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# Two-Month NSSD and Multi-Coil rPMS in Large Lumbar Disc Herniation: MRI Outcomes vs. a Three-Month Protocol

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## Abstract

**Background:** Non-invasive treatment of large lumbar disc herniation (LDH > 6 mm) combining non-surgical spinal decompression (NSSD) and single-coil repetitive peripheral magnetic stimulation (rPMS) is effective but demanding (3 months, 40 sessions). Modern double-coil and handheld rPMS configurations may optimize field coverage and shorten treatment duration. **Aim:** To evaluate a 2-month (24-session) NSSD and multi-coil rPMS protocol for large LDH and compare structural and clinical outcomes with the earlier 3-month regimen. **Methods:** Nine consecutive patients with refractory LDH (>6 mm) received NSSD and multi-coil rPMS three times weekly for two months (Group 1). Pre- and post-treatment T2 MRI parameters (AP length, area, canal dimensions, Herniation Index [HI], Michigan State University classification grade [MSU]), qualitative pain resolution, and clinical tests were assessed within Group 1 and compared with a historical 3-month comparator group (Group 2, n = 8). **Results:** In Group 1, herniation AP length decreased from 8.35 ± 2.40 to 3.05 ± 1.41 mm, area from 111.34 ± 28.96 to 43.81 ± 17.49 mm$^2$, and HI improved by 66.4 ± 16.8% (all $p < 0.005$). Canal dimensions increased significantly. All patients improved by ≥ 1 MSU grade, experienced complete pain resolution, and achieved normalization of neurological tests. Between-group comparisons showed no significant differences in MRI parameter improvements ($p > 0.05$). Clinical findings were maintained at three-month follow-up. **Conclusion:** A 2-month NSSD and multi-coil rPMS protocol achieves marked MRI regression and complete pain resolution, and no statistically significant between-group difference was detected compared to a 3-month regimen.

**Keywords**

Lumbar Disc Herniation, Non-Surgical Spinal Decompression, Repetitive Peripheral Magnetic Stimulation, Magnetic Resonance Imaging, Herniation Index, Conservative Management

## 1. Introduction

Low back pain (LBP) is the leading cause of years lived with disability worldwide and the most frequent reason for reduced working capacity in most economies [1]. Its prevalence has continued to rise with population growth and ageing, and further increases are projected over the coming decades [2]. Up to 80% of adults experience at least one episode of LBP during their lifetime [3].

Herniation of an intervertebral disc is among the most clinically relevant causes of LBP, particularly between the third and fifth decades of life. The condition is more common in men and is associated with heavy physical work, weightlifting, smoking, obesity and sedentary occupations [4] [5]. Herniation typically develops on a background of age-related degeneration, in which reduced proteoglycan synthesis leads to disc desiccation and loss of disc height; superimposed axial loading and biomechanical stress may then extrude nuclear material, often producing an acute symptomatic episode after physical exertion [4] [5]. When radicular symptoms are present, the resulting limitation of walking, standing and everyday activity is substantial [6].

Initial management is conservative and comprises relative rest, analgesia, physiotherapy and, in selected cases, epidural steroid injection. Urgent surgery is indicated for progressive neurological deficit, bladder or bowel dysfunction or saddle anaesthesia, whereas elective discectomy is generally considered when symptoms persist after conservative care has been exhausted [7] [8]. Most patients improve without surgery, and spontaneous regression of herniated material is well documented, but it occurs predominantly within the first six to twelve weeks after symptom onset; patients whose symptoms persist beyond this window are substantially less likely to recover spontaneously [9].

Quantitative assessment of herniation size on magnetic resonance imaging (MRI) is the most objective way of grading severity and informs the choice between conservative and operative management [10]. Herniations exceeding 6 mm in anteroposterior (AP) length have been associated with superior postoperative outcomes, and this dimension is often treated in practice as a marker of surgical suitability [10]. No precise size threshold reliably separates patients who will benefit from surgery from those who will not [11], yet large herniations remain a considerable therapeutic challenge for non-invasive care. Most studies of conservative modalities do not repeat MRI and rely instead on subjective symptom scores, which limits what can be concluded about structural recovery [12].

Non-surgical spinal decompression (NSSD) applies computer-regulated dis-

traction to lower intradiscal pressure and relieve neural compression, either as monotherapy or combined with other physical modalities [13] [14]. Although clinically effective across various spinal levels [15]-[17], objective imaging data remain limited. Choi *et al.* reported a 27% reduction in Herniation Index [13] and Demirel *et al.* observed a 1.7 mm decrease in herniation thickness [14]; however, both studies examined mild-to-moderate herniations and omitted canal and disc area metrics. Our previous work addressed this gap in large herniations (>6 mm) using a 3-month, 40-session protocol of NSSD, high-intensity laser (HIL), and single-coil rPMS [18]. Nevertheless, the clinical and financial burden of such an extended course limits its practical feasibility.

