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Original Article

High cord signals on magnetic resonance and other factors predict poor outcomes of cervical spine surgery: A review

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Abstract

Background: High cord signals (HCS) on preoperative/postoperative T1, T1 gadolinium-diethylenetriaminepentaacetic acid (Gd-DTPA), and T2 magnetic resonance (MR) studies, postoperative failure of HCS to regress and/or cord re-expansion, and a triangular cord configuration are poor prognostic factors for surgical patients with cervical spondylotic myelopathy (CSM).

Methods: Here, we reviewed the negative prognostic import of high Grades/Types and more extensive locations of preoperative/postoperative HCS on T1, T1 Gd-DTPA, and T2 MR studies in surgical patients with CSM. Additional predictors of poor operative outcomes included postoperative failure of HCS to regress, cord re-expansion at the site of a HCS, and the triangular vs. teardrop or boomerang cord configuration. The Types/Grades of HCS on MR follow:Type/Grade 0 – no/absent signal changes; Type/Grade 1 – mild/light/fuzzy/obscure/low cord signal (LCS) changes; Type/Grade 2 – sharp/intense/well-defined HCS; and Type/Grade 3 – mixed/HCS. The definitions of location/extent of LCS/HCS were: focal (1 level), multifocal (with skip areas), and multisegmental (continuous over >1 segment), while cord configuration was categorized as triangular, teardrop, or boomerang.

Results: On MR studies, preoperative/postoperative Types/Grades 0–1 changes correlated with better prognoses (e.g., improved Japanese Orthopedic Association (JOA) scores or Nurick Grades), while Types/Grades 2–3 correlated with poorer outcomes. Multiple poor prognostic indicators also included; failure of postoperative HCS on MR to regress (particularly if multisegmental), postoperative cord re-expansion at the site of a prior HCS, and triangular cord configuration.

Conclusions: Grade/Types 2–3 HCS on T1, T1 Gd-DTPA, and T2-weighted MR images on preoperative/postoperative MR studies, failure of HCS to regress (multisegmental), cord re-expansion at the site of a prior HCS, and a triangular cord configuration (atrophy) all contributed to poorer outcomes for CSM surgery.

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Key Words: Cervical surgery, cord configuration, hyperintense/high cord signal (HCS), ossification of the posterior longitudinal ligament, magnetic resonance, prognostic indicators, spondylotic myelopathy

INTRODUCTION

Here, we reviewed the prognostic import of preoperative/postoperative high cord signals (HCS) on magnetic resonance images [MR: T1, T1 gadolinium-diethylenetriaminepentaacetic acid (Gd-DTPA), and T1] for patients with cervical spondylotic myelopathy. Outcomes were correlated with patients undergoing anteiror cervical diskectomy/fusion (ACDF), anterior corpectomy/fusion (ACF), laminectomy with/without posterior fusion (LAM), and laminoplasty (LOP) [Tables 1–3; Figures 1–6].[1-15] Several Types/Grades helped assess the severity/prognostic import of low cord signals (LCS) and high cord signals (HCS) on preoperative/postoperative MR studies; Type/Grade 0: no/absent low cord signal (LCS), Type/Grade 1: faint/fuzzy/mild/obscure LCS; Grade 2: middle/intense/sharp HCS; and Type/Grade 3: mixed/HCS.[1,5,8,14] Additionally, the location/extent of HCS on T2 sagittal MR studies also impacted outcome and were defined as: focal (single level),

Table 1: Postoperative magnetic resonance imaging documenting adequate spinal cord decompression following cervical laminectomy/fusion (2003–2010)

