The purpose of this study was to investigate whether pre- to postoperative changes of increased signal intensity (ISI) of the spinal cord as seen on T2-weighted magnetic resonance imaging (MRI) reflect the surgical outcome in patients with cervical spinal cord injury without radiologic evidence of trauma (SCIWORET). In this study, 54 patients with SCIWORET who underwent expansive laminoplasty were retrospectively analyzed. All patients underwent MRI at an average of 1.9 days (range, 1–5 days) after injury and 7.9 days (range, 6–10 days) postoperatively. The pre- and postoperative range and degree of ISI were measured on computer software using the same sagittal view on T2-weighted MRI. Then, the post-preoperative ratio of range and degree of ISI were calculated. Pre- and postoperative neurologic evaluations were performed according to the criteria proposed by the Japanese Orthopedic Association (JOA). A significant negative correlation existed between the ratio of range of ISI and the recovery rate ($r=-0.504$, $P<.01$). The ratio of degree of ISI negatively correlated with the recovery rate, but this was not statistically significant. Patients were divided into 2 groups according to the ratio of degree of ISI: group A included patients with a ratio of degree of ISI of $\leq 1$ (n=24) and group B included patients with a ratio of degree of ISI of $>1$ (n=30). Patients’ mean recovery rate was 65.0%±6.3% in group A and 52.4%±7.4% in group B. A significant difference was found between the 2 groups ($P<.001$, Student’s $t$ test) when comparing recovery rate. The pre- to postoperative changes of the range and degree of ISI significantly reflected prognosis for surgical outcome in patients with SCIWORET.
Spinal cord injury without radiographic abnormalities was first described by Pang et al.\textsuperscript{1,2} and was defined as a clinicoradiological entity that presents as acute traumatic myelopathy with normal radiographic and computed tomography (CT) findings. However, the term spinal cord injury without radiologic evidence of trauma (SCIWORET) was recommended for use in the adult population to include situations in which plain radiographs and CT scans do not show any evidence of trauma, with the exception of instances of preexisting cervical spondylosis.\textsuperscript{3-5} The quality of imaging modalities has had great progress over the years, especially magnetic resonance imaging (MRI), leading to better understanding of SCIWORET. Magnetic resonance imaging is the best clinical tool for the examination and evaluation of patients with SCIWORET because it can show not only the degree of spinal degeneration, but also the intramedullary state of the spinal cord in detail.\textsuperscript{6} Magnetic resonance imaging is helpful in the diagnosis and prognosis of patients with SCIWORET because it can not only reliably reveal intrinsic injury to the spinal cord and clearly depicting the lesion location, extent, and severity, but it can also provide the best imaging evaluation of the intervertebral discs, the adjacent ligaments, and the soft tissues.

Increased signal intensity (ISI) of the spinal cord on T2-weighted MRI are well-known changes in spinal cord lesions. These signal changes reflect various intramedullary lesions.\textsuperscript{7} The correlation between the range and degree of ISI in the spinal cord, clinical symptoms, and surgical outcome has not been well discussed.\textsuperscript{5,8-10} In the current study, the authors report the ISI of the spinal cord on T2-weighted MRI pre- and postoperatively. The purpose of the current study was to investigate whether pre- to postoperative changes of the range and degree of ISI reflect the surgical outcome in patients with SCIWORET.

**Materials and Methods**

A retrospective review of 54 patients with SCIWORET who had undergone expansive laminoplasty was conducted at the authors’ institution from January 1, 2008, to August 30, 2011. In this study, SCIWORET was defined as (1) the presence of neurologic deficit; (2) having no signs of fracture or dislocation of the cervical spine on plain radiographs and CT scans; and (3) the presence of a cervical spinal cord injury seen on MRI. Surgical intervention was indicated for patients with neurologic deficits and spinal cord compression resulting from cervical spinal canal stenosis. Approval to conduct this study was obtained from the authors’ institutional review board. All personal identifiers were removed and the anonymous data independent to individuals were collected.

In this study, the American Spinal Cord Injury Association (ASIA) scale was used to evaluate the patients’ neurologic status, and the neurologic evaluation was performed pre- and postoperatively according to the criteria proposed by the Japanese Orthopedic Association (JOA) (maximum score=17 points). The recovery rate was calculated using Hirabayashi’s formula:

\[
\text{Recovery rate}=\frac{\text{postoperative JOA score} - \text{preoperative JOA score}}{\text{maximum score}} \times 100
\]

All patients underwent high-resolution MRI with a 1.5-Tesla imager (Signa; GE Medical Systems, Milwaukee, Wisconsin) at an average of 1.9 days after injury (range, 1-5 days) and 7.9 days (range, 6-10 days) postoperatively. Sagittal T1- and T2-weighted MRIs of the cervical cord were obtained using a spine echo sequence system for T1-weighted MRI and a fast-spin echo sequence system for T2-weighted MRI. Slice width was 3 mm and the acquisition matrix was 512x512. Sequence parameters were a repetition time of 1892 ms and echo time of 10.1 ms for T1-weighted MRI and a repetition time of 2700 ms and echo time of 123 ms for T2-weighted MRI. Window width and level were set differently in each patient by the MRI operators so that the optimal contrast between each tissue could be obtained.

