The evolution of T2-weighted intramedullary signal changes following ventral decompressive surgery for cervical spondylotic myelopathy

Clinical article

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Object. T2-weighted intramedullary increased signal intensity (ISI) on MRI in patients with cervical spondylotic myelopathy (CSM) appears to represent a wide spectrum of pathological changes that determine reversibility of cord damage. Although sharp T2-weighted ISI on preoperative imaging may correlate with poorer surgical outcomes, there are limited data on how these changes progress following surgery. In this study, the authors characterized pre- and postoperative ISI changes in patients undergoing surgery for CSM and studied their postoperative evolution in an attempt to quantify their clinical significance.

Methods. The preoperative and postoperative MR images obtained in 56 patients who underwent oblique cervical corpectomy for CSM were reviewed, and the ISI was classified into 4 subtypes based on margins and intensity: Type 0 (none), Type 1 (“fuzzy”), Type 2 (“sharp”), and Type 3 (“mixed”). The locations of the ISI were further classified as focal if they represented single discrete lesions, multifocal if there were multiple lesions with intervening normal cord, and multisegmental if the lesions were continuous over more than 1 segment. The maximum cranio-caudal length of the ISI was measured on each midsagittal MR image. The Nurick grade and Japanese Orthopaedic Association (JOA) score were used to assess clinical status. The mean duration of follow-up was 28 months.

Results. T2-weighted ISI changes were noted preoperatively in 54 patients (96%). Most preoperative ISI changes were Type 1 (41%) or Type 3 (34%), with a significant trend toward Type 2 (71%) changes at follow-up. Multisegmental and Type 3 lesions tended to regress significantly after surgery (p = 0.000), reducing to Type 2 changes at follow-up. Clinical outcomes did not correlate with ISI subtype; however, there was a statistically significant trend toward improvement in postoperative Nurick Grade in patients with a > 50% regression in ISI size. In addition, patients with more than 18 months of follow-up showed significant regression in ISI size compared with patients imaged earlier. On logistic regression analysis, preoperative Nurick grade and duration of follow-up were the only significant predictors of postoperative improvement in functional status (OR 4.136, p = 0.003, 95% CI 1.623–10.539 and OR 6.402, p = 0.033, 95% CI 1.165–35.176, respectively).

Conclusions. There is a distinct group of patients with multisegmental Type 3 intramedullary changes who show remarkable radiological regression after surgery but demonstrate a residual sharp focal ISI at follow-up. A regression of the ISI by > 50% predicts better functional outcomes. Patients with a good preoperative functional status remain the most likely to show improvement, and the improvement continues to occur even at remote follow-up. The clinical relevance of the quality of the T2-weighted ISI changes in patients with CSM remains uncertain; however, postoperative regression of the ISI change is possibly a more important correlate of patient outcome than the quality of the ISI change alone.

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Key Words • T2-weighted intramedullary changes • oblique corpectomy • cervical spondylotic myelopathy

Intramedullary increased signal intensity (ISI) changes on T2-weighted MRI of the cervical spine are seen in the majority of patients with cervical spondylotic myelopathy (CSM). Efforts to classify these signal changes to predict neurological recovery following surgery are based on either the longitudinal extent of the T2-weighted ISI or the quality of the change. The quality of the T2-weighted signal changes in CSM has been described as either “fuzzy” or “sharp,” presumed pathological correlates of reversible and irreversible cord pathology, respectively. There are limited data on the temporal profile of these T2-weighted ISI changes following surgery, and a definite relationship between their resolution and functional improvement has not been established.
The multilevel oblique cervical corpectomy affords excellent ventral decompression of the spinal cord with good clinical outcomes in CSM while preserving spinal stability without the need for bony fusion.\textsuperscript{2,15,16,27,31} We reviewed the records of patients with CSM and ossification of the posterior longitudinal ligament (OPLL) who had undergone this procedure at our institution. The purpose of this study was to describe the prognostic significance and postoperative evolution of T2-weighted ISI changes and see if further radiological characterization was possible to determine functional outcome.