Author [Ref] Year	Number of patients	Study design	Study variables	Findings and correlations	Postoperative MR finding
Suri[9] 2003	HCS impact outcomes 146 CSM 1999-2001 Surgery: ACDF ACF Lam/LOP	HCS Preop 121 (82.9%) MR changes 81 T1/T2 40 T2 only 0 T1 alone	Postop MR obtained in 44 (36.4%) of 121 with preop HCS; 14 Postop HCS on MR Regressed	Significant correlation outcomes and: Age, longer symptoms, more Discs, type surgery, preop HCS/MR, postop compression	Postop MR Better outcomes No HCS On postop T2 Worse outcomes HCS both T1 and T2 MR Reduced HCS T2; Best results
Matsuyama[6] 2004	44 CSM patients + OPLL Surgery LOP	Prognosis preop MR/US Axial studies: Boomerang Teardrop Triangles	Postop US/MR Preop low T1 and HCT T2 most triangle Least Re-expansion	Good recovery Teardrop or boomerang	Triangular worst cord atrophy and outcomes + Postop low T1 and HCS T2 MR
Naruse[7] 2009	LOP for 101 CSM	Postop dorsal cord MR/US migration	US cutoff 3 degrees	MR cutoff 20 degrees Beak angle C5/6	US better predicts outcomes LOP
Yagi[13] 2010	Outcomes HCS on preop vs. postop MR 71 CSM OPLL LOP	Severe OPLL/ Kyphosis Outcomes JOA score Followed mean 60.6 mos	Preop MR HCS on 50/71 T2 studies Lower postop JOA scores correlated with preop T2 HCS	Risk for HCS Instability anterior compression Poorer outcomes 16 Postop MR: HCS despite re-expansion	No better outcomes with postop HCS on T2 study despite cord re-expansion
Zhang[14] 2010	T2 MR studies 73 CSM Surgery 2005-7	Does HCS Predict Clinical outcomes	3 MR groups 1: Low cord signals 2: Middle cord signals 3: HCS	Group 1 with low HCS Younger Shorter symptoms Better outcomes	Group 3 Higher HCS Poorer outcomes
Avadhani[1] 2010	35 LAM T1, T2 HCS on MR Average age 57.8	Postop MR 51.3 mos. later HCS T2 Preop Grades 0=Absent: 1 1=Obscure: 13 2=Intense: 13	Location HCS preop MR 18 Focal/1 level 16 MS: > 1 level	Postop T1 MR Grades HCS: Group A 1 Group B 29 Group C 5	Poorer outcomes for HCS on both postop T1 and T2 MR

Signal, W: Weighted, Lam: Laminectomy, mos.: Months, avg.: Average, MS: Multisegmental, JOA: Japanese Orthopedic Association score, CCS: Cervical corpectomy/fusion, preop: Preoperatively, postop: Postoperatively, ACDF: Anterior cervical diskectomy/fusion, ACF: Anterior Corpectomy/Fusion, Lam: Laminectomy, LOP: Laminoplasty, Nurick: Nurick Grades (1–5): US: Ultrasound, #: Number, LCS: Low cord signal

Table 2: Postoperative magnetic resonance imaging documenting adequate spinal cord decompression following cervical laminectomy/fusion (2011-2015)

Author [Ref] Year	Number of patients	Study design	Study variables	Findings and correlations	Postoperative MR finding
Cho[3] 2011	MR Gd-DTPA correlate prognosis 74 CSM surgery JOA postop	1 to 2 Level ventral cord compression ACDF 2006-9 Followed Avg. 39.7 mos	HCS MR Groups: T1, T2, T1/Gd-DTPA JOA Preop 1.5 Postop 15.0	No impact on outcomes; Age, symptom duration Preop JOA Residual cord compression	Worst outcomes for preoperative T1 MR/Gd-DTPA with HCS
Vedantam[12] 2013	11 Studies 1508 CSM Data: PubMed Cochrane	Different classification T2 HCS on preop MR	Improved HCS on postop T2 MR Better outcomes	MS/sharp-intense HCS MR T2 Poorer outcomes	Regression T2 HCS postop MR Best outcomes
Uchida[11] 2014	HCS preop T2 MR predicts outcomes 102 CSM 46 OPLL	HCS based on C7T1 disc JOA scores 25 MR >6 mos. postop	Postop HCS on T1 not T2 MR Better outcomes	Postop LCS on T1 Better outcomes	Postop HCS on T2 Poorer outcomes
Sarkar[8] 2014 JNS	56 MR oblique CCF for CSM Preop HCS on MR correlate postop JOA Nurick grade 54/56 HCS on preop MR Followed avg. 28 mos	Measured sagittal length HCS T2 MR 4 Types HCS 0 = No HCS 1 = Fuzzy (Preop 41%) 2 = Sharp (Postop 71%) 3 = Mixed (Preop 34%)	Local HCS on preop MR: Focal (Single) Multifocal (Skip areas) MS (>1 level (Continuous segment)	MS and Type 3 HCS Preop: Significant regression postop to Type 2 (71%): Best prognosis	Significant trend improved postop Nurick grade >50% HCS regression follow-up >18 mos
Tauchi[10] 2015	41 CSM 1995-2011 Symptom duration avg. 11.6 mos	Surgery ACDF/ACF Posterior fusion LOP	LCS on T1 MR HCS T2 MR Preop and postop	Outcomes 25 Excellent 6 Good 9 Fair 1 Poor	Longer symptoms; Poorer outcomes Recommend surgery < 4 mos