Repetitive peripheral magnetic stimulation (rPMS) generates eddy currents that depolarize neuromuscular structures without direct skin contact [19] [20]. Bypassing skin impedance renders rPMS virtually painless and enables deeper penetration than surface electrotherapy [20] [21]. Clinical evidence demonstrates that rPMS reduces pain and improves mobility in low back pain (LBP) [22], enhances symptomatic and electrophysiological outcomes in lumbar radiculopathy [23], and restores spinal motor control during multifidus stimulation [24] [25]. Proposed mechanisms include proprioceptive afferent recruitment [26], gate-control segmental inhibition [27], neuropathic pain modulation [28], and enhanced microvascular perfusion via muscle pumping [29].

Spatial distribution depends heavily on coil geometry [30]. Unlike angled joint configurations (e.g., knees at ~90˚) where converging fields enhance depth, side-by-side placement on the flat lumbar contour distributes magnetic energy over a significantly broader surface, prioritizing spatial coverage and tolerability over depth [31]-[33]. Combining double-coil with dynamic handheld rPMS induces widespread activation across the lumbopelvic myofascial complex. Clinically, attenuating hypertonicity and reflex guarding through this broad-field approach preconditions paraspinal tissues, reducing mechanical resistance and optimizing non-surgical spinal decompression (NSSD) distraction [34].

These advancements suggest that combining double-coil, single-coil, and handheld rPMS might reproduce previously observed structural regression within a shorter, 2-month (24-session) course [18]. This study primarily aimed to quantify clinical and MRI changes following a 2-month NSSD and multi-coil rPMS protocol in large lumbar disc herniations (>6 mm). The secondary aim was to compare these outcomes with the historical 3-month cohort [18].

## 2. Materials and Methods

### 2.1. Study Design and Setting

This was a retrospective, uncontrolled, single-centre study of consecutive patients treated at the BioSalus Rehabilitation Centre, Surdo di Rende, Italy. During the study period between March 2025 and June 2026, a total of nine patients met the inclusion and exclusion criteria and initiated the two-month protocol. All nine patients completed the full 24-session treatment course and had paired pre- and

post-treatment transverse T2-weighted MRI examinations available. The acquisition of all MRI scans was requested and coordinated by our centre. No patients were excluded, discontinued therapy, or were lost to follow-up. Thus, "consecutive" refers to all eligible patients treated with this protocol at our centre during the specified timeframe (Group 1). Eight patients treated at the same centre between November 2022 and September 2024 with a three-month protocol, previously reported in full [18], provided a historical comparator (Group 2). Group allocation was determined by the period of presentation and not by any patient characteristic; no randomisation or concurrent control was possible.

The study was conducted in accordance with the 1975 Declaration of Helsinki as adopted by the Convention on Human Rights and Biomedicine of the Council of Europe (1997) and endorsed by the General Assembly of the World Medical Association [35]. Retrospective ethical approval for the present cohort was granted by the Territorial Ethics Committee of the Calabria Region, which met on 29 December 2025 at the Renato Dulbecco University Hospital (A.O.U.), Catanzaro, and issued an opinion of approval under protocol number 319/2025. All patients gave written informed consent to treatment and to publication of their anonymised results.

## 2.2. Participants

Inclusion and exclusion criteria were identical for both groups and were those applied in the previous investigation [18]. Eligible patients had painful and disabling symptoms attributable to LDH, confirmed on functional assessment by the femoral nerve tension test [36], the straight leg raise test [37], evaluation of the ability to walk on tiptoes and heels, the Medical Research Council (MRC) scale for muscle strength [38] and pain assessment [39]. MRI had to confirm disc herniation with an AP length greater than 6 mm. Because most patients with symptomatic LDH recover spontaneously within the first 6 to 12 weeks of conservative treatment [9], only patients who had failed prior conservative care were eligible: the programme could begin no earlier than one month after the end, and three months after the start, of the preceding conventional treatment. Patients also had to consent to participate in the intensive non-invasive programme and to the associated assessments.

Patients were excluded if they had any contraindication to NSSD, namely malignant bone tumour, fracture, joint inflammation, spastic paralysis, osteoporosis, meningeal signs, abdominal hernia, pregnancy, cardiac or pulmonary insufficiency, haemorrhagic conditions, infectious disease, claustrophobia, or any condition in which movement was contraindicated. Patients with contraindications to rPMS, including implanted pacemakers, defibrillators, neurostimulators or other electronic or metallic implants, drug delivery pumps and a history of seizures, were also excluded, as were patients with contraindications to HIL in the cohort in which laser therapy was used.

## 2.3. Treatment Protocols

Group 1 (two-month protocol). Patients attended three times weekly for two con-

secutive months, completing 24 combined sessions. Each session began with NSSD (BTL Spinal Decompression, BTL Industries Ltd.), performed with the patient supine on a therapeutic couch with movable segments allowing precise positioning. A computerised control unit delivered the distraction force to the affected motion segment; the force never exceeded 50% of the patient's body weight. The decompression phase lasted 30 minutes and was followed by a stabilisation period during which the patient remained still and relaxed [13] [14].