**Methods**

**Patient Group**

The records of 56 patients who had undergone oblique cervical corpectomy for CSM and OPLL and had pre- and postoperative MRI studies were retrospectively reviewed. The majority were middle-aged men (93%, mean age at presentation 50 years). Most patients underwent a 1- or 2-level procedure, and the posterior longitudinal ligament was ossified in 25%.

**Clinical and Radiological Evaluation**

A detailed clinical evaluation was performed prior to surgery and at follow-up, and the functional status was assessed by the Nurick Grade and JOA score.

Images were obtained using 0.5- to 3-T MRI units, and images obtained at other institutions were scanned and scaled for analysis. Depending on the machine used, the imaging protocol involved 3- to 10-mm-thick slices for T1-weighted images (TR 100–240 msec, TE 7–15 msec) and 3-mm-thick slices for T2-weighted images (TR 2940–4000 msec, TE 108–120 msec). The variation in imaging quality did not affect our ability to accurately classify and measure T2-weighted ISI change. Only images obtained within 3 months of surgery were included for preoperative analysis. The postoperative images were obtained at a median of 16 months after surgery (range 10–98 months). For patients with lengthy follow-up periods and multiple postoperative images, the last follow-up image was considered for analysis.

The preoperative and postoperative MR images were stored on a GE Centricity 1.0 picture archiving and communication system (PACS) server and viewed on clinical workstations. We classified the ISI lesions using 3 systems, based on their location (at the level of compression or remote) and extent (focal, multifocal, or multisegmental) and quality (“fuzzy,” “sharp,” or “mixed”).

Figures 1–3 illustrate the ISI classification used. Midsagittal MR images were evaluated for the presence of T1- and T2-weighted changes. Lesions confined to a single vertebral body were termed focal, whereas continuous lesions spanning more than 1 vertebral body were described as multisegmental. If there were multiple lesions with intervening normal cord, they were classified as multifocal. Characterization of the ISI quality was based on the system described by Chen et al.\textsuperscript{4} and modified further as follows: Type 0, no intramedullary changes seen; Type 1, “fuzzy,” defined as a faint intramedullary change with a predomi-

nantly indistinct and hazy border; Type 2, “sharp,” defined as a bright intramedullary change with a predominantly well-defined margin. We added a third category, Type 3, or “mixed,” defined as a fuzzy intramedullary change with a distinct central or eccentric sharp component.

The T2-weighted hyperintensities were then measured in millimeters along the greatest vertical axis. If the ISI change was multifocal, only the length of the largest lesion was included for the purpose of analysis. The presence of OPLL, if any, was also noted. The images were reviewed by 3 of the authors, all of whom were blinded to the clinical outcomes. Only one of these 3 authors (A.G.C.) was the operating surgeon and primary treating physician; the other two (S.S. and M.K.T.) were neurosurgical trainees who were not directly involved in patient care. Patients were identified by medical record numbers with a follow-up duration of at least 10 months, thus minimizing the possibility of a bias in image interpretation. In the event of disagreement, the decision of the senior author (A.G.C.) was final.

**Statistical Analysis**

We calculated descriptive statistics: mean and standard deviation for continuous variables and frequency and percentages for categorical variables. The Student t-test or ANOVA and chi-square test were employed to test the significance of continuous and categorical variables, respectively. The paired t-test was employed to assess the significance of changes in continuous variables and the Wilcoxon signed ranks test was used for change in categorical variables over time. Finally, we used a multiple linear and logistic regression analysis to study outcomes after adjusting for age, duration of symptoms, and preoperative Nurick Grade.