CSM: Cervical spondylotic myelopathy, MR: Magnetic resonance, HCS: High cord signal, W: Weighted, Lam: Laminectomy, mos.: Months, avg.: Average, MS: Multisegmental, JOA: Japanese Orthopedic Association score, CCS: Cervical corpectomy score/fusion, preop: Preoperatively, postop: Postoperatively, ACDF: Anterior cervical diskectomy/fusion, ACF: Anterior corpectomy/fusion, Lam: Laminectomy, LOP: Laminoplasty, Nurick: Nurick grades (1–5), US: Ultrasound, #: Number, LCS: Low cord signal

multifocal (with skip areas), and/or multisegmental (MS: >1 level; continuous).[1,8] Better outcomes for CSM patients correlated with Type/Grade 0/Type Grade 1 findings on preoperative/postoperative MR studies.[5,9] Significant trends toward improvement also correlated with >50% regression of HCS on postoperative T2 MR, particularly when patients were followed for >18 postoperative months.[8] In summary, worse/poor prognostic indicators for postoperative outcomes in CSM patients, therefore, included; HCS (Types/Grade 2 and 3) on preoperative/postoperative MR studies, failure of HCS to regress (especially if multisegmetal), cord re-expansion at sites of HCS, and triangular cord configuration (indicative of underlying cord atrophy) [Tables 1–3].[1,3,4,6,11,13,14]

Types/grades of HCS on preoperative/postoperative MR studies

Several studies proposed different Types/Grades of HCS identified on preoperative/postoperative T1, T1-DTPA, and T2 MR studies [Tables 1–3; Figures 1–6].[1,5,8,14] These included: Type/Grade 0: no/none/absent/LCS; Type/Grade 1: faint/fuzzy/mild/obscure/LCS; Type/Grade 2: middle/intense/sharp HCS; and Type/Grade 3: mixed/HCS. For the 505 CSM patients in Machino *et al.* series, nearly equal numbers of patients were assigned to one of the three Types/Grades of HCS on T2 MR studies: Type/Grade 0 (none – 168 patients); Type/Grade 1 (light/obscure – 169 patients); and Type/Grade 2 (intense/bright – 168 patients) [Table 3].[5] Notably, the higher the Types/Grades documenting HCS on preoperative/postoperative MR studies, the greater the likelihood of poorer outcomes.[1,5,8,14]

Location/extent of HCS and dorsal cord migration on preoperative/postoperative MR studies in CSM patients

Several series also correlated the location/extent of HCS on T2-weighted (T2W) sagittal MR studies with prognoses for CSM surgery [Tables 1 and 2; Figure 2].[1,7,8] The best results were seen with focal (single level) or multifocal (with skip areas) HCS on T2 MR, while the worst outcomes occurred if HCS were multisegmental (MS: >1 level; continuous).

