NEURAL REGENERATION RESEARCH
Volume 8, Issue 12, April 2013
www.nrronline.org

doi:10.3969/j.issn.1673-5374.2013.12.009 [http://www.nrronline.org; http://www.sjzsyj.org]
Feng Y, Gao Y, Yang WD, Feng TY. Reduction in nerve root compression by the nucleus pulposus after Feng's Spinal Manipulation. Neural Regen Res. 2013;8(12):1139-1145.

Reduction in nerve root compression by the nucleus pulposus after Feng's Spinal Manipulation☆

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Abstract

Ninety-four patients with lumbar intervertebral disc herniation were enrolled in this study. Of these, 48 were treated with Feng's Spinal Manipulation, hot fomentation, and bed rest (treatment group). The remaining 46 patients were treated with hot fomentation and bed rest only (control group). After 3 weeks of treatment, clinical parameters including the angle of straight-leg raising, visual analogue scale pain score, and Japanese Orthopaedic Association score for low back pain were improved. The treatment group had significantly better improvement in scores than the control group. Magnetic resonance myelography three-dimensional reconstruction imaging of the vertebral canal demonstrated that filling of the compressed nerve root sleeve with cerebrospinal fluid increased significantly in the treatment group. The diameter of the nerve root sleeve was significantly larger in the treatment group than in the control group. However, the sagittal diameter index of the herniated nucleus pulposus and the angle between the nerve root sleeve and the thecal sac did not change significantly in either the treatment or control groups. The effectiveness of Feng's Spinal Manipulation for the treatment of symptoms associated with lumbar intervertebral disc herniation may be attributable to the relief of nerve root compression, without affecting the herniated nucleus pulposus or changing the morphology or position of the nerve root.

Key Words

neural regeneration; traditional Chinese medicine; spinal column; rotating reduction; manipulation; Chinese medicine bone-setting; lumbar intervertebral disc herniation; intervertebral disc; nerve root; magnetic resonance imaging; biomechanics; grants-supported paper; neuroregeneration

Research Highlights

(1) The nerve root sleeve is filled with cerebrospinal fluid that acts as a natural pressure receptor. We evaluated changes in the anatomical and biomechanical characteristics of the nerve root sleeve to investigate the mechanisms underlying the curative effect of Feng's Spinal Manipulation.
(2) Magnetic resonance myelography can clearly show nerve root compression, and was used to assess the effectiveness of Feng's Spinal Manipulation for treatment of symptoms associated with lumbar intervertebral disc herniation.
(3) Feng's Spinal Manipulation for treatment of lumbar intervertebral disc herniation reduces compression of the nerve root, but does not reduce disc herniation.

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Received: 2012-12-23
Accepted: 2013-02-04
(N20120529002)

INTRODUCTION

Lumbar intervertebral disc herniation is a common cause of low back pain. In the 1970s, Tianyou Feng described Feng's Spinal Manipulation[1], also known as Feng's rotating reduction at fixed points of the spine, for the treatment of lumbar intervertebral disc herniation. The theory underlying Feng's Spinal Manipulation was based on the anatomical, pathophysiological, and biomechanical knowledge of modern western medicine, as well as the bone-setting expertise of traditional Chinese medicine. Feng's Spinal Manipulation has been proven to be clinically effective for over 40 years, and has become the most widely adopted treatment for patients with lumbar intervertebral disc herniation in China[2].

