normalized 100-point scale) have been established as the MCIDs in patients suffering from chronic lower back pain [32]. Given its sensitivity and strong correlation with patient satisfaction [33], a change of 1 in PGI is generally accepted as the MCID [34–36]. A previous study has established an MCID threshold for sleep-related outcomes measured using the MOS Sleep Scale scores (100-point scale) at ≥6.41 [37].

Table 1: Baseline characteristics of the patients

Characteristics	QMRG *n* = 58	*P*-value*
Age (years) at enrolment Mean value ± SD (range)	51.20 ± 10.73 (32.00–75.00)	—
Sex *n* (%)		0.094
Male	34 (57.6)	
Female	24 (40.7)	
BASAL_DN4 Mean value ± SD (Range)	4.42 ± 1.23 (0–7)	—
Marital status *n* (%)		0.001
Single	7 (11.9)	
Married	32 (54.2)	
Widowed	1 (1.7)	
Divorced	5 (8.5)	
Education *n* (%)		0.003
None	1 (1.7)	
Primary	14 (23.7)	
Secondary	19 (32.2)	
Tertiary	11 (18.6)	
Employment *n* (%)		0.002
Employed	22 (37.3)	
Unemployed	1 (1.7)	
Retired	8 (13.6)	
Homemaker	3 (5.1)	
Sick leave	4 (6.8)	
Work disabled	7 (11.9)	
Stress *n* (%)		0.663
Yes	21 (35.6)	
No	24 (40.7)	

**P*-value < 0.05 considered statistically significant.
SD: standard deviation; QMRG: quantum molecular resonance radiofrequency coblation and percutaneous microdiscectomy with grasper forceps.

2.5 Statistical analysis

Statistical analysis was performed using IBM SPSS Statistics for Windows, Version 26.0 (IBM Corp. Armonk, NY). Descriptive statistics were used to summarize the demographic variables (mean age and gender) and other medical variables (concomitant diseases). For quantitative data, mean value and standard deviation were reported for

Table 2: Mean patient scores for NRS, ODI, SF12, PGI, and CGI

	Pre-treatment Mean value ± SD (range)	1 month Mean value ± SD (range)	3 months Mean value ± SD (range)	6 months Mean value ± SD (range)	*P*-value *†
NRS	8.06 ± 1.25 (5–10)	5.28 ± 2.65 (0–10)	5.22 ± 2.74 (0–10)	5.26 ± 2.84 (0–10)	0.001
ODI	48.60 ± 14.28 (18–72)	37.32 ± 19.89(0–70)	35.21 ± 20.66 (0–70)	34.56 ± 20.19 (0–68)	0.001
SF12 Physical	20.36 ± 18.55 (0–87.50)	38.44 ± 28.55 (0–91.70)	39.78 ± 30.42 (4.20–100.0)	41.45 ± 30.76 (4.20–100.0)	0.009
SF12 Mental	40.22 ± 21.44 (10.0–85.80)	55.70 ± 26.73 (14.20–96.70)	55.17 ± 25.93 (14.50–96.70)	56.14 ± 26.14 (21.70–100.0)	0.001
SF12 Total	30.16 ± 17.44 (5.0–85.40)	46.66 ± 25.34 (11.30–94.20)	47.49 ± 26.29 (11.40–96.70)	47.44 ± 25.94 (15.80–96.70)	0.001
PGI	4.0 ± 0.0 (4–4)	2.79 ± 1.19 (1–5)	2.78 ± 1.22 (1–5)	2.84 ± 1.28 (1–5)	0.001
CGI	3.0 ± 0.0 (3–3)	2.04 ± 0.91 (1–4)	1.97 ± 0.99 (1–4)	2.07 ± 1.06 (1–4)	0.001

**P*-value <0.05 considered statistically significant.
†Comparison between different follow-up stage score trends.
SD: standard deviation; NRS: Numeric Rating Scale; ODI: Oswestry Disability Index; SF12: Short Form 12 Health Survey; PGI: Patient Global Impression of Improvement; CGI: Clinical Global Impression of Improvement.

variables with normal distribution, while minimum and maximum ranges were reported for variables without normal distribution. Qualitative variables were presented as relative and absolute frequencies. Inferential statistics were used to determine the level of statistical significance of the results. Fisher's exact test and paired *t*-test were used, with a significance level set at $p < 0.05$.