NSSD was followed by rPMS (Super Inductive System DUO, BTL Industries Ltd.), which supports single-coil, double-coil and handheld applicators. Stimulation was delivered using a standard manufacturer-preset sequence comprising five consecutive sections (total duration of 540 seconds [9 minutes]), with frequencies ranging from 60 to 100 Hz, alternating frequency modulation (60 - 85 Hz), and a combination of constant and trapezoidal amplitude envelopes (trains featuring ramp-up, plateau, ramp-down, and rest periods). While the preset sequence parameters were applied as default, stimulation intensity was titrated individually for each patient based on subjective tolerance and verbal feedback, ensuring strong yet comfortable and non-painful neuromuscular activation. Stimulation was applied in two steps. In step 1, the double-coil applicator was positioned bilaterally on either side of the lumbar spine at an inter-coil angle adapted to the patient's anatomy and to the location of the symptomatic segment, and was used for myofascial release of the lumbar region. In step 2, radiculopathy of the affected lower limb was treated with the handheld applicator, which the therapist moved manually along the symptomatic limb to provide analgesia and muscle relaxation over the whole affected territory, combined with the single-coil applicator positioned over the affected spinal segment to support healing of the herniated tissue. Stimulation intensity was set individually according to patient tolerance and was maintained or increased in small increments at subsequent sessions, always with the patient's agreement. Treatment was individualised to the presenting symptoms and to the side of the radicular deficit. During the final phase of the programme, therapeutic exercise was added to consolidate the gains achieved: proprioceptive work to improve balance and body awareness, ambulatory step activities to improve gait, global postural re-education to correct posture, diaphragmatic rehabilitation to improve breathing mechanics, and core stability exercises to strengthen the deep trunk muscles. HIL was not used in Group 1.

Group 2 (three-month comparator protocol). The comparator cohort followed the protocol described previously [18]. Patients completed 40 combined sessions over three months, delivered five times weekly in the first month, three times weekly in the second and twice weekly in the third. Each session comprised NSSD as described above, followed by HIL, a modality with documented benefit when added to spinal decompression in lumbar disc protrusion [40], and single-coil rPMS (Super Inductive System, BTL Industries Ltd.). The same programme of therapeutic exercise was introduced in the final month. The two protocols therefore differ in three respects: total duration and number of sessions (two months

and 24 sessions versus three months and 40 sessions), rPMS configuration (double-coil, single-coil and handheld versus single-coil alone), and the presence of HIL in Group 2 only.

### 2.4. Outcome Measures

MRI was performed at baseline and immediately after completion of the programme. Patients were scanned in the standard supine position with extended legs and lumbar support. For both baseline and post-treatment examinations, the affected intervertebral level was identified on sagittal T2-weighted views, and corresponding transverse T2-weighted slices passing through the maximum extent of the herniation were selected via visual cross-referencing to ensure anatomical correspondence. All images were analysed by a single experienced clinician who routinely evaluates spinal MRI in everyday rehabilitation care; the assessor was blinded to study allocation and group comparisons, although blinded assessment of time point (pre- vs. post-treatment) was not feasible due to chronological DICOM headers and noticeable anatomical differences. While formal intra-observer reliability coefficients (e.g., ICC) were not formally calculated, measurement accuracy and anatomical consistency were systematically verified: total canal boundary dimensions (combined herniation and canal areas, and canal AP length) were compared between baseline and post-treatment images to ensure slices matched the identical anatomical level and to rule out slice selection errors. Transverse T2-weighted images of the affected level were analysed with a DICOM viewer (MicroDicom DICOM Viewer, version 2023.3 x86). Five quantitative parameters were recorded. Herniation AP length, defined as the maximum anteroposterior extension of the herniated material, was the primary indicator of herniation size. Herniation area was measured by planimetry of the herniated tissue. Canal AP length, defined in this context as the distance from the most posterior point of the disc to the posterior wall of the canal, and canal area described the residual space available for the neural structures. The Herniation Index (HI) was calculated according to the formula proposed by Choi *et al.* [13]:

$$\mathrm{HI} = \left(\mathrm{HL} \times \mathrm{HW}\right) / \left(\mathrm{TCL} \times \mathrm{TCW}\right) \times 1000$$

where HL is the herniation AP length as defined above, HW the herniation width measured at half the HL distance, TCL the maximal AP canal length and TCW the canal width measured at the level of half the HL distance. Transverse images were additionally graded with the Michigan State University classification grade (MSU), which assigns a size grade of 1 to 3 and a location of A, AB, B or C [41].

Clinical outcomes comprised pain [39] and a standard battery of provocation and neurological tests performed at baseline and after treatment: the Delitala, Lasègue (straight leg raise), Wassermann (femoral nerve tension), FABER, FADIR, Mingazzini and Valleix tests, the ability to walk on tiptoes and on heels, and deep tendon reflexes [37] [38]. Nerve conduction studies and needle electromyography were available in six of the nine Group 1 patients as part of routine diagnostic work-up. All patients had been assessed by a neurosurgeon before enrol-

ment, and the recorded recommendation was retained as a descriptor of baseline severity.

