A Meta-Analysis on the Clinical Significance of Redundant Nerve Roots in Symptomatic Lumbar Spinal Stenosis

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■ OBJECTIVE: **Symptomatic lumbar spinal stenosis (LSS), which leads to severe socioeconomic consequences and places a heavy burden on global healthcare system, is a relatively frequent spine disorder. Redundant nerve roots (RNRs) are a relatively common finding in which slender, serpiginous, or tortuous nerve roots are found in the subarachnoid space of the lumbar spine. Previous studies that evaluated the prognostic assessment of RNRs in patients with symptomatic LSS are composed of doubtful results. Therefore, the clinical significance of RNRs in symptomatic LSS is still uncertain. The aim of this meta-analysis is a systematic assessment of the clinical significance of RNR syndrome in symptomatic LSS.**

■ METHODS: **This study used a highly sensitive search strategy to identify all published studies in multiple databases up to January 1, 2017. All identified trials were systematically evaluated using specific inclusion and exclusion criteria. Cochrane methodology was also applied to the results of this study.**

■ RESULTS: **This study identified 4 relevant studies involving 297 patients. Compared with a non-RNR group, the RNR group results included worse clinical outcomes that were assessed using the Japanese Orthopedic Association scores after surgery (weighted mean difference [WMD], −0.78; 95% confidence interval [CI], −1.26 to −0.29; $P = 0.002$; $I^2 = 0\%$), for recovery rate (WMD, −9.87; 95% CI, −15.07 to −4.67; $P = 0.0002$; $I^2 = 0\%$), and for older age (WMD, 2.51; 95% CI, 0.45–4.57; $P = 0.02$; $I^2 = 43\%$).**

■ CONCLUSIONS: **RNR is an entity in association with symptomatic LSS, which may be viewed as a potentially powerful prognostic indicator of worse postoperative functional recovery for symptomatic LSS.**

INTRODUCTION

Symptomatic lumbar spinal stenosis (LSS) is a relatively common reason for performing spinal surgery, which has been defined as lower-extremity or gluteal region pain that occurs with or without low back pain and is associated with reduced space available of spinal canals for dural sac, vascular, and neural elements in the lumbar spine.[1,2] In addition, symptomatic LSS also leads to severe socioeconomic consequences and places a heavy burden on global healthcare system.

Verbiest[3] first described the redundant nerve roots (RNRs) in 1954, and Cressman and Pawl[4] subsequently coined the term in 1968. RNRs, a status described as serpiginous, slender, enlarged, tortuous nerve roots in the subarachnoid space of the lumbar spine canal,[5-8] which is relatively common in patients with symptomatic LSS and can be identified by MRI. Prior reports revealed that the incidence rate of RNRs apparent on magnetic resonance imaging (MRI) in symptomatic LSS patients were 33.8%–42.3%.[9-11] Although myelography with contrast was previously needed to diagnose RNRs, noninvasive MRI is sufficient to make an accurate diagnosis.[5,6,12]

There were few available clinical studies of the clinical significance of RNRs. Chen et al.[13] found that patients with symptomatic LSS with RNRs could have poor operation outcomes. Another study[10] on RNRs demonstrated that the operation outcomes in

Key words
- Meta-analysis
- Prognosis
- Redundant nerve roots
- Symptomatic lumbar spinal stenosis

Abbreviations and Acronyms
CI: Confidence interval
CSA: cross sectional area
CSF: Cerebrospinal fluid
JOA: Japanese Orthopedic Association
LSS: Lumbar spinal stenosis
MRI: Magnetic resonance imaging
OR: Odds ratio
QUADAS: Quality Assessment of Diagnostic Accuracy Studies
RNR: Redundant nerve root
SMD: Standardized mean difference
WMD: Weighted mean difference

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the non-RNRs group were not statistically different from those in the RNRs group. Previous studies that evaluated the prognostic assessment of RNRs in patients with symptomatic LSS are composed of doubtful results. Therefore, the clinical significance of RNRs in symptomatic LSS is still uncertain.

The objective of this meta-analysis is a systematic assessment of the clinical significance of RNRs in symptomatic LSS.