3 Results

Fifty-eight of the initial 64 patients (90.6%) met the established inclusion/exclusion criteria. These patients constituted the single cohort included in the study. In the 58 patients studied, no relevant complications related to the intervention were reported during the follow-up period. General personal baseline characteristics of the sample are shown in Table 1.

Table 2 shows the mean value ± standard deviations scores for pain and function outcomes at the established follow-up time periods. A statistically significant change during the follow-up was observed for all pain and function-related outcome measures.

Table 3 presents mean value ± standard deviations scores at the established follow-up time periods, for sleep-related outcome scores. A statistically significant change during the follow-up was observed for sleep disturbance (SLPD4) and sleep adequacy (SLPA2), as well as the two sleep problems indexes (SLP6 and SLP9).

Table 4 shows the differences in the pre- and 6-month post-intervention outcome scores and how these differences relate to the established MCID thresholds for each outcome measure. The results show that 6 months after treatment with QMRG, the MCID threshold is met by 26–98% of patients, depending on the outcome measure, for the non-sleep-related outcomes and by 17–62% of patients for the sleep-related outcome measures. Of the 14 outcome measures studied, in 8 of them at least 50% of patients met the MCID threshold.

4 Discussion

Back pain is very common, with an estimated overall prevalence between 54% and 80%, and its incidence is only expected to increase in the future mainly due to population aging [38]. Predictions estimate that close to 50% of those over 65 years could suffer from back pain [38]. Back pain has been proven to have a significant negative effect on

Table 3: Mean patient scores for MOS sleep scale subscales

	Pre-treatment	1 month		3 months		6 months			*P*-value*†
	Mean value ± SD	95% CI		Mean value ± SD		95% CI	Mean value ± SD	95% CI	
SLPD4	53.74 ± 21.68	(46.97–60.05)		42.93 ± 20.08		(36.90–48.96)	42.79 ± 18.97	(37.09–48.49)	43.46 ± 20.00	(37.45–49.47)	0.012
SLPSNR1	39.55 ± 24.67	(32.14–46.96)		39.11 ± 22.94		(32.21–46.00)	37.77 ± 1.83	(31.21–44.33)	37.77 ± 21.83	(31.21–44.33)	0.979
SLPSOB1	24.44 ± 19.94	(18.45–30.43)		20.44 ± 19.76		(14.50–26.38)	19.55 ± 19.30	(13.75–25.35)	18.66 ± 19.25	(12.88–24.45)	0.596
SLPA2	33.38 ± 19.00	(27.67–39.09)		47.11 ± 25.10		(39.56–54.65)	45.33 ± 23.21	(38.35–52.30)	45.33 ± 24.91	(37.84–52.81)	0.011
SLPS3	36.14 ± 15.27	(31.55–40.73)		31.26 ± 13.24		(27.28–35.24)	31.56 ± 12.74	(27.73–35.39)	31.04 ± 14.13	(26.79–35.29)	0.305
SLP6	47.40 ± 13.08	(43.47–51.33)		38.37 ± 15.07		(33.84–42.89)	38.81 ± 13.94	(34. 62–43.00)	38.56 ± 14.02	(34.34–42.77)	0.003
SLP9	48.50 ± 13.84	(44.34–52.66)		39.17 ± 14.98		(34.67–43.68)	39.73 ± 14.47	(35.38–44.08)	39.48 ± 14.50	(35.12–43.83)	0.002

*P-value <0.05 considered statistically significant.
†Comparison between different follow-up stage score trends.
SD: standard deviation; 95% CI: 95% confidence interval.