**Results**

**Clinical**

Table 1 documents the sociodemographic and clinical characteristics of the sample. The majority of the patients were male and middle-aged. The mean symptom duration was 15.4 ± 17.4 months. A single-level corpectomy was performed in 38% of patients, while the remainder underwent multilevel procedures. The mean preoperative Nurick grade was 3.4 ± 1.0 and the mean preoperative JOA score was 12.2 ± 2.4, which improved to 2.3 ± 0.8 and 14.8 ± 1.9, respectively, at follow-up. The median duration of follow-up was 16 months (range 10–98 months).

**Radiology**

Tables 2 and 3 summarize the radiological characteristics of these patients on preoperative and postoperative imaging.

**Quality of ISI Changes**

T2-weighted ISI changes were present in 54 patients on preoperative imaging (96%). Type 1 (“fuzzy”) and Type 3 (“mixed”) ISI changes were the most common, noted on MRI studies obtained prior to surgery in 41% and 34% of cases, respectively. On postoperative imaging,
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however, Type 2 (“sharp”) changes were the most frequent overall (71%), and this trend was statistically significant ($p < 0.001$).

Neither of the 2 patients without ISI changes prior to surgery developed new lesions on follow-up. Preoperative Type 1 ISI changes (found in 23 patients) completely re-

Fig. 1. A–C: Preoperative (A and B) and postoperative (C) sagittal MR images obtained in a man with CSM who underwent a C-6 oblique corpectomy at the age of 54 years showing a focal Type 1 ISI on the preoperative T2-weighted sequence (A), no T1-weighted hypointensity (B), and a focal Type 2 ISI change 2 years after a C-6 oblique corpectomy (C).  

D–F: Preoperative (D and E) and postoperative (F) sagittal MR images obtained in a 33-year-old man, with a preoperative focal Type 2 ISI (D) that regressed craniocaudally but continued to demonstrate a focal Type 2 signal change at 3 years’ follow-up (F). There was no preoperative T1-weighted hypointensity (E).
solved in 3 patients, remained Type 1 in 5, and transformed to Type 2 changes in the rest (65%) on follow-up. In the 5 patients who continued to have Type 1 changes after surgery, the ISI decreased in craniocaudal size in 4 of them, with only 1 patient showing a postoperative ISI expansion. In 11 of the 12 patients with Type 2 lesions on presentation, there was no change in postoperative quality; in the remaining case, the signal change appeared fuzzy on follow-up.

Of the 19 patients with Type 3 ISI changes on preoperative imaging, 14 (74%) had Type 1 changes (sharp) on follow-up. Two patients still showed Type 3 ISI changes at follow-up, but both showed a substantial (mean 51%) decrease in size of the preoperative lesion.

There were a total of 9 patients with postoperative Type 1 changes, including 4 who had sharp or mixed changes (Types 2 and 3) prior to surgery. At a mean follow-up of 34 ± 25 months, 8 of the 9 patients showed a significant reduction (mean 51.5%) in size of the ISI; in the other patient, ISI expansion was seen 11 months after surgery.

**Location and Extent of the ISI**

The level of cord compression ranged from C-3 to C-6. The most frequently affected segments (affected in 66% of cases) were C-5 and C-6). The location of the preoperative ISI corresponded to the level of cord compression in almost all patients (91.1%); only 2 patients had lesions at remote sites. ISI lesions were most frequently focal or multisegmental, and only 2 preoperative and 10 postoperative intramedullary changes were multifocal. Multisegmental lesions showed a significant propensity to reduce to focal or multifocal changes after surgery (p < 0.001).