Although clinical studies have shown that Feng's Spinal Manipulation is effective for the treatment of lumbar intervertebral disc herniation, there is currently no direct evidence that Feng's Spinal Manipulation can alleviate nerve root compression or improve the shape or position of the nucleus pulposus, and some treatment providers therefore only use Feng's Spinal Manipulation in selected cases[3]. CT and MRI can show the size and position of the nucleus pulposus, but cannot show biomechanical changes in the nucleus pulposus or compressed nerve root. Studies did not find any decrease in the size of the herniated nucleus pulposus after Feng's Spinal Manipulation treatment. Changes in morphological findings on CT or MRI images before and after Feng's Spinal Manipulation treatment may provide support for the effectiveness of this treatment[4]. The nerve root sleeve is filled with cerebrospinal fluid. When the pressure on the nerve root sheath increases, the cerebrospinal fluid in the sheath may decrease in volume or disappear. Magnetic resonance myelography vertebral canal three-dimensional reconstruction imaging displays the three-dimensional structure of nerve root sleeves, and is the optimal modality for observing the shape of the sleeve in all planes to evaluate compression[5-7]. Magnetic resonance myelography is a better modality than MRI for the evaluation of nerve root compression in patients with lumbar intervertebral disc herniation[8-9]. CT and MRI show the morphological characteristics of the intervertebral discs, but do not show biomechanical characteristics[10-11]. Compared with MRI, magnetic resonance myelography images allow better visualization of the spinal cord and nerve roots in patients with lumbar intervertebral disc herniation. In this study, we evaluated changes in the compressed nerve root sleeves on magnetic resonance myelography images before and after Feng's Spinal Manipulation to determine the mechanisms by which Feng's Spinal Manipulation reduces symptoms in patients with lumbar intervertebral disc herniation.

RESULTS

Quantitative analysis of subjects

Ninety-four patients with lumbar intervertebral disc herniation were enrolled in this study. Of these, 48 were treated with Feng's Spinal Manipulation, hot fomentation, and bed rest (treatment group). The remaining 46 patients were treated with hot fomentation and bed rest only (control group). All 94 patients were included in the final analysis.

General clinical data of patients with lumbar intervertebral disc herniation

There were no significant differences in gender, age, pathological changes, or disease course between the treatment and control groups ($P > 0.05$; Table 1).

Table 1 Baseline data of patients with lumbar intervertebral disc herniation in the treatment and control groups

Item	Treatment group (n = 48)	Control group (n = 46)	t/x^2	P
Gender (male/female, n)	28/20	27/19	0.001	> 0.05
Age (mean±SD, year)	38.5±5.4	38.2±5.4	0.77	> 0.05
Pathological changes (n)				
L_5–S_1	23	22	< 0.001	> 0.05
$L_{4–5}$	25	24	< 0.001	> 0.05
Course of disease (mean±SD, month)	22.7±17.8	24.4±16.5	0.63	> 0.05

There were no significant differences in baseline data between the treatment and control groups; chi-square test or t-test were used.

Changes in clinical parameters after treatment with Feng's Spinal Manipulation

All patients were evaluated by clinical doctors before treatment. The clinical parameters recorded included the angle of straight-leg raising[12-13], visual analogue scale pain score[14], and Japanese Orthopaedic Association score for low back pain[15]. The results are shown in Table 2. There were no significant differences in these parameters between the treatment and control groups before treatment ($P > 0.05$). After 3 weeks of treatment, the angle of straight-leg raising, visual analogue scale pain score, and Japanese Orthopaedic Association score

for low back pain were improved in all patients. In the treatment group, the angle of straight-leg raising, visual analogue scale pain score, and Japanese Orthopaedic Association score for low back pain were significantly improved after treatment ($P < 0.01$), but these parameters did not change significantly in the control group ($P > 0.05$). The angle of straight-leg raising, visual analogue scale pain score, and Japanese Orthopaedic Association score for low back pain were significantly better in the treatment group than in the control group after treatment ($P < 0.01$; Table 2). This indicates that treatment with Feng's Spinal Manipulation relieved pain and diminished clinical symptoms.