Table 4: Difference in outcome scores pre-intervention and at 6-month post-intervention

	Change Mean value ± SD	Normalized change† Mean value ± SD	Patients over MCID†† *n* (%)
NRS (MCID ≥2)	−2.65 ± 2.97	−0.32 ± 0.37	30 (52.3%)
ODI (MCID ≥10)	−13.20 ± 25.24	−0.17 ± 0.56	29 (50.0%)
SF12 Physical (MCID ≥3.29)	20.55 ± 35.88	2.13 ± 3.91	44 (75.0%)
SF12 Mental (MCID ≥3.77)	15.48 ± 28.11	4.87 ± 1.25	41 (70.5%)
SF12 Total (MCID ≥7.06)	65.80 ± 54.32	2.35 ± 3.71	56 (97.7%)
PGI (MCID ≥1)	−1.11 ± 1.26	−0.28 ± 0.32	25 (43.2%)
CGI (MCID ≥1)	−0.89 ± 1.04	−0.30 ± 0.35	23 (38.63%)
SLPD4 (MCID ≥6)	−10.05 ± 23.97	−0.09 ± 0.44	28 (43.1%)
SLPSNR1 (MCID ≥6)	−1.78 ± 18.50	0.06 ± 0.56	11 (16.9%)
SLPSOB1 (MCID ≥6)	−5.78 ± 16.31	−0.18 ± 0.50	14 (21.5%)
SLPA2 (MCID ≥6)	11.94 ± 25.89	0.69 ± 1.31	24 (36.9%)
SLPS3 (MCID ≥6)	−5.10 ± 16.36	−0.13 ± 0.32	26 (57.8 %)
SLP6 (MCID ≥6)	−8.84 ± 15.03	−0.15 ± 0.31	28 (62.2%)
SLP9 (MCID ≥6)	−9.03 ± 15.89	−0.15 ± 0.29	26 (57.8%)

†Mean change divided by initial score.

††Patients above the MCID threshold at 6 months post-intervention.

SD: standard deviation; MCID: minimal clinically important difference; NRS: Numeric Rating Scale; ODI: Oswestry Disability Index; SF12: Short Form 12 Health Survey; PGI: Patient Global Impression of Improvement; CGI: Clinical Global Impression of Improvement.

quality of life and currently, it is one of the first causes of long-standing limitation in performing usual activities and working hours lost [39].

Patients diagnosed with LR and treated with QMRG in this prospective cohort study showed significant improvement in pain, function, quality of life, and sleep 6 months post-treatment. However, it is important to note that the long-term effectiveness of QMRG should be reported as well, since bone remodeling and nerve compression can reoccur over time. Currently, with the available treatment options, the recurrence rate for spinal pain is estimated to be anywhere from 24 to 80% [38] with up to 60% of patients reporting pain 5 years after the initial episode [6,40–44].

LR is associated with poor sleep quality [45–47], which can in turn affect pain perception, increasing symptoms, and has also been associated with other negative short- and long-term effects on patient health [48–50]. Six months after treatment with QMRG, the patients included in this study presented significantly better results in the sleep-related outcome measures. This improvement in patient sleep quality after the treatment of their LR could mean that sleep was in fact significantly impacted by the LR.

When it comes to surgical techniques, there is a difference between technical and clinical results, technical success is not the same as clinical outcome success. Recently, the focus when evaluating surgical techniques has shifted toward a more patient and clinical outcome centered approach. Coblation for disc decompression has a technical success rate close to 100%, with the rare complications reported mainly related to pain due to the percutaneous approach [51–54]. Meanwhile, the rate of clinical success of this technique is estimated at between 56 and 85% [51–54].

Furthermore, the risk-reward factor of the intervention should be established, given the delicate nature of the areas treated and the associated risk. If QMRG is found to be a safe and effective long-term treatment option for LR, it could significantly improve the quality of life of patients who suffer from this condition as well as decrease its economic burden and societal impact on patients, their families, and the community as a whole [40,55–68].

4.1 Limitations

One of the main limitations of the study was the small sample size. This is due to the fact that the technique has not been available in Spain for very long, and therefore the sample of patients with a minimum follow-up time is limited. The comparison of the sample by personal or socio-economic characteristics that could elucidate a specific patient profile most likely to benefit from treatment with QMRG was not possible due to the sample size. Also, the lack of comparative data due to the absence of a control group may be a source of bias as the change observed in the cohort group could be due to the treatment being studied or to other factors. In this particular case, however, it would first not be responsible to leave patients with LR untreated just to be able to use them as a control group

and the cohort of patients included in the study in the first place is made up of patients with long-term persistent LR and spontaneous improvement due to factors outside of treatment with QMRG seems unlikely. In any health care system, specially a publicly funded one as is the case in this study, economic considerations must be taken into account when analyzing the efficacy of any novel treatment. However, in this study, neither total nor individualized cost or system utilization was recorded. Another limitation that should be noted is the possible selection bias that arises from the variations in the clinical judgment of the health care professionals involved in the treatment of LR. Finally, the impossibility for blinding to either the health care professionals or participants could possibly introduce an element of treatment bias and/or placebo effect.