MATERIALS AND METHODS

Search Methods for Identification of Studies

This study was completed in accord with the guidance outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement.[14] The databases used for the search were PubMed, Ovid EMBASE, Ovid MEDLINE, Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials, ACP Journal Club, Scopus, Web of Science, and the Database of Abstracts of Review of Effectiveness, from initiation to January 1, 2017. A combination of controlled vocabulary and text words was used. MEDLINE uses a single term, "redundant nerve roots," but EMBASE and others use the term "redundant nerve root" and include more specific terms for RNRs. To be as inclusive as possible, the search also included "RNR" and "RNR*." The same approach was used for lumbar spinal stenosis: "lumbar spinal stenosis" is used by MEDLINE, but EMBASE and others use "spinal stenosis," with more specific terms such as "canal stenosis" and "lumbar canal stenosis." The results were downloaded into EndNote X7 (Thomson ResearchSoft, Stamford, Connecticut, USA), and duplicates were removed. To avoid outcome misconstrued by language bias, we tried to consider all studies without language restrictions, including articles in Mandarin.

Criteria for Selected Trials

All trials assessing the clinical significance of RNRs in symptomatic LSS were reviewed in this study. We systematically identified published articles according to the following inclusion criteria: 1) all patients underwent supine position lumbar spine MRI examination; 2) all patients had records of diagnostic tests; and 3) all patients had the self-reported symptoms of progressive, intermittent low back or leg pain with standing and walking that is relieved by sitting or lying down. We contacted authors personally to retrieve the original data when the publications had insufficient published data. We chose reports with the most details when multiple reports had been published for the same population. Studies were excluded for the following reasons: 1) they lacked 1 or more inclusion criteria; 2) before the MRI examination, the surgeon had previously performed the operation on patients included in the identified study for lumbar spinal disease; 3) they were case reports, abstracts, conference presentations, review, expert opinions, or editorials.

Primary outcomes obtained in this study were as follows: 1) Japanese Orthopedic Association (JOA) scores before surgery; 2) JOA scores after surgery; 3) recovery rate (%); 4) dural sac cross sectional area (CSA) (mm^2); 5) segmental angulation; 6) symptom duration (months); and 7) age.

Quality Assessment and Data Extraction

All titles, abstracts, and the full text of the potentially eligible trials based on abstract review were reviewed independently by 2 investigators (L.C. and Y.Z.). Next, they selected the eligible trials according to the inclusion and exclusion criteria. Disagreements were addressed by discussion with the 2 reviewers and, if necessary, by further discussion with another independent co-author. This study used the Quality Assessment of Diagnostic Accuracy Studies (QUADAS) tool to assess the methodological quality of each included study.[15,16] The two investigators independently extracted data from included studies, and further discussion with another independent co-author was needed to resolve the disagreements. The extracted data's categories were as follows: author, publication year, country, language, published journal, study design, participants, magnetic field strength, reference standard, follow-up, study groups, age, sexual ratio, symptom duration, segmental angulation, dural sac CSA, JOA scores, and recovery rate.

Measures of Treatment Effect

This study attempted a statistical pooling of data from the included trials to obtain the data of primary outcomes. The calculated results were expressed in terms of odds ratio (OR) or weighted mean difference (WMD) and a 95% confidence interval (CI) for dichotomous or continuous outcomes. When we measured the same continuous outcomes in different scales, we calculated standardized mean difference (SMD) and 95% CI. If primary outcomes were expressed as continuous data in some trials while in the other trials shown as dichotomous data, we would re-express OR as SMD to allow continuous and dichotomous data to be pooled together. Two reviewers checked the collected data, entered them into the computer, and then analyzed the data using Review Manager (RevMan) software (version 5.3; The Nordic Cochrane Centre, The Cochrane Collaboration, Copenhagen, Denmark). The Laird Q test was performed for heterogeneity, and the I^2 statistic were also calculated for each analysis.[17] If the P value was 0.05 or less, indicating obvious heterogeneity between studies, we would perform the random-effects model to evaluate the pooled OR[18,19]; otherwise, we would use the fixed-effects model.[20] This study performed an asymmetry test with Stata software and produced a funnel plot to assess publication bias visually. Next, we used the rating system with 5 levels of evidence of Cochrane Back Review Group to assess the level of evidence.[21,22]

RESULTS

Description of Studies

To achieve a systematic evaluation of our current understanding of the clinical significance of RNRs in symptomatic LSS, we identified eligible studies by filtering for different inclusion and exclusion criteria (Figure 1). After initial screening, 895 references were removed that examined symptomatic LSS but did not focus on RNRs. Upon further evaluation of titles and abstracts, 44 additional references were omitted (Figure 1). Of the remaining 17 candidate studies, 13 more studies were excluded because assessment of the full text revealed these studies to be case reports, reviews, experiments involving an unreasonable control group (Figure 1). Finally, 4 trials having definite inclusion and exclusion criteria with 297 symptomatic LSS patients entered this study.[6,9,10,13]

Tables 1 and 2 summarize the characteristics of 4 included trials. In all included trials, patients with symptomatic LSS were enrolled