Table 3: Postoperative MR imaging documenting adequate spinal cord decompression following cervical laminectomy/fusion (2016-2017)

Author [Ref] Year	Number of patients	Study design	Study variables	Findings and correlations	Postoperative MR finding
Zhang[15] 2016	88 CSM	50 Better outcomes; Duration, symptoms <3 mos	Poor outcomes Risk factors: Duration 3-6 mos. vs. > 6 mos	MR poorer outcomes atrophy Ventral root compression Anterior horn compression	Worst outcomes Anterior horn and ventral root compromise Distal disease Longer symptom duration >6 mos
Chen[2] 2016	10 Studies 650 CSM Preop T1/T2 HCS on MR poorer outcomes	Medline/Cochrane databases Meta-analysis CSM +/- Preop HCS MR	Focal/Faint HCS and no HCS postop MR Same JOA outcomes	Well-defined MS HCS on postop T2 MR Poorer JOA outcomes	Postop T1 HCS changes Poorer JOA outcomes
Kim[4] 2016	Prognosis of HCS on MR preop/ postop 112 CSM	1 to 2 Level ACDF T1 MR, T2 MR T1-Gd-DTPA HCS Preop/Postop Correlated with poor JOA results	HCS grades 0: None 1: Light 2: Bright	Poor prognosis Longer symptom duration	Poor prognosis >Severe myelopathy >HCS postop MR
Machino[5] 2017	505 CSM Avg. age 66.6	Outcomes JOA scores Preop MR HCS grades 0-2	Postop MR T2 signals: Grade 0: None 168 Grade 1: Light 169 Grade 2: Intense 168	Similar ages grades 0-2 Grade 2 longer symptom duration	Preop HCS Grade 0=Better postop JOA Better JOA recovery rates

CSM: Cervical spondylotic myelopathy, MR: Magnetic resonance, HCS: High cord signal, W: Weighted, Lam: Laminectomy, mos.: Months, avg.: Average, MS: Multisegmental, JOA: Japanese Orthopedic Association score, CCS: Cervical corpectomy/fusion, preop: Preoperatively, postop: Postoperatively, ACDF: Anterior cervical diskectomy/fusion, ACF: Anterior corpectomy/fusion, Lam: Laminectomy, LOP: Laminoplasty, Nurick: Nurick grades (1–5), US: Ultrasound, #: Number, LCS: Low cord signal

Figure 1: This midline sagittal T2W MR study documented marked cord compression attributed to severe anterior (C4-C6, C6-C7) OPLL, and marked dorsolateral cord compression (C4-C7; ossification of the yellow ligament with laminar shingling). Not the compression was so severe opposite the C5 body that a HCS could not be readily seen on the preoperative T2 MR study

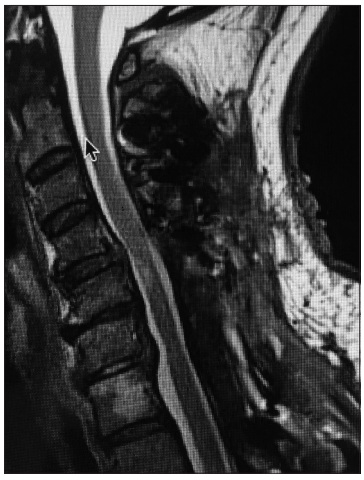

Figure 2: The patient in Figure 1 underwent a laminectomy C5-C7, undercutting of C4 and T1, with posterior fusion C2-T2. Although the postoperative sagittal T2 MR study documented adequate cord decompression at all levels, the HCS opposite the C5 body reflected intrinsic cord damage that correlated with residual/improving myelopathy (preoperative Nurick Grades 4 and 5 to postoperative Nurick Grade 1)

Specifically, when Sarkar *et al.* (2014) categorized 56 patients' HCS on T2 MR as focal/single lesions, multifocal/with skip areas, or multisegmental/continuous lesions, the latter yielded the poorest results.[8] Additionally, Naruse *et al.* (2009) correlated better outcomes for 101 CSM patients undergoing LOP with greater postoperative dorsal cord migration (e.g. with both ultrasound and MR).[7]

Prognostic import of axial MR cord shape on outcomes for CSM surgery

Axial MR images documenting different cord configurations (e.g. boomerang, teardrop, or triangular) reflected differing degrees/severity of cord atrophy that also impacted outcomes of CSM surgery [Tables 1 and 3].[6,15]