5 Conclusion

In conclusion, this study demonstrated an improvement in outcome measures in patients with LR secondary to a contained lumbar disc hernia or lumbar disc protrusion treated with QMRG at 6 months following intervention. If patients present with LR that does not improve with previous treatments, QMRG is a minimally invasive technique that does not raise the temperature and can improve their clinical situation without significantly affecting the integrity of the disc. It is less aggressive than percutaneous lumbar endoscopic discectomy and therefore should have fewer secondary effects on the surrounding tissues of the lesion produced by the technique. With the results observed in this study, the novel technique of QMRG appears to be an effective alternative treatment option for LR, but given its newness, additional research is still needed to clarify its place among LR treatments and its long-term effects in patients.

Research ethics: Research involving human subjects complied with all relevant national regulations, institutional policies and is in accordance with the tenets of the Helsinki Declaration (as amended in 2013), and has been approved (registration number 2021-341-1) by the "Comité de Ética de la Investigación conmedicamentos del Instituto de Investigación Sanitaria La Fe."

Informed consent: Verbal and written informed consents were obtained from the patients prior to their inclusion in the study.

Author contributions: All authors have accepted responsibility for the entire content of this manuscript and approved its submission.

Competing interests: Authors state no conflict of interest.

Research funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Data availability: Data not available due to ethical/legal/commercial restrictions. The data used to support the findings of this study are restricted by the Research Ethics Committee of the La Fe University and Polytechnic Hospital in order to protect patient privacy.

References

[1] Nardella M. Management of lumbar disc herniation with Quantum Molecular Resonance. Preliminary study. Foggia: University of Foggia; 2017.
[2] Ito T, Takano Y, Yuasa N. Types of lumbar herniated disc and clinical course. Spine. 2001;26(6):648–51.
[3] Freburger JK, Holmes GM, Agans RP, Jackman AM, Darter JD, Wallace AS, et al. The rising prevalence of chronic low back pain. Arch Intern Med. 2009;169(3):251–8.
[4] Croft PR, Macfarlane GJ, Papageorgiou AC, Thomas E, Silman AJ. Outcome of low back pain in general practice: a prospective study. BMJ. 1998 May;316(7141):1356–9.
[5] Elliott AM, Smith BH, Hannaford PC, Smith WC, Chambers WA. The course of chronic pain in the community: results of a 4-year follow-up study. Pain. 2002;99(1-2):299–307.
[6] Enthoven P, Skargren E, Oberg B. Clinical course in patients seeking primary care for back or neck pain: a prospective 5-year follow-up of outcome and health care consumption with subgroup analysis. Spine. 2004 Nov;29(21):2458–65.
[7] Miedema HS, Chorus AM, Wevers CW, van der Linden S. Chronicity of back problems during working life. Spine. 1998;23(18):2021–8.
[8] Standiford Helm II, Medtronic SJ. Effectiveness of thermal annular procedures in treating discogenic low back pain. Pain Physician. 2012;15(3):E279–E304.
[9] Pang WW, Mok MS, Lin ML, Chang DP, Hwang MH. Application of spinal pain mapping in the diagnosis of low back pain–analysis of 104 cases. Acta Anaesthesiol Sin. 1998 Jun;36(2):71–4.
[10] Manchikanti L. Interventional pain medicine: a specialty in the New Millennium. Pain Physician. 2001 Oct;4(4):296–304.
[11] Chou R, Loeser JD, Owens DK, Rosenquist RW, Atlas SJ, Baisden J, et al. Interventional therapies, surgery, and interdisciplinary rehabilitation for low back pain: an evidence-based clinical practice guideline from the American Pain Society. Spine. 2009;34(10):1066–77.
[12] Salmerón Ríos R, Salmerón Ríos S, Tárraga Marcos L, Madrona Marcos F, Tárraga López PJ. Eficacia de la ozonoterapia en el tratamiento de la hernia de disco: Revisión Sistemática. J Negat No Posit Results. 2021;6(3):588–607.
[13] Manchikanti L, Abdi S, Atluri S, Benyamin RM, Boswell MV, Buenaventura RM, et al. An update of comprehensive evidence-based guidelines for interventional techniques in chronic spinal pain. Part II: guidance and recommendations. Pain Physician. 2013;16(2 Suppl):S49–S283.