Increased signal intensity of the spinal cord on sagittal T2-weighted MRI was evaluated by an experienced neuroradiologist. The existence of slightly increased signal intensity was identified by axial view in the cases that were difficult to estimate. The pre- to postoperative range of ISI was measured at the same sagittal view on T2-weighted MRI. The pre- to postoperative degree of ISI was calculated using sagittal T2-weighted MRI at the same spinal cord level and approximately the same area using ImageJ software version 1.46 (National Institutes of Health, Bethesda, Maryland). Each was measured 3 times and mean data were used. Using this data, the post-preoperative ratio of the range and ratio of degree of ISI was obtained (Figure 1).

**Statistical Analysis**

SPSS version 21.0 for Windows (IBM Corporation, Armonk, New York) was used for statistical analysis. Analyses of the difference between pre- and postoperative JOA scores were performed using Student’s t test. Spearman rank correlation coefficient was used to determine the correlations between the recovery rate and the ratio of range or ratio of degree of ISI. All P values less than .05 were considered statistically significant.

**Results**

Mean±SD age of the 54 patients with SCIWORET was 60.4±16.5 years (range, 37-84 years). Most patients were between 61 and 75 years (n=26, 48.1%) or between 46 to 60 years (n=17, 32%). Overall causes of injuries were slight falls in 26 (48.1%) patients and traffic injuries in 28 (51.9%). The neurological levels (ie, injury levels) were as follows: C4 (n=7, 13.0%), C5 (n=26, 48.1%), and C6 (n=21, 38.9%). All patients underwent expansive laminoplasty. In addition, 3 (5.6%) patients with...
Preexisting kyphosis or cervical instability underwent spinal instrumentation with fusion simultaneously. The mean interval between injury and surgery was 3.0 days (ranged, 2-7 days). Mean follow-up period was 17 months (range, 12-27 months).

The mean JOA score increased from 8.75±3.23 points preoperatively (range, 3-13 points) to 13.31±3.43 points (range, 5-16 points) postoperatively. Mean recovery rate with the JOA score was 62.7%. There was a significant difference between pre- and postoperative JOA score in this series (P<.001, Student’s t test), showing a statistically significant improvement of the clinical symptoms and JOA scores.

The preoperative ASIA impairment scale grades were as follows: A (n=1, 1.9%), B (n=3, 5.6%), C (n=32, 59.3%), D (n=18, 33.3%), and E (n=0, 0%). Postoperative ASIA impairment scale grade at the final follow-up evaluation were as follows: A (n=0, 0%), B (n=2, 3.7), C (n=5, 9.3%), D (n=30, 55.6%), and E (n=17, 31.5%). According to the ASIA impairment scale, 79% of patients had 1 or more grades of improvement postoperatively.

The ratio of range of ISI ranged from 0.45 to 0.83. With the ratio of range of ISI increased, the recovery rate began to decrease. A significant negative correlation was found between the ratio of range of ISI and the recovery rate (r=-0.504, P<.01) (Figure 2). The linear regression equation (R² = 0.233) was as follows:

Recovery rate=1.047–0.657 ratio of range of ISI.

With the ratio of degree of ISI increased, the recovery rate began to decrease. The ratio of degree of ISI negatively correlated with the recovery rate but was not statistically significant.

The ratio of degree of ISI ranged from 0.79 to 1.17. Patients were further divided into 2 groups according to the ratio of degree of ISI: group A included patients with a ratio of degree of ISI of ≤1 (n=24) and group B included patients with a ratio of degree of ISI of >1 (n=30). The recovery rates were 65.0%±6.3% in group A and 52.4%±7.4% in group B. A significant difference was found between the 2 groups (P<.001, Student’s t test) when comparing recovery rate, with statistically significant improvement in the clinical symptoms and JOA scores in group A.
Magnetic resonance imaging is the best imaging modality for the evaluation of spinal cord injury, providing information that helps determine a patient’s diagnosis and prognosis by depicting the internal architecture of the spinal cord. Increased signal intensity on T2-weighted MRI and decreased signal intensity on T1-weighted MRI reflects various intramedullary lesions. Preoperative range of ISI in the spinal cord on T2-weighted MRI has been studied but mainly in relation to surgical outcome. However, no studies have reported the correlation between pre- and postoperative changes of the range and degree of ISI and the prognosis of patients with SCIWORET. This study has shown that patients with more decreased range of ISI in the spinal cord on T2-weighted MRI have better postoperative outcomes. Furthermore, patients with preoperative ISI on T2-weighted MRI who exhibited a decreased change in the degree of ISI postoperatively had a better prognosis than patients who exhibited an increased postoperative change in the degree of ISI. Patients with acute SCIWORET and MRI manifestation of spinal cord hemorrhage and maximum spinal cord compression have a poor prognosis. Other research has demonstrated that patients with a T2-weighted hyperintense signal and a T1-weighted hypointense signal have a worse prognosis than patients with the same T2- and T1-weighted signal changes. However, the authors believe that the range and degree of ISI is a variant with large range and dependent on the patient. During the course of the current study, the authors found that patients who manifested the same neurologic status preoperatively may exhibit a different range and degree of ISI on T2-weighted MRI. Therefore, it will bias the analysis if only the preoperative range and degree of ISI are investigated. The authors considered that it would be more objective to calculate the ratio of range and degree of ISI change from pre- to postoperative to exactly reflect decompression outcome. The inherent limitation in this study is that it is a retrospective review of patients, which has a lower level of evidence. As the result of patients with SCIWORET being infrequent, it is nearly impossible to conduct a prospective study with a rational time point for completion.

**Conclusion**

The pre- to postoperative changes of the range and degree of ISI significantly reflected prognosis for surgical outcome.

**References**