Table 2 Clinical and imaging parameters in patients with single-level lumbar intervertebral disc herniation before and after Feng's Spinal Manipulation

Item	Treatment group (n = 48)	
	Pretreatment	Posttreatment
SI	0.41±0.25	0.40±0.21
Nerve sleeve diameter (cm)	0.03±0.05	0.40±0.28[ab]
α (°)	26.29±5.67	26.59±6.06
ASLR (°)	56.18±11.35	86.17±8.24[ab]
VAS	6.52±1.17	0.95±1.24[ab]
JOA	18.46±3.02	27.07±1.02[ab]
Item	Control group (n = 46)	
	Pretreatment	Posttreatment
SI	0.40±0.11	0.39±0.27
Nerve sleeve diameter (cm)	0.04±0.06	0.04±0.08
α (°)	27.63±6.55	27.85±6.95
ASLR (°)	53.28±12.53	60.08±11.17
VAS	7.03±1.02	6.28±2.60
JOA	17.98±3.54	19.09±2.78

Data are expressed as mean ± SD. [a]$P < 0.01$, *vs*. pretreatment (*t*-test); [b]$P < 0.01$, *vs*. post-treatment in the control group (analysis of variance).

SI: Sagittal diameter index of nucleus pulposus herniation; α: angle between the nerve root sleeve and the thecal sac; ASLR: angle of straight leg raising, higher values are closer to normal; VAS: visual analogue scale pain score, higher values indicate greater pain; JOA: Japanese Orthopaedic Association score for low back pain, the normal score is 29 points.

Magnetic resonance myelography findings before and after Feng's Spinal Manipulation

Figure 1 shows the typical magnetic resonance myelography and MRI findings before and after treatment with Feng's Spinal Manipulation. After treatment, the L_4 offset was corrected, and the low back pain and right-sided sciatica pain disappeared. The size of the herniated nucleus pulposus did not change significantly in the axial MRI view (Figures 1A, B). Magnetic resonance myelography clearly showed an increased amount of fluid in the nerve root sleeve after Feng's Spinal Manipulation (Figures 1C, D).

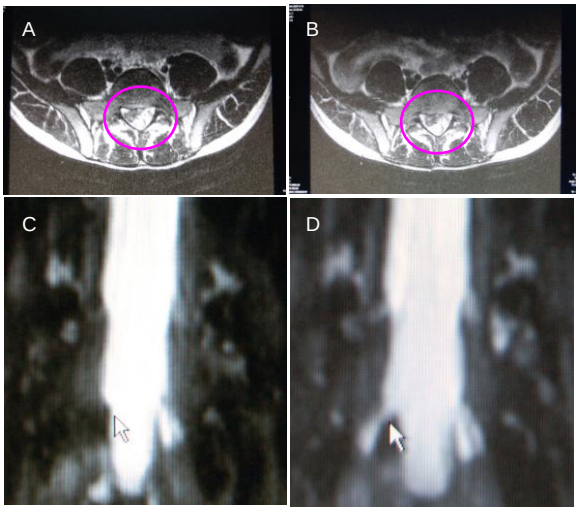

Figure 1 A 25-year-old male patient with low back pain and right leg pain for 1 month.

Axial MRI images of the herniated nucleus pulposus before treatment (A) and after treatment (B) with Feng's Spinal Manipulation (FSM); and magnetic resonance myelography (MRM) vertebral canal three-dimensional (3D) reconstruction images of the nerve root sleeves before treatment (C) and after treatment (D) with FSM. There was no significant change in the size of the herniated nucleus pulposus on the axial MRI images (A and B, circle).

On MRM, the nerve root sleeve was not visualized before treatment (C, arrow) and became clearly visible after treatment (D, arrow) with FSM. The MRM 3D reconstruction images of the vertebral canal demonstrated increased filling of the nerve root sheath with cerebrospinal fluid.

Imaging indexes before and after Feng's Spinal Manipulation

After 3 weeks of treatment, the diameter of the nerve root sleeve was significantly increased in the treatment group, and was significantly different between the treatment and control groups. The sagittal diameter index of the herniated nucleus pulposus and the angle between the nerve root sleeve and the thecal sac did not change significantly after treatment in either the treatment or control groups (Table 2).