**Craniocaudal Length of the ISI**

The mean preoperative length of the ISI was 19.3 ± 17.6 mm. The mean preoperative lengths of the various subtypes were as follows: Type 1, 12.6 ± 8.7 mm; Type 2, 16.2 ± 22.9 mm; Type 3, 31.4 ± 17.3 mm (F = 2.741, p = 0.011). Over the entire series, ISI lesions reduced to only a third of their original size on follow-up (19.26 ±
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TABLE 1: Sociodemographic and clinical characteristics of the sample (n = 56)*

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>sex</td>
<td></td>
</tr>
<tr>
<td>male</td>
<td>52 (92.9)</td>
</tr>
<tr>
<td>female</td>
<td>4 (7.1)</td>
</tr>
<tr>
<td>mean age (yrs)</td>
<td>49.6 ± 8.73</td>
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<tr>
<td>mean preop JOA score</td>
<td>12.2 ± 2.39</td>
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<tr>
<td>mean preop Nurick grade</td>
<td>3.39 ± 0.99</td>
</tr>
<tr>
<td>corpectomy level</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>21 (37.5)</td>
</tr>
<tr>
<td>2</td>
<td>25 (44.6)</td>
</tr>
<tr>
<td>3</td>
<td>10 (17.9)</td>
</tr>
<tr>
<td>OPLL</td>
<td></td>
</tr>
<tr>
<td>present</td>
<td>14 (25.0)</td>
</tr>
<tr>
<td>absent</td>
<td>42 (75.0)</td>
</tr>
<tr>
<td>mean postop JOA score</td>
<td>14.8 ± 1.85</td>
</tr>
<tr>
<td>mean postop Nurick grade</td>
<td>2.25 ± 0.82</td>
</tr>
<tr>
<td>mean change in JOA score</td>
<td>2.57 ± 2.60</td>
</tr>
<tr>
<td>mean change in Nurick grade</td>
<td>−1.14 ± 0.98</td>
</tr>
<tr>
<td>duration of follow-up (in mos)</td>
<td></td>
</tr>
<tr>
<td>median</td>
<td>16</td>
</tr>
<tr>
<td>range</td>
<td>10–98</td>
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</table>

* Values represent numbers of patients (%) unless otherwise indicated. Means are presented ± SD.

17.64 mm vs 6.56 ± 7.3 mm), a trend that was statistically significant (p = 0.001). The postoperative ISI length was significantly related to the preoperative length (Pearson correlation coefficient [r] = 0.33; p = 0.013), and the reduction in ISI length showed a significant negative relationship with the preoperative length (r = 0.091; p < 0.005). Thus, larger preoperative ISI changes were more likely to regress substantially on follow-up.

The postoperative changes in length of the ISI lesions were significantly related to the ISI quality on preoperative MR images (ANOVA F = 4.72; p = 0.005), with statistically significant differences (mean difference −16.2 ± 4.7 mm) between the Type 1 (“fuzzy”) group (mean −6.9 ± 10.9 mm) and the Type 3 (mixed) group (mean −23.1 ± 14.6 mm) using post hoc analysis with the Bonferroni statistic. Thus, reductions in ISI length in the Type 3 and Type 1 groups contributed to the statistical significance, with much greater reductions in the former than in the latter.

Correlation Between Radiology, Clinical Outcomes, and Duration of Follow-Up

Preoperative Nurick grade predicted postoperative Nurick grade (B = 0.35; standard error of the coefficient [SE] = 0.10; p = 0.001), and this remained statistically significant after adjusting for age, sex, and duration of symptoms using multiple linear regression (B = 0.35; SE = 0.11; p = 0.002). However, the quality, extent, location, and length of the T2-weighted ISI lesions on preoperative MRI were not significantly associated with clinical outcomes (postoperative JOA score and Nurick grade or their relative change).

Nevertheless, patients with a postoperative decrease in craniocaudal length of the ISI that was greater than 50% (n = 31) had significantly (t = 4.13, df = 34.9, p = 0.000) smaller preoperative lesions (mean 4.13 ± 4.9 mm) than those with smaller reductions in length (n = 23, mean 21.07 ± 17.7 mm). The difference between these groups showed a trend toward statistical significance with respect to the postoperative Nurick grade (mean 1.67 ± 0.52 vs mean 2.52 ± 0.82, t = −1.9, df = 54, p = 0.063) and the postoperative JOA score (mean 16.0 ± 1.55 vs mean 14.6 ± 1.8, t = 1.74, df = 54, p = 0.08). Thus, a regression of the ISI extent by more than 50% at follow-up predicted a better outcome in our patients. Patients who were followed up for more than 18 months had significantly (t = −2.11, df = 31.82, p = 0.043) smaller lesions at follow-up (mean 4.5 ± 2.5 mm) compared with those whose lesions were assessed only on earlier postoperative images (mean 8.4 ± 9.6 mm). However, duration of follow-up did not significantly correlate with clinical functional grade.