### 2.5. Statistical Analysis

Continuous variables are presented as mean ± standard deviation and as median with interquartile range (IQR). The distribution of the paired within-patient differences was examined with the Shapiro-Wilk test. Within-group changes from baseline were tested with the paired t-test, with the Wilcoxon signed-rank test reported alongside for every parameter and taken as the primary test where normality was rejected. Mean changes are reported with 95% confidence intervals, and effect size is expressed as Cohen's d for paired data. Percentage improvement was calculated for each patient individually and then averaged across the group. Between-group comparisons of baseline values, post-treatment values and percentage improvement used the Welch t-test with the Mann-Whitney U test as a distribution-free confirmation. Ordinal MSU grades were compared with the Wilcoxon signed-rank test within groups and the Mann-Whitney U test between groups, and categorical variables with Fisher's exact test. A two-sided p value below 0.05 was considered statistically significant. Analysis was conducted using the Matlab environment (MatLab R2010b, Mathworks, Inc., Natick, MA, USA) with a custom script. Given the exploratory nature of the study and the small sample, no correction for multiple comparisons was applied and no formal sample size calculation was performed; the between-group analysis should be read as hypothesis-generating.

## 3. Results

### 3.1. Baseline Characteristics

Nine patients were treated with the two-month protocol (Group 1): six women and three men, with a mean age of 43.7 ± 17.2 years (median 37, range 17 to 73). The herniation involved L4-L5 in six patients and L5-S1 in three. All patients had an AP herniation length above 6 mm, all reported unbearable pain at presentation, and all had radicular signs with a motor deficit on tiptoe walking, heel walking, or both. Reported duration of lumbar symptoms before enrolment ranged from 3 to 12 months and was six months or longer in five of the nine patients. Every patient had failed at least one previous course of conservative treatment, including pharmacological therapy and one or more cycles of physiotherapy, transcutaneous electrical nerve stimulation or magnetotherapy. Eight of the nine had been given a conditional surgical indication by a neurosurgeon, discectomy being planned if the motor deficit did not recover within one month. Baseline characteristics are detailed in **Table 1**.

The retrospective comparator cohort (Group 2) comprised the eight patients described in the original publication [18]: four women and four men, with a mean age of 48.5 ± 7.1 years (range 33 to 57); all eight had L4-L5 herniation. The two groups did not differ significantly in age ($p = 0.46$, Welch t-test) or sex distribution ($p = 0.64$, Fisher's exact test), nor in any of the five baseline MRI parameters ($p \geq$

0.45 for all comparisons). Baseline MSU grade was higher in Group 2 (mean 2.75 ± 0.46 versus 2.22 ± 0.44), a difference that reached significance (p = 0.04, Mann-Whitney U test) despite the MRI-based measures showing no such difference—addressed in Limitations.

Table 1. Baseline demographic and clinical characteristics of the nine patients treated with the two-month protocol (Group 1).

| No. | Sex/Age | Level | Occupation | Duration of symptoms | Neurosurgical recommendation |
|---|---|---|---|---|---|
| 1 | F/37 | L4-L5 | Employee | 12 months | Surgery if the heel-walking deficit did not recover within one month |
| 2 | F/35 | L5-S1 | Employee | 3 months | Surgery if the heel and tiptoe deficit did not recover within one month |
| 3 | F/17 | L4-L5 | Student | 3 months | Surgery if the heel and tiptoe deficit did not recover within one month |
| 4 | M/36 | L5-S1 | Nurse | 12 months | Electromyography and surgery if the tiptoe deficit did not improve within one month |
| 5 | F/60 | L4-L5 | Employee | 3 months | Electromyography and surgery if the deficit did not improve within one month |
| 6 | M/40 | L4-L5 | Nurse | 12 months | Electromyography and surgery if the deficit did not improve within one month |
| 7 | F/35 | L4-L5 | Employee | 12 months | Medical therapy and physiotherapy |
| 8 | F/60 | L5-S1 | Teacher | 6 months | Electromyography and surgery if the tiptoe deficit did not improve within one month |
| 9 | M/73 | L4-L5 | Retired | 3 months | Surgery if the heel deficit did not improve within one month |

### 3.2. MRI Outcomes in Group 1

Individual values for all five MRI parameters before and after the two-month programme are shown in Table 2, and the corresponding group statistics in Table 3. Every parameter moved in the expected direction in every patient: herniation AP length and area decreased, while canal AP length and canal area—the space available for the neural structures—increased. The Herniation Index, which combines herniation and canal dimensions in a single measure, fell substantially, consistent with an overall reduction in the severity of nerve root compromise.

Expressed as within-patient percentage change (Table 3), all five parameters improved significantly on both the paired t-test and the Wilcoxon signed-rank test (p = 0.004 for every parameter on the latter, the smallest value attainable with n = 9), with effect sizes ranging from 1.75 to 3.59. The Shapiro-Wilk test rejected normality of the paired differences only for herniation AP length (p = 0.037), for which the Wilcoxon result should be regarded as primary; for the remaining four parameters the assumption of normality was tenable (p ≥ 0.076). The two canal parameters were strongly right-skewed because two patients had a severely compromised canal at baseline (canal AP length 2.84 mm and 3.38 mm), so that even a moderate absolute gain represented a very large relative change. The median values in Table 3 describe the typical response more faithfully than the means. Individual responses were consistent in direction: all nine patients improved on all five parameters, six of nine achieved a reduction of at least 50% in herniation AP length and all nine a reduction of at least 30%, while eight of nine achieved a reduction of at least 50% in HI. The distribution of values before and after treatment is shown in Figure 1.