DISCUSSION

Based on the bone-setting expertise of traditional Chinese medicine, and the knowledge of modern western medicine, Feng Tianyou hypothesized that single- or multi-level lumbar vertebral misalignment is the major pathological alteration in lumbar intervertebral disc herniation[16]. This theory is distinct from those of other researchers, who have suggested that the local irritant

effect of nucleus pulposus herniation is a key pathogenic factor associated with lumbar intervertebral disc herniation[17]. Based on this hypothesis, Feng established Feng's Spinal Manipulation to restore the alignment of the vertebrae. Theoretically, Feng's Spinal Manipulation treatment can restore the spine and related tissues back to their normal positions[18], thereby relieving the nerve root compression resulting from nucleus pulposus herniation. Many clinical studies have supported this theory[19-23]. In this study, we used MRI imaging data to further validate the theory.

Magnetic resonance myelography vertebral canal three-dimensional reconstruction imaging shows the three-dimensional structure of the nerve root sleeves, and is the optimal modality for observing the shape of the sleeves in all planes and evaluating nerve root compression[24-25]. The nerve root sleeve acts as a natural pressure cushion, and when it is compressed by herniation of the nucleus pulposus, there may be a reduced volume of cerebrospinal fluid in the sleeve, which is visualized as a filling defect on magnetic resonance myelography[8]. Magnetic resonance myelography can show changes in the morphological characteristics of compressed nerve root sleeves after treatment with Feng's Spinal Manipulation[9]. In this study, magnetic resonance myelography provided evidence of morphological changes indicating that Feng's Spinal Manipulation may relieve nerve root compression.

The angle of straight-leg raising, visual analogue scale pain score, and Japanese Orthopaedic Association score for low back pain are good quantitative indicators of patient symptoms. This study found that the angle of straight-leg raising, visual analogue scale pain score, and Japanese Orthopaedic Association score for low back pain improved significantly in the treatment group, but did not change significantly in the control group, indicating that treatment with Feng's Spinal Manipulation can relieve the symptoms associated with lumbar intervertebral disc herniation. The angle between the nerve root sleeve and the thecal sac reflects the anatomical course of the nerve root[26], and the sagittal diameter index reflects the size of the nucleus pulposus[27]. In the present study, these two imaging parameters did not change significantly in either of the two groups. However, magnetic resonance myelography three-dimensional reconstruction imaging of the vertebral canal demonstrated that filling of the compressed nerve root sleeve with cerebrospinal fluid increased significantly in the treatment group, but did not change significantly in the control group, indicating that compression of the nerve root sleeve was reduced in the treatment group only. These findings suggest that Feng's Spinal Manipulation may result in biomechanical changes in the herniated nucleus pulposus and the nerve root sleeve[28]. The relief of nerve root compression by this method is different to the relief caused by operation, which removes the herniated nucleus pulposus[29].

This study included only patients with single-level herniation, and excluded patients with thickening of the ligamentum flavum, spinal canal stenosis, or lateral recess stenosis. This is because the aim was to determine whether Feng's Spinal Manipulation can reduce or remove nerve root compression caused by the herniated nucleus pulposus. It is more difficult to determine the level causing symptoms in cases of multi-level intervertebral disc herniation, and sciatica is caused by different mechanisms in protruding and non-protruding type nucleus pulposus herniation[30]. Patients with lumbar intervertebral disc herniation combined with thickening of the ligamentum flavum, spinal canal stenosis, or lateral recess stenosis may have nerve root compression, but this compression may be caused by conditions other than lumbar intervertebral disc herniation[31]. As inclusion of patients with these conditions may have biased the results, this study enrolled only patients with single-level lumbar intervertebral disc herniation. This may be the reason for the relatively young age of patients in the study.

Not all patients in the treatment group had their nerve root sleeves restored to normal. A longer course of disease may be associated with a limited ability to resolve compression by treatment with Feng's Spinal Manipulation.