Temporal Correlates of the Quality of ISI Change

There was no statistically significant association (using ANOVA) between preoperative quality of ISI change and either duration of symptoms (F = 0.788; p = 0.506) or period of follow-up (F = 0.561; p = 0.643). Similarly, the postoperative quality of ISI change was not associated with symptom duration (F = 0.533; p = 0.662) or length of follow-up (F = 1.265; p = 0.296). Patients with an ISI transition from Type 1 to Type 2 did not differ significantly in terms of duration of symptoms (F = 0.788, p = 0.506) or length of follow-up (F = 0.788, p = 0.506) from those who had Type 1 ISI postoperatively as well as preoperatively. There was also no statistically significant correlation between change in craniocaudal length of the ISI and either duration of symptoms or period of follow-up (t = 0.575, df = 54, p = 0.567 and t = −0.357, df = 54, p = 0.722, respectively) or percentage clinical improvement over time (r = −0.005, p = 0.970 and r = 0.043, p = 0.752, respectively).

Results of Logistic Regression Analysis

We applied logistic regression analysis to establish if there were any factors predicting clinical improvement, defined as a decrease in Nurick grade by at least 1 at fol-
low-up, after adjusting for age, duration of symptoms, and preoperative Nurick grade. The results are summarized in Table 4. We concluded that a preoperative Nurick Grade of 2 or less was a significant indicator of functional improvement following surgery. We also observed that patients followed up for longer periods (more than 18 months) had better outcomes, suggesting that the neurological recovery following decompression was sustained even at remote follow-up. Patients whose T2-weighted ISI size (as measured by craniocaudal length) regressed by more than half craniocaudally after surgery appeared to be more likely to have better outcomes than those without such a decrease, and a Type 2 ISI, either on preoperative or postoperative imaging, may negatively impact outcomes, but these associations were not statistically significant.

Discussion

Preoperative T2-Weighted Changes and Type 3 ISI

The intramedullary increased signal intensity (ISI) on T2-weighted MR images obtained in patients with CSM correlates with a number of pathological findings at autopsy.21,25 These findings may range in severity from reversible cord edema and ischemia, to irreversible cavitation and necrosis. The latter are postulated to appear as “sharp” and the former as “fuzzy” changes on MRI.1,21,25,32,33 Various attempts have been made to characterize these ISI changes further. Mehalic et al.20 graded the intensity of these intramedullary changes on a scale of 0 to 4; however, the subjectivity of this assessment limited its popularity. The current “fuzzy/sharp/none” terminology was first introduced by Chen et al.9 and remains widely used, remarkable for its simplicity and convenience. However, we feel that the dynamic nature of intramedullary pathological changes in CSM necessitates the inclusion of an additional subtype of ISI to provide for the simultaneous presence of edema and ischemia evolving and merging into necrosis, gliosis, and cavitation. These “mixed,” or Type 3, ISI changes are a heterogeneous combination of the fuzzy and sharp extremes and were seen in one-third of our patients on preoperative imaging, indicating the simultaneous presence of both irreversible and reversible changes in the cord.