[14] Ben-Yishay A Lumbar Radiculopathy. 2012; https://www.spine-health.com/conditions/lower-back-pain/lumbar-radiculopathy. Accessed April 6th, 2021.
[15] Ekşi MŞ, Kara M, Özcan-Ekşi EE, Aytar MH, Güngör A, Özgen S, et al. Is diabetes mellitus a risk factor for modic changes?: A novel model to understand the association between intervertebral disc degeneration and end-plate changes. J Orthop Sci. 2020;25(4):571–5.
[16] Li S, Huang C, Xiao J, Wu Y, Zhang Z, Zhou Y, et al. The potential role of cytokines in diabetic intervertebral disc degeneration. Aging Dis. 2022;13:5.
[17] Kosztowski T, Gokaslan ZL. Determining the extent of lumbar discectomy in patients with herniated lumbar discs. Insights Neurosurg. 2016;1:1.
[18] Eichen PM, Achilles N, Konig V, Mosges R, Hellmich M, Himpe B, et al. Nucleoplasty, a minimally invasive procedure for disc decompression: a systematic review and meta-analysis of published clinical studies. Pain Physician. 2014;17(2):149.
[19] Menchetti PPM, Canero G, Bini W. Percutaneous laser discectomy: experience and long term follow-up. Advances in Minimally Invasive Surgery and Therapy for Spine and Nerves. Springer; 2011. pp. 117–121
[20] Freeman BJ, Mehdian R. Intradiscal electrothermal therapy, percutaneous discectomy, and nucleoplasty: what is the current evidence? Curr Pain Headache Rep. 2008;12(1):14–21.
[21] Canós-Verdecho Á, Robledo R, Izquierdo R, Bermejo A, Gallach E, Argente P, et al. Preliminary evaluation of the efficacy of quantum molecular resonance coablative radiofrequency and microdiscectomy. Pain Manag. 2022;12(08):917–30.
[22] Wright A, Hannon J, Hegedus EJ, Kavchak AE. Clinimetrics corner: a closer look at the minimal clinically important difference (MCID). J Man Manip Ther. 2012;20(3):160–6.
[23] Schünemann HJ, Guyatt GH. Commentary – goodbye M (C) ID! Hello MID, where do you come from? Health Serv Res. 2005;40(2):593–7.
[24] Schünemann HJ, Puhan M, Goldstein R, Jaeschke R, Guyatt GH. Measurement properties and interpretability of the Chronic respiratory disease questionnaire (CRQ). J. Chronic Obstr Pulm Dis. 2005;2(1):81–9.
[25] Cook CE. Clinimetrics corner: the minimal clinically important change score (MCID): a necessary pretense. J Man Manip Ther. 2008;16(4):82E–3E.
[26] Salas Apaza JA, Franco JVA, Meza N, Madrid E, Loézar C, Garegnani L. Minimal clinically important difference: The basics. Medwave. 2021;21(3.
[27] Farrar JT, Young Jr JP, LaMoreaux L, Werth JL, Poole RM. Clinical importance of changes in chronic pain intensity measured on an 11-point numerical pain rating scale. Pain. 2001;94(2):149–58.
[28] Copay AG, Glassman SD, Subach BR, Berven S, Schuler TC, Carreon LY. Minimum clinically important difference in lumbar spine surgery patients: a choice of methods using the Oswestry disability index, medical outcomes study questionnaire short form 36, and pain scales. Spine J. 2008;8(6):968–74.
[29] Johnsen LG, Hellum C, Nygaard ØP, Storheim K, Brox JI, Rossvoll I, et al. Comparison of the SF6D, the EQ5D, and the Oswestry Disability Index in patients with chronic low back pain and degenerative disc disease. BMC Musculoskeletal Disord. 2013;14(1):1–9.
[30] Glassman S, Gornet MF, Branch C, Polly Jr D, Peloza J, Schwender JD, et al. MOS short form 36 and Oswestry Disability Index outcomes in lumbar fusion: a multicenter experience. Spine J. 2006;6(1):21–6.