The conclusions of this study are as follows. (1) The nerve root sleeve is filled with cerebrospinal fluid that acts as a natural pressure receptor. We evaluated changes in the anatomical and biomechanical characteristics of the nerve root sleeve to investigate the mechanisms underlying the curative effect of Feng's Spinal Manipulation. (2) Magnetic resonance myelography can clearly show nerve root compression, and was used to assess the effectiveness of Feng's Spinal Manipulation for the treatment of symptoms associated with lumbar intervertebral disc herniation. (3) Feng's Spinal Manipulation reduces compression of the nerve root in patients with lumbar intervertebral disc herniation, but does not reduce disc herniation. (4) Chinese medicine manipulation can clearly reduce nerve root compression caused by intervertebral disc herniation.

SUBJECTS AND METHODS

Design

Neuroimaging, clinical controlled trial.

Time and setting

Patients were treated at the General Hospital of the Air Force from August 2009 to December 2011.

Subjects

Ninety-four patients with lumbar intervertebral disc herniation were enrolled. All patients met the diagnostic criteria for lumbar intervertebral disc herniation as described by Hu[32], namely displacement of the tissues of the intervertebral disc beyond the intervertebral space.

The inclusion criteria were: (1) single-level herniation, and (2) herniated nucleus pulposus with nerve root compression confirmed on CT or MRI.

The exclusion criteria were: (1) symptoms or signs of cauda equina compression, (2) common peroneal nerve palsy causing loss of muscle strength, and (3) presence of other spinal or spinal cord disease.

Informed consent was obtained from all participants. Study protocols were in accordance with the relevant ethical requirements of the *Declaration of Helsinki*.

Methods

Feng's Spinal Manipulation technique

First, the patient sat up straight on the treatment chair, and the doctor held one thumb against the misaligned spinal process and pushed it towards the midline. Using the other hand, the doctor then flexed the patient's spine, and while holding the flexion position, rotated the lumbar spine to the right or left. This manipulation helped to correct the position of the misaligned spinous process and restore it to its normal position in relation to the adjacent spinous processes.

Therapy administered in the treatment and control groups

Treatment group: Patients in the treatment group were first treated with Feng's Spinal Manipulation, and then with hot fomentation using the traditional Chinese medicine *Tengfu* (which includes common clubmoss herb, safflower, and pricklyash peel) made by the Pharmaceutical Department of the General Hospital of the Air Force, China for 30 minutes, followed by bed rest. Each patient received this treatment 2–3 times per week for 3 weeks.

Control group: Patients in the control group were treated only with hot fomentation using *Tengfu* for 30 minutes and bed rest.

Lumbar MRI scanning

Patients were scanned before and after treatment with a 1.5 T super-conducting MR scanner (Siemens Avanto, Munich, Germany) using turbo spin-echo sequences. The vertebral bodies were assessed in the anteroposterior plane on T1- and T2-weighted images. The intervertebral discs from L_3 to S_1 were usually assessed in the axial plane on T2-weighted images. The other intervertebral discs were also assessed in the anteroposterior plane. The specific scanning parameters are shown in Table 3.

Magnetic resonance myelography vertebral canal scanning

A three-dimensional half-Fourier acquisition single-shot turbo spin-echo sequence was used to scan the vertebral canal, including the anterior and posterior margins of the thecal sac. The frequency-selective fat-suppression technique and magnetization transfer contrast technique were used to decrease the interference of fat tissue and improve contrast. The specific parameters for scanning were as follows: repetition time: 8 000 ms; echo time: 267 ms; field of view: 250 × 250 mm^2; matrix: 256 × 256; acquisition frequency: 1; layer thickness: 0.8 mm; layers: 44; space between layers: –0.24 mm; flip angle: 170°; echo-train length: 256 mm; echo-wave gap: 9.5 ms.

Magnetic resonance myelography three-dimensional reconstruction of the vertebral canal

Raw data collected from the three-dimensional half-Fourier acquisition single-shot turbo-spin echo sequences were reconstructed into three-dimensional images with the aid of maximum intensity projection.