Prognostic Relevance of T2-Weighted ISI

In our series of patients, the quality of the preoperative or postoperative T2-weighted ISI change did not predict clinical outcomes, echoing the findings of others3,19,34 who were also unable to confirm the prognostic significance of these intramedullary changes. Despite our observation that T2-weighted ISI changes tend to reduce to sharper focal changes at follow-up, the quality of the ISI per se did not appear to impact postoperative Nurick grades. This disparity between clinical and radiological parameters may be related to factors independent of radiology, such as preoperative functional status, symptom duration, and concurrent lumbar spine or peripheral nerve disease as well as parameters that are difficult to quantify, such as patient motivation and expectation, glycemic control, and nicotine dependence.2,8,12,23,36 The presence of a T1-weighted hypointensity is probably the single best predictor of outcome on preoperative imaging,3,6,10,22,32,33 but these changes are relatively uncommon. The exact prognostic relevance of the quality of T2-weighted ISI changes in the absence of T1-weighted changes remains elusive.

Postoperative Evolution of Quality and Extent of T2-Weighted ISI

A substantial proportion (28.6%) of patients had extensive Type 3 multisegmental lesions on presentation.
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<table>
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<tr>
<th>Characteristics</th>
<th>Postop Nurick Grade Change ≥1</th>
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<tr>
<td>preop Nurick grade (1, 2 vs 3, 4, 5)</td>
<td>OR = 4.136, p = 0.003, 95% CI 1.623–10.539</td>
</tr>
<tr>
<td>preop quality (Type 2 vs Type 1 or 3)</td>
<td>OR = 0.340, p = 0.228, 95% CI 0.590–1.964</td>
</tr>
<tr>
<td>postop quality (Type 2 vs Type 1 or 3)</td>
<td>OR = 0.211, p = 0.201, 95% CI 0.019–2.297</td>
</tr>
<tr>
<td>change in craniocaudal length (&gt;50% vs &lt;50%)</td>
<td>OR = 3.998, p = 0.315, 95% CI 0.268–59.707</td>
</tr>
<tr>
<td>follow-up (&gt;18 mos vs &lt;18 mos)</td>
<td>OR = 6.402, p = 0.033, 95% CI 1.165–35.176</td>
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(mean craniocaudal length 31 ± 18.9 mm) with a larger fuzzy component and a smaller central or eccentric area of sharp ISI. In more than three-quarters of these patients, the postoperative ISI lesion was sharp and focal. Conversely, the majority of patients with multifocal Type 2 lesions at follow-up had preoperative ISI changes that were classified as Type 1 or 3 (fuzzy or mixed) and were extensive (mean length 22.3 mm). It would appear that surgical decompression reverses the fuzzy changes, leaving behind small residual focal or multifocal sharp ISI lesions. This probably accounts for persistent neurological deficits or symptoms such as paresthesias on follow-up. We hypothesize that extensive cord edema in these patients regressed following decompression, unmasking single or multiple, sharp, cavitory lesions at follow-up. These patients tended to have a poor functional status prior to surgery, but clinical improvement was noted in all of them.

**Regression of T2-Weighted ISI**

Extensive T2-weighted ISI changes spanning multiple segments predict poor outcomes, and regression of the ISI postoperatively appears to herald better neurological recovery. Type 3 and extensive hyperintensities were most likely to regress in our patients, and although there was reduction in the craniocaudal extent of sharp ISI changes as well, this was minimal in comparison. We were also able to establish that objectively, a craniocaudal ISI regression of more than 50% tended to correlate with clinical improvement at follow-up. Thus, it is possible that while larger preoperative radiological lesions are more likely to demonstrate postoperative ISI regression, the greatest clinical improvements are probably noted in patients with regression of smaller preoperative lesions. Larger groups of patients will need to be followed up over longer periods of time to confirm this possibility. The relevance of quantitatively measuring the degree of regression of the ISI has been described by other authors in smaller subsets of patients with similar conclusions.

Arvin et al. analyzed 52 cases involving patients with CSM and demonstrated that a focal bright T2-weighted signal (probably corresponding to our Type 2 change) 6 months postoperatively predicts a poor functional outcome at one-year follow-up. While Mastronardi et al. report that the temporal profile of ISI regression or spinal cord diameter reexpansion is clinically irrelevant, we observed that patients imaged more than 18 months following surgery were more likely to have substantial regression of the ISI with better outcomes compared with those patients imaged earlier. This provides reasonable evidence that clinical and radiological improvement continues even at remote follow-up and argues in favor of employing relative ISI change as a marker for outcome.