[31] Monticone M, Baiardi P, Vanti C, Ferrari S, Pillastrini P, Mugnai R, et al. Responsiveness of the Oswestry Disability Index and the Roland Morris Disability questionnaire in Italian subjects with subacute and chronic low back pain. Eur Spine J. 2012;21(1):122–9.
[32] Díaz-Arribas MJ, Fernández-Serrano M, Royuela A, Kovacs FM, Gallego-Izquierdo T, Ramos-Sánchez M, et al. Minimal clinically important difference in quality of life for patients with low back pain. Spine. 2017;42(24):1908–16.
[33] Fischer D, Stewart AL, Bloch DA, Lorig K, Laurent D, Holman H. Capturing the patient's view of change as a clinical outcome measure. JAMA. 1999;282(12):1157–62.
[34] Jaeschke R, Singer J, Guyatt GH. Measurement of health status: ascertaining the minimal clinically important difference. Control Clin Trials. 1989;10(4):407–15.
[35] Wyrwich KW, Wolinsky FD. Identifying meaningful intra-individual change standards for health-related quality of life measures. J Eval Clin Pract. 2000;6(1):39–49.
[36] Turner D, Schünemann HJ, Griffith LE, Beaton DE, Griffiths AM, Critch JN, et al. The minimal detectable change cannot reliably replace the minimal important difference. J Clin Epidemiol. 2010;63(1):28–36.
[37] Wells G, Li T, Maxwell L, MacLean R, Tugwell P. Determining the minimal clinically important differences in activity, fatigue, and sleep quality in patients with rheumatoid arthritis. J Rheumatol. 2007 Feb;34(2):280–9.
[38] Hoy D, March L, Brooks P, Blyth F, Woolf A, Bain C, et al. The global burden of low back pain: estimates from the Global Burden of Disease 2010 study. Ann Rheum Dis. 2014 Jun;73(6):968–74.
[39] Lidgren L. The bone and joint decade 2000–2010. Bull W H O. 2003;81:629.
[40] Boswell MV, Shah RV, Everett CR, Sehgal N, McKenzie Brown AM, Abdi S, et al. Interventional techniques in the management of chronic spinal pain: evidence-based practice guidelines. Pain Physician. 2005 Jan;8(1):1–47.
[41] Sjolie AN. Persistence and change in nonspecific low back pain among adolescents: a 3-year prospective study. Spine. 2004;29(21):2452–7.
[42] Brattberg G. Do pain problems in young school children persist into early adulthood? A 13-year follow-up. Eur J Pain. 2004;8(3):187–99.
[43] Elders LA, Burdorf A. Prevalence, incidence, and recurrence of low back pain in scaffolders during a 3-year follow-up study. Spine. 2004;29(6):E101–6.
[44] Smith BH, Elliott AM, Hannaford PC, Chambers WA, Smith WC. Factors related to the onset and persistence of chronic back pain in the community: results from a general population follow-up study. Spine. 2004;29(9):1032–40.
[45] Kelly GA, Blake C, Power CK, O'keeffe D, Fullen BM. The association between chronic low back pain and sleep: a systematic review. Clin J Pain. 2011;27(2):169–81.
[46] Marin R, Cyhan T, Miklos W. Sleep disturbance in patients with chronic low back pain. Am J Phys Med Rehabil. 2006 May;85(5):430–5.
[47] Alsaadi SM, McAuley JH, Hush JM, Maher CG. Prevalence of sleep disturbance in patients with low back pain. Eur Spine J. 2011;20(5):737–43.
[48] Medic G, Wille M, Hemels ME. Short- and long-term health consequences of sleep disruption. Nat Sci Sleep. 2017 May 19;9:151–61.
[49] Watson NF, Badr MS, Belenky G, Bliwise DL, Buxton OM, Buysse D, et al. Joint consensus statement of the American Academy of Sleep