Table 2. Individual MRI-derived parameters before and after the two-month protocol (Group 1, n = 9).

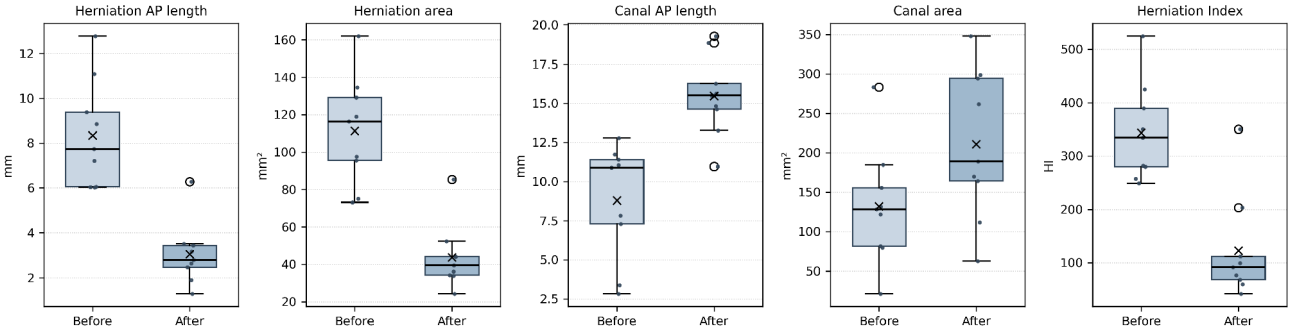
| Patient | Time point | MSU | Herniation AP length (mm) | Herniation area (mm²) | Canal AP length (mm) | Canal area (mm²) | HI |
|---|---|---|---|---|---|---|---|
| 1 | Before | 2B | 7.20 | 95.50 | 11.40 | 122.30 | 350.17 |
| | After | 1A | 1.90 | 34.01 | 19.28 | 294.12 | 67.98 |
| 2 | Before | 2A | 6.05 | 75.06 | 7.83 | 79.86 | 424.52 |
| | After | 1A | 3.44 | 44.06 | 10.96 | 111.65 | 203.68 |
| 3 | Before | 2A | 7.74 | 118.92 | 11.05 | 81.88 | 334.53 |
| | After | 1A | 2.63 | 36.17 | 16.26 | 164.24 | 99.43 |
| 4 | Before | 2B | 9.39 | 116.33 | 10.88 | 283.16 | 257.14 |
| | After | 1A | 3.51 | 52.46 | 18.85 | 347.82 | 91.35 |
| 5 | Before | 2B | 8.85 | 161.92 | 7.30 | 184.74 | 280.14 |
| | After | 1A | 2.79 | 44.06 | 13.26 | 298.56 | 59.71 |
| 6 | Before | 2B | 6.02 | 97.60 | 12.79 | 131.93 | 281.88 |
| | After | 1A | 3.16 | 39.50 | 15.62 | 189.00 | 112.18 |
| 7 | Before | 2B | 6.04 | 73.13 | 11.72 | 128.72 | 248.65 |
| | After | 1B | 2.46 | 34.27 | 15.48 | 170.22 | 76.57 |
| 8 | Before | 3B | 12.77 | 134.45 | 3.38 | 155.87 | 389.74 |
| | After | 1A | 1.28 | 24.34 | 14.61 | 261.81 | 41.87 |
| 9 | Before | 3AB | 11.08 | 129.14 | 2.84 | 21.46 | 524.62 |
| | After | 2A | 6.28 | 85.40 | 14.83 | 62.57 | 350.41 |

AP: anteroposterior; HI: Herniation Index; MSU: Michigan State University classification; SD: standard deviation.

Table 3. Within-group changes in MRI parameters after the two-month protocol (Group 1, n = 9).

| Parameter | Before (mean ± SD) | After (mean ± SD) | Mean change (95% CI) | Improvement, mean ± SD (%) | Improvement, median [IQR] (%) | d |
|---|---|---|---|---|---|---|
| Herniation AP length (mm) | 8.35 ± 2.40 | 3.05 ± 1.41 | −5.30 (−7.33 to −3.27) | 61.5 ± 15.4 | 62.6 [47.5 - 68.5] | 2.01 |
| Herniation area (mm²) | 111.34 ± 28.96 | 43.81 ± 17.49 | −67.53 (−90.97 to −44.09) | 59.0 ± 15.2 | 59.5 [53.1 - 69.6] | 2.21 |
| Canal AP length (mm) | 8.80 ± 3.69 | 15.46 ± 2.57 | +6.66 (4.08 to 9.25) | 124.4 ± 146.4 | 69.1 [40.0 - 81.6] | 1.98 |
| Canal area (mm²) | 132.21 ± 73.96 | 211.11 ± 94.94 | +78.90 (44.18 to 113.62) | 77.8 ± 56.4 | 61.6 [39.8 - 100.6] | 1.75 |
| Herniation Index | 343.49 ± 90.76 | 122.58 ± 97.26 | −220.91 (−268.22 to −173.60) | 66.4 ± 16.8 | 69.2 [60.2 - 78.7] | 3.59 |

All parameters: $p < 0.001$ by paired t-test and $p = 0.004$ by Wilcoxon signed-rank test. Percentage improvement was computed for each patient and then averaged. AP: anteroposterior; CI: confidence interval; d: Cohen's d for paired data; IQR: interquartile range; SD: standard deviation.