Figure 3: This preoperative midline sagittal T2 MR without a HCS showed moderate anterior osteophytic ridging and maximal dorsolateral cord compression (ossification of the yellow ligament/laminar shingling) from C4-C7 with an excellent cervical lordosis. Here, following a cervical laminectomy of C5-C7, undercutting of C4/T1, and posterior C2-C2 fusion, the patient was fully neurologically intact (Nurick Grade IV to 0)

Figure 4: The 6-week postoperative midline sagittal T2 MR in another patient documented adequate cord decompression following a C5-C7 laminectomy, undercutting C4/T1, and posterior C2/T2 fusion. Note, this patient also had no preoperative HCS on the T2 study that correlated with his full postoperative neurological recovery

Figure 5: This midline sagittal postoperative 6-week T1 MR documented excellent cord decompression in another patient following a C5-C7 laminectomy, undercutting of C4/T1, with posterior C2/T2 fusion. Note this patient showed neither LCS nor HCS on the preoperative or postoperative T1 or T2 MR studies that nicely correlated with his completely intact neurological status

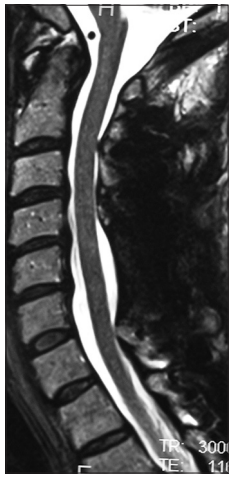

Figure 6: For the same patient in Figure 5, the midline sagittal T2 MR documented excellent postoperative cord decompression. Note the complete perimeter of spinal fluid around the cord at all levels, without any residual evidence of intrinsic LCS or HCS

Matsuyama *et al.* (2004) correlated the preoperative MR cord shape with postoperative outcomes in 44 patients with CSM/ossification of the posterior longitudinal ligament (OPLL) undergoing LOP.[6] The best outcomes correlated with the teardrop configuration, intermediate outcomes with the boomerang shape, and the worse outcomes with the triangular cord configuration.[6] Additional poor prognostic factors included: LCS on T1/HCS on T2 preoperative MR studies, and postoperative cord re-expansion at the sites of prior HCS (e.g. reflecting cord atrophy). When Zhang *et al.* (2016) evaluated poor prognostic risk factors for 88 patients with CSM undergoing cervical surgery, poorer outcomes correlated with MR evidence of more anterior horn compression with/without ventral root compression, distal cord atrophy, and longer symptom duration (e.g. >6 months).[15]

Better outcomes with Types/Grades 0–1 and worse outcomes with Types/Grades 2–3 HCS on T1/T2 preoperative/postoperative MR studies

On preoperative/postoperative T1/T2 MR studies, Types/Grades 0–1 (no/LCS) correlated with better neurological outcomes, while Types/Grades 2–3 (severe/HCS) correlated with poorer outcomes [Tables 1–3; Figures 3–6].[5,8,9,12] Suri *et al.* (2003) assessed how HCS on preoperative/postoperative T1/T2 MR studies impacted outcomes for 146 CSM patients undergoing ACDF, ACF, LAM, or LOP.[9] Preoperative HCS were seen in 121 of 146 patients (82.9%); 81 had

both T1/T2 HCS on MR, while 40 had HCS on only T2 studies. The best outcomes occurred in 14 of 44 patients whose preoperative HCS on T2 MR regressed; the worst outcomes were observed for those with postoperative residual T1/T2 HCS reflecting longstanding, chronic/multiple disc herniations, and/or residual cord compression. When Vedantam and Rajshekhar (2013) looked at preoperative HCS on T2W MR images for 1508 CSM patients (11 studies; PubMed and Cochrane databases), better outcomes correlated with the regression of HCS on postoperative MR scans (e.g. 5 of 10 studies), while poorer results were seen where HCS remained sharp/intense (6 studies) and/or multisegmental (5 studies) [Table 2].[12] In Sarkar *et al.* (2014), where 54 of 56 patients had HCS on preoperative T2 MR studies, there was a significant trend toward improved postoperative JOA scores/Nurick grades where multisegmental Type 3 (mixed) lesions improved postoperatively to Type 2 lesions [sharp: 71% (>50% regression of HCS on T2 MR; followed >18 months)] [Table 2].[8] In Machino *et al.* (2017 Spine) series of 505 patients with preoperative HCS on T2 MR, those showing postoperative regression to Grade 0 demonstrated better postoperative outcomes.[5]