Table 3 Parameters of routine MRI sequences

Item	Repetition time (ms)	Echo time (ms)	Field of view (mm^2)	Matrix	Acquisition frequencies	Layer thickness (mm)	Space between layers (mm)	Flip angle (°)	Echo train length (mm)
Sagittal T_1WI	3 000	96	330×330	256×205	2	4	0.4	170	17
Sagittal T_2WI	480	10	330×330	256×205	2	4	0.4	150	7
Axial T_2WI	3 000	100	250×203	448×218	2	4	0.4	170	17

Twenty coronal reconstructions were carried out at an interval angle of 9°.

Observation parameters

Imaging parameters included the sagittal diameter index (Figure 2), the angle between the nerve root sleeve and the thecal sac (Figure 3), and diameter of the nerve root sleeve (direct measurement using software). The sagittal diameter index was calculated as A/B, where A was the maximum sagittal diameter of the herniated nucleus pulposus, and B was the maximum sagittal diameter of the spinal canal.

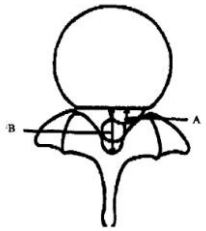

Figure 2 Measurement of the sagittal diameter index (SI) to evaluate the size of the herniated mass.

SI = A/B, where A is the maximum diameter of the mass and B is the maximum sagittal diameter of the spinal canal of the same level.

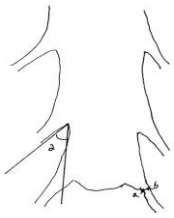

Figure 3 Measurements of the angle between the nerve root sleeve and the thecal sac (α) and the diameter of the nerve sleeve (ab).

Evaluation of clinical parameters

To measure the angle of straight-leg raising[12-13], the patient lay flat on the bed, and was asked to slowly lift the leg on the affected side without bending the knee, until pain was felt. The doctor then measured the angle between the bed and a line connecting the greater trochanter of the femur and the lateral malleolus of the ankle. The angle was measured at least three times, and the mean value was used in the analyses to reduce errors. To measure the visual analogue scale pain score[14], the doctor explained to subjects that 0 indicated no pain and 10 indicated intolerable pain, and patients marked their score on the scale with a pen. The Japanese Orthopaedic Association score for low back pain[15] score for low back pain was assessed according to subjective symptoms, clinical signs, limitation of daily activities, and bladder function. The maximum Japanese Orthopaedic Association score for low back pain score is 29.

Statistical analysis

Statistical analyses were performed by the first author using SAS 6.12 and 8.0 software (SAS 6.12 & 8.0; SAS, Raleigh, NC, USA). Measurement data were expressed as mean ± SD. The *t*-test and analysis of variance were used for intergroup comparisons. A value of $P < 0.05$ was considered statistically significant.

Acknowledgments: We are very grateful to Professor Liangping Hu from the Academy of Military Medical Science of the PLA for providing the SAS 6.12 & 8.0 software.

Funding: This study was supported by grants from the Key Topics of China Traditional Chinese Medicine Scientific Research Project, General Logistics Department of Chinese PLA, No. 10ZYZ125; and the Army Medical Science and Technology the 12 • 5 Scientific Research Projects, Chinese PLA, No. AKJ11J004.

Author contributions: Yu Feng participated in study design, clinical treatment of patients, data processing, and manuscript writing. Yan Gao participated in data collection, integrity, and analysis. Wendong Yang participated in clinical data collection. Tianyou Feng was responsible for supervision of the study and supervision of the writing of the manuscript. All authors have read and approved the final version of the manuscript.

Conflicts of interests: None declared.

Ethical approval: The study protocol was approved by the Ethics Committee of the General Hospital of the Air Force, China.

Author statements: This manuscript is original, has not been submitted to and is not under consideration by another publication, has not been previously published in any language or any form, including electronic, and contains no disclosure of confidential information or authorship/patent application/funding source disputations.

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(Reviewed by Elgin M, Norman C, Xiao YY, Fang MR)
(Edited by Wang LM, Qiu Y, Li CH, Song LP)