Boxes span the interquartile range, the horizontal line is the median and the cross marks the mean; whiskers extend to the most extreme values within 1.5 interquartile ranges and circles denote values beyond that limit. Individual patient values are overlaid as points.

**Figure 1.** Distribution of MRI parameters before and after the two-month protocol (Group 1, n = 9).

### 3.3. Herniation Grade and Clinical Outcomes in Group 1

Before treatment, herniations were graded MSU 2A in two patients, 2B in five, 3B in one and 3AB in one. After treatment, seven patients were graded 1A, one 1B and one 2A. Every patient improved by at least one grade and one patient improved by two grades, a significant shift overall ($p = 0.004$). The location component moved towards the midline in most patients, so that no patient retained a predominantly lateral (B) location apart from one graded 1B (**Table 2**).

Clinical improvement paralleled the imaging findings. All nine patients experienced complete resolution of baseline pain upon completion of therapy. At the post-treatment assessment, the Delitala, Lasègue, Wassermann, FABER, FADIR and Valleix tests were negative in all patients, the Mingazzini test remained negative, deep tendon reflexes had returned from hyporeflexia to normal, and the tiptoe and heel walking deficits had resolved in every case. No patient underwent surgery during follow-up. Nerve conduction studies performed before treatment in six patients had shown axonal motor and sensory changes consistent with the clinically affected root, including reductions in compound muscle action potential amplitude of 28% to 98%.

No adverse events, treatment-related discomfort or discontinuations were recorded in Group 1, and no patient required a change of analgesic medication during the programme.

### 3.4. Comparison between the Two-Month and Three-Month Protocols

**Table 4** sets the two-month protocol against the previously reported three-month protocol. The groups were comparable at baseline on all five MRI parameters, so the comparison of improvement is not confounded by differences in initial herniation size or canal compromise, and remained statistically indistinguishable after treatment. None of the five between-group differences in percentage improvement approached significance, whether tested parametrically or non-parametrically (**Table 4**); the two distributions are shown in **Figure 2**. Both groups improved by at least one MSU grade in every patient, and the magnitude of grade change did not differ significantly between groups ($p = 0.51$, Mann-Whitney U test); the higher baseline

MSU grade in Group 2 noted above is addressed in Limitations.

**Table 4.** Comparison of the two-month protocol (Group 1) with the retrospective three-month protocol (Group 2).

| Parameter | Measure | Group 1 (n = 9); 24 sessions/2 months | Group 2 (n = 8); 40 sessions/3 months | p (t-test) | p (Mann-Whitney) |
|---|---|---|---|---|---|
| Herniation AP length (mm) | Baseline | 8.35 ± 2.40 | 8.33 ± 1.54 | 0.99 | 0.92 |
| | Post-treatment | 3.05 ± 1.41 | 2.87 ± 1.01 | 0.76 | 0.96 |
| | Improvement (%) | 61.6 ± 15.4 | 66.0 ± 9.0 | 0.47 | 0.48 |
| Herniation area ($mm^2$) | Baseline | 111.34 ± 28.96 | 106.61 ± 42.92 | 0.80 | 0.54 |
| | Post-treatment | 43.81 ± 17.49 | 46.67 ± 23.13 | 0.78 | 1.00 |
| | Improvement (%) | 59.0 ± 15.2 | 56.2 ± 10.2 | 0.66 | 0.61 |
| Canal AP length (mm) | Baseline | 8.80 ± 3.69 | 9.38 ± 2.16 | 0.69 | 0.96 |
| | Post-treatment | 15.46 ± 2.57 | 14.75 ± 1.90 | 0.53 | 0.74 |
| | Improvement (%) | 124.4 ± 146.4 | 63.9 ± 38.2 | 0.26 | 0.67 |
| Canal area ($mm^2$) | Baseline | 132.21 ± 73.96 | 132.21 ± 40.82 | 1.00 | 1.00 |
| | Post-treatment | 211.11 ± 94.94 | 194.50 ± 43.45 | 0.65 | 0.61 |
| | Improvement (%) | 77.8 ± 56.4 | 54.3 ± 39.1 | 0.33 | 0.32 |
| Herniation Index | Baseline | 343.49 ± 90.76 | 309.03 ± 93.01 | 0.45 | 0.54 |
| | Post-treatment | 122.58 ± 97.26 | 83.82 ± 26.41 | 0.28 | 0.54 |
| | Improvement (%) | 66.4 ± 16.8 | 72.4 ± 4.6 | 0.33 | 0.61 |

Values are mean ± standard deviation. Percentage improvement was calculated per patient and then averaged. Group 2 is the retrospective comparator treated with non-surgical spinal decompression, high-intensity laser therapy and single-coil rPMS. AP: anteroposterior.