Medicine and Sleep Research Society on the recommended amount of sleep for a healthy adult: methodology and discussion. Sleep. 2015;38(8):1161–83.
[50] Institute of Medicine (US). Committee on Sleep Medicine and Research. Sleep Disorders and Sleep Deprivation: An Unmet Public Health Problem. in: Colten HR, Altevogt BM, editors Washington (DC): National Academies Press (US); 2006.
[51] Mirzai H, Tekin I, Yaman O, Bursali A. The results of nucleoplasty in patients with lumbar herniated disc: a prospective clinical study of 52 consecutive patients. Spine J. 2007;7(1):88–92.
[52] Bhangle SD, Sapru S, Panush RS. Back pain made simple: an approach based on principles and evidence. Cleve Clin J Med. 2009 Jul;76(7):393–9.
[53] Choy DS, Case RB, Fielding W, Hughes J, Liebler W, Ascher P. Percutaneous laser nucleolysis of lumbar disc. N Engl J Med. 1987;317:771–2.
[54] Reddy AS, Loh S, Cutts J, Rachlin J, Hirsch JA. New approach to the management of acute disc herniation. Pain Physician. 2005;8(4):385.
[55] Latza U, Kohlmann T, Deck R, Raspe H. Can health care utilization explain the association between socioeconomic status and back pain? Spine. 2004;29(14):1561–6.
[56] Luo X, Pietrobon R, Sun SX, Liu GG, Hey L. Estimates and patterns of direct health care expenditures among individuals with back pain in the United States. Spine. 2004 Jan;29(1):79–86.
[57] McGorry RW, BSPT BSW, Snook SH, Hsiang SM. The relation between pain intensity, disability, and the episodic nature of chronic and recurrent low back pain. Spine. 2000;25(7):834–41.
[58] Leigh JP, Markowitz SB, Fahs M, Shin C, Landrigan PJ. Occupational injury and illness in the United States: estimates of costs, morbidity, and mortality. Arch Intern Med. 1997;157(14):1557–68.
[59] Freedman VA, Martin LG, Schoeni RF. Recent trends in disability and functioning among older adults in the United States: a systematic review. JAMA. 2002;288(24):3137–46.
[60] Eriksen J, Sjøgren P, Ekholm O, Rasmussen NK. Health care utilisation among individuals reporting long-term pain: an epidemiological study based on Danish National Health Surveys. Eur. J. Pain. 2004;8(6):517–23.
[61] Turner JA, Franklin G, Heagerty PJ, Wu R, Egan K, Fulton-Kehoe D, et al. The association between pain and disability. Pain. 2004;112(3):307–14.
[62] Bell GK, Kidd D, North RB. Cost-effectiveness analysis of spinal cord stimulation in treatment of failed back surgery syndrome. J Pain Symptom Manage. 1997;13(5):286–95.
[63] De Lissovoy G, Brown RE, Halpern M, Hassenbusch SJ, Ross E. Cost-effectiveness of long-term intrathecal morphine therapy for pain associated with failed back surgery syndrome. Clin Ther. 1997;19(1):96–112.
[64] Turk DC. Clinical effectiveness and cost-effectiveness of treatments for patients with chronic pain. Clin J Pain. 2002;18(6):355–65.
[65] Walker BF, Muller R, Grant WD. Low back pain in Australian adults: the economic burden. Asia Pac J Pub Health. 2003;15(2):79–87.
[66] Steenstra IA, Verbeek JH, Heymans MW, Bongers PM. Prognostic factors for duration of sick leave in patients sick listed with acute low back pain: a systematic review of the literature. Occup Environ Med. 2005 Dec;62(12):851–60.
[67] Kent PM, Keating JL. The epidemiology of low back pain in primary care. Chiropr Osteopath. 2005;13(1):1–7.
[68] Thelin A, Holmberg S, Thelin N. Functioning in neck and low back pain from a 12-year perspective: a prospective population-based study. J Rehabil Med. 2008;40(7):555–61.