Poorer prognoses for HCS on MR, triangular cord configuration, and cord re-expansion

In several studies, poorer prognoses correlated with preoperative HCS on MR (T1, T1-Gd-DTPA, and T2), preoperative and persistent postoperative triangular cord configuration (reflecting underlying cord atrophy), and cord re-expansion at the site of a prior HCS [Tables 1 and 2; Figures 1 and 2].[1-4,6,11,13,14] When Matsuyama *et al.* (2004) evaluated 44 patients with CSM/OPLL undergoing LOP, the worst postoperative outcomes correlated with preoperative LCS on T1/HCS on T2 MR, postoperative MR-documented cord re-expansion, and triangular cord configuration (e.g. best prognosis-teardrop, intermediate prognosis-boomerang).[6] In Yagi *et al.* (2010) 50 of 71 CSM/OPLL patients undergoing LOP, the worst JOA outcomes correlated with persistent postoperative HCS on MR; this remained true even for the 16 patients showing postoperative re-expansion [Table 1].[13] Also in 2010, Avadhani *et al.* found poorer postoperative Nurick grades in 35 CSM patients undergoing LAM, where HCS on preoperative T2 MR failed to resolve or patients developed the late onset of LCS on T1 MR (average 51.3 postoperative months).[1] Additionally, for the 73 CSM patients with HCS on preoperative MR studies, Zhang *et al.* (2010) correlated poorer surgical outcomes for those with the most severe persistent HCS (Grade 3) on postoperative MR studies.[14] Further, Cho *et al.* (2011) found that HCS on preoperative T1 Gd-DTPA MR studies constituted the worst prognostic sign for JOA outcomes in 74 CSM patients undergoing 1 to 2 level ACDF (followed on average 39.7 months).[3] In Uchida *et al.* (2014) study of 148 patients (102 CSM; 46 OPLL), poorer outcomes correlated with LCS on preoperative T1/HCS on T2 MR, while better outcomes were seen with HCS on preoperative T1/no HCS on postoperative T2 MR.[11] When Chen *et al.* (2016) evaluated 10 studies (Medline/Cochrane databases) involving 650 CSM surgical patients, better JOA outcomes correlated with Types/Grades 0–1 preoperative MR findings, while poorer outcomes were seen with postoperative HCS on T1/T2 studies (especially multisegmental).[2] For 112 patients with CSM undergoing 1 to 2 level ACDF, Kim *et al.* (2016) also correlated HCS on preoperative/persistent postoperative MR studies (T1, T1 Gd-DTPA, T2) with poorer outcomes.[4]

Early surgery recommended for CSM based on MR findings

Tauchi *et al.* (2015) recommended that CSM patients with preoperative MR studies already showing LCS on T1 and HCS on T2 MR studies, along with extensive/severe stenosis, cord compression, and kyphosis, should be considered for early surgery (within <4 months; whether ACDF, ACF, LOP, LAM) [Table 2].[10]

CONCLUSION

Here we reviewed multiple MR-based (MR: T1, T2, T1 enahnced studies) prognostic factors for CSM patients undergoing spinal surgery [Tables 1–3].[1-15] The best/better outcomes correlated with Grade 0/Grade 1 MR changes on preoperative/postoperative MR studies, or trends toward improvement where postoperative T2 HCS regressed.[5,8,9] Poorer/worse prognoses correlated with HCS seen on all preoperative/postoperative MR scans, their failure to regress, documentation of cord re-expansion at sites of prior HCS, and residual triangular cord configurations.[1,3,4,6,11,13,14]

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Conflicts of interest

There are no conflicts of interest.

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