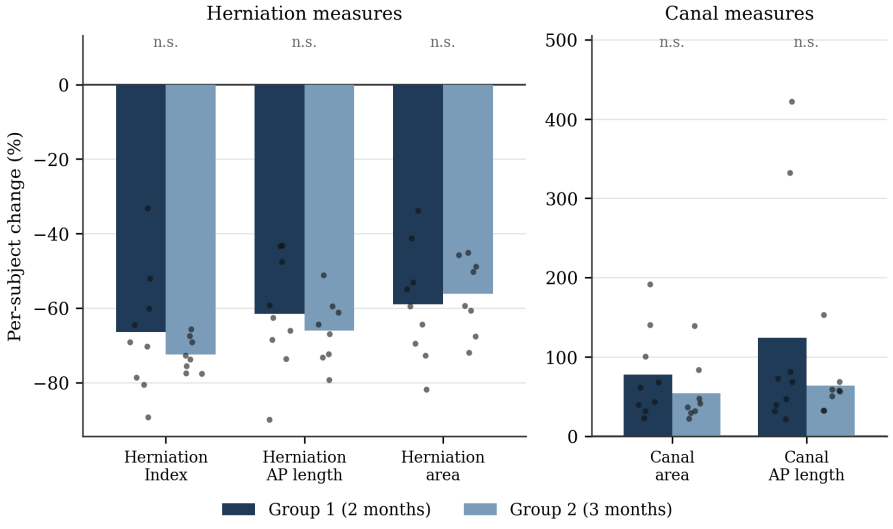



**Figure 2.** Mean per-subject percentage change by parameter and group, with individual patient values overlaid. No between-group comparison reached significance (n.s.). Herniation and canal measures are shown on separate axes because they change in opposite directions and on different scales.

Patients were monitored for three months after completion of the protocol, as in the comparator cohort, and improvement in pain and functional testing was maintained in all nine. In the comparator cohort, seven of eight patients had complete symptom resolution, and one retained minor residual signs with marked overall improvement [18].

## 4. Discussion

This study shows that a two-month, 24-session programme combining non-surgical spinal decompression with double-coil, single-coil and handheld rPMS was followed by substantial regression of large lumbar disc herniations on MRI and by complete resolution of pain and radicular signs in every patient treated. Mean reductions of 61.5% in herniation AP length, 59.0% in herniation area and 66.4% in the Herniation Index were accompanied by increases of 124.4% in canal AP length and 77.8% in canal area, and all patients improved by at least one MSU grade. These changes occurred in a cohort in which eight of nine patients carried a conditional surgical indication and no patient underwent surgery during follow-up.

The clinical relevance of these figures rests on the population in which they were obtained. Herniations exceeding 6 mm in AP length are those most often cited as favouring operative management [10], and the MSU location categories AB and B, which predominated at baseline in both cohorts, are the ones classically associated with poor responsiveness to non-operative care [41]. Furthermore, all patients had already failed conservative treatment and had symptoms lasting beyond the window in which spontaneous regression is most likely [9]. Spontaneous resolution cannot be excluded in an uncontrolled design, but it is an improbable explanation for a coordinated, large-magnitude change across five independent imaging parameters in nine consecutive chronic patients.

Set against the published quantitative evidence for spinal decompression alone, the magnitude of change is considerable. Choi *et al.* reported a mean 27% reduction in HI after ten NSSD sessions over eight weeks in subacute herniation [13], roughly two fifths of the 66.4% observed here over a comparable calendar period. Demirel *et al.* found a mean reduction in herniation thickness of 1.7 mm after a shorter physiotherapy programme with or without NSSD and no significant difference between the two arms [14], against a mean reduction of 5.30 mm in the present cohort. Both comparator studies enrolled patients with predominantly mild to moderate herniation, so a smaller absolute change is expected; nevertheless, the contrast supports the view that intensity and composition of the protocol, rather than decompression alone, drive the structural response.

The central question was whether the treatment course could be shortened. Compared with our previous 3-month, 40-session protocol, no statistically significant between-group difference was detected for the 2-month, 24-session regimen. Two features explain this higher per-session potency. First, rather than increasing penetration depth—which relies on converging fields in angled joint models [31]

[32]—the lumbar double-coil configuration provides broader spatial coverage, greater field homogeneity, and superior patient comfort. This enables more comprehensive neuromuscular activation. Second, the dynamic handheld applicator allows continuous stimulation along the entire radicular tract within a single session. This combined static-lumbar and dynamic-limb approach has shown substantial clinical efficacy [34], mirroring rapid gains seen with double-coil rPMS in other applications [33].