**Postoperative Expansion of T2-Weighted ISI**

Postoperative expansion of the hyperintensity was seen in only 7 of our patients, none of whom deteriorated clinically. Moreover, radiographs did not demonstrate cervical spine instability in these patients. We have described 2 of these 7 patients in a previous report and have observed a gradual resolution of these ISI changes on serial MRI. Despite the initial radiological “worsening,” 5 of these patients had better Nurick grades postoperatively than preoperatively, while in the other 2 cases, the postoperative Nurick grade was the same as the preoperative Nurick grade. It is likely that sudden decompression of the spinal canal results in postoperative expansion of the edematous cord without clinical deterioration, and the resolution of the edema over time indicates that this feature may not have sinister implications. On the other hand, in the setting of postoperative clinical worsening, direct trauma, alterations in venous circulation, or arterial ischemia needs to be considered. Indeed, postoperative blooming of T2-weighted ISI after laminoplasty for CSM related to cervical spine instability seems to correlate with poorer outcomes, prompting additional posterior fixation procedures for these patients.

**Pathophysiology of T2-Weighted ISI**

The neurological deficit that occurs secondary to chronic cord compression in CSM has traditionally been presumed to be a result of impaired perfusion through the anterior spinal artery and its radicular reinforcements, or venous congestion and dysfunction of the pial capillaryplexus. The high water content of injured and edematous myelin appears to account for varying degrees of T2-weighted signal hyperintensity on MRI, a finding that has been confirmed by autopsy in patients with CSM. However, ischemia alone cannot account for all the pathological changes seen in CSM, and this point is further supported by the frequent absence of demonstrable vasculopathy on histopathological examination in cadavers with CSM. There is also reasonable evidence to support a role for chronic repetitive stress and shear-related axonopathy, resulting from restriction of cord mobility in a stenosed vertebral canal or local tethering at a site of extramedullary compression. Variations in individual axonal configuration within the cervical cord imply differences in susceptibility to biomechanical injury as well.
as secondary ischemia. This has implications with regard to clinical reversibility and recovery in CSM, and the variable neural response to untethering of the cord and restoration of spinal compliance and mobility may contribute to the relatively unpredictable degree of clinico-radiological improvement that we observed in our patients.

Strengths and Limitations of This Study

Our study is limited by its retrospective nature and the fact that serial MRI was available for only a few patients. We have identified a “mixed” type of ISI and suggest its incorporation to accommodate cases with elements of both reversible and irreversible cord changes. The relative change in the craniocaudal extent of the ISI may be employed as an index for clinical and radiological improvement. The multiplicity and heterogeneity of factors that influence patient outcomes in CSM may mean that this study was statistically underpowered, but our findings nevertheless contribute to the limited body of literature concerning the temporal progression of the T2-weighted ISI change following surgery for CSM.

Conclusions

The vast majority of patients with CSM benefit from surgery, but it is difficult to predict neurological recovery based on the quality of T2-weighted ISI changes alone. In addition to the established “fuzzy” and “sharp” types of ISI changes it may be necessary to include a “Type 3” or mixed category, which is frequently multisegmental on presentation but with adequate decompression reduces to a focal sharp ISI at follow-up. ISI regression by more than 50% appears to predict better clinical outcomes. T2-weighted ISI changes also regress with time even at long-term follow-up, and therefore even patients with extensive intramedullary changes may expect reasonable symptom improvement after surgery.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: Chacko, Sarkar. Acquisition of data: Sarkar. Analysis and interpretation of data: all authors. Drafting the article: Chacko, Sarkar. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Chacko. Statistical analysis: Sarkar, Jacob. Study supervision: Chacko.

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