It must be stressed that the design does not permit attribution of the shortened course to the change in rPMS configuration specifically. Group 2 additionally received HIL, a modality with documented benefit when added to spinal decompression in lumbar disc protrusion [40], so the two protocols differ in more than one component and in opposite directions: Group 1 gained a more elaborate rPMS regimen but lost the laser component. That comparable results were obtained despite the absence of HIL and despite 16 fewer sessions is the observation of interest, but the design cannot separate the contribution of each element.

The clinical outcomes are consistent with the wider rPMS literature. Meta-analysis of randomised trials shows reduction of pain intensity and improvement of functional mobility in LBP [22], and in lumbar radiculopathy specifically, rPMS improved both pain and electromyographic parameters, with the greatest benefit when combined with a structured rehabilitation programme [23]. This is directly relevant to the present protocol, in which rPMS was never delivered in isolation but always after decompression and, in the final phase, alongside therapeutic exercise. Proposed mechanisms include recruitment of proprioceptive afferents with modulation of cortical and spinal excitability [24] [26], segmental inhibition of nociceptive transmission [27], modulation of neuropathic pain components [28] and improved local perfusion through repeated muscle contraction [29] [42]. In a herniated segment, reduced paraspinal hypertonus and improved local circulation may plausibly support the resorptive process, although no mechanistic data were collected in this study to test that hypothesis.

## 5. Limitations

The principal limitations are the small sample, the absence of a concurrent control or sham group and the retrospective, non-contemporaneous nature of the comparator. Group 2 was treated at the same centre by the same team but in an earlier period, so secular changes in practice, patient selection and measurement cannot be excluded, and the between-group analysis should be regarded as hypothesis-generating rather than as a test of superiority or equivalence. With nine and eight patients in the two groups respectively, the study had power to detect only large between-group differences; the absence of a significant difference is therefore not evidence of equivalence, and moderate differences in favour of either protocol would have gone undetected. The two groups were not perfectly matched: L5-S1 were more frequent in Group 1, all eight Group 2 patients had L4-L5 herniation only, and baseline MSU grade was significantly higher in

Group 2 (mean 2.75 versus 2.22, p = 0.04) despite the five continuous MRI parameters showing no significant baseline difference. This discrepancy between a categorical severity score and continuous morphometric measures is difficult to resolve with the available data and means the two cohorts were not fully equivalent in baseline severity, which should temper the equivalence-suggestive framing of the percentage-improvement comparison. Follow-up MRI was obtained immediately after treatment, so the durability of the structural changes is unknown; imaging at six and twelve months would be needed to establish whether the regression persists. Clinical assessments were not blinded, and no validated disability or quality-of-life instrument, such as the Oswestry Disability Index, was recorded, which limits comparability with the wider LBP literature. Finally, the study was conducted at a single centre with a single treating team, which limits generalisability.

Future work should compare the two protocols prospectively within the same time frame and in the same population, ideally with randomisation, blinded image analysis and a control arm, so that the effect of the shortened course can be separated from patient selection and from the parallel change in rPMS configuration and the removal of HIL. A factorial design would additionally allow the specific contribution of the double-coil and handheld applicators to be quantified. Longer follow-up, standardised disability outcomes and a health-economic comparison against discectomy would help to define where such a protocol belongs in the care pathway for patients with large lumbar disc herniation.

## 6. Conclusion

In patients with large, refractory lumbar disc herniations (>6 mm) facing surgery, a 2-month protocol combining NSSD with multi-configuration rPMS achieved complete pain resolution, marked MRI regression, and no patient underwent surgery during follow-up. Crucially, leveraging double-coil and dynamic handheld rPMS yielded structural and clinical outcomes for which no statistically significant between-group difference was detected compared to an earlier 3-month protocol, effectively reducing treatment burden by 40%. These findings suggest that advanced rPMS field geometry may accelerate non-invasive spinal recovery, though prospective randomized trials are needed to confirm these results.

## Declaration

Ethics approval and consent to participate: Retrospective approval for this study was granted by the Territorial Ethics Committee of the Calabria Region, meeting on 29 December 2025 at the Renato Dulbecco University Hospital (A.O.U.), Catanzaro, under protocol number 319/2025; the Committee examined the submitted documentation and issued an opinion of approval. The study was conducted in accordance with the Declaration of Helsinki and the Convention on Human Rights and Biomedicine [35]. All patients provided written informed consent to treatment and to the publication of their anonymised data and images.

## Availability of Data

The anonymised measurement data supporting the findings of this study are available from the corresponding author on reasonable request.

## Author Contributions

Conceptualisation, V.D.M.; methodology, V.D.M. and G.J.S.; investigation and data curation, V.D.M.; formal analysis, V.D.M.; writing of the original draft, V.D.M.; review and editing, G.J.S. Both authors have read and approved the final manuscript.

## Conflicts of Interest

Vincenzo Di Modica has a financial relationship with BTL Industries Ltd., the manufacturer of the Super Inductive System DUO system used in this study, in the form of speaking and lecture fees. Giuseppe J. Sciarrone declares no competing interests. The article processing charge for this manuscript is to be paid by BTL Industries Ltd. BTL Industries Ltd. had no role in the study design, data collection, analysis, interpretation of data, writing of the manuscript, or the decision to submit the article for publication.

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