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Extension MRI is clinically useful in cervical myelopathy

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Abstract
Introduction Cervical spine MRI with the neck in extension has been well described over the last 10 years, but its clinical value remains unknown.
Methods We performed extension imaging in 60 patients in whom the initial neutral study showed borderline cord compression. Images were assessed using a previously validated grading system for cord compression. Multiple linear and area measurements were also obtained. Images were scored blindly and randomly. Inter- and intra-rater variability were determined in a subset of 20 cases. Independent clinical assessment utilised the Ranwat criteria.
Results For most parameters inter/intra-observer variance of kappa/ICC>0.6 was highly satisfactory. Standard MR was poor at discriminating between patients with and without myelopathy (ROC analysis, area under the curve (AUC), 0.52). This was considerably improved with extension imaging (AUC, 0.60), or by using the change in compression score between neutral and extension studies. Most measurements were not helpful; however, the ratio of cord area/CSF area at the level of maximum compression on extended images was the best discriminator (AUC, 0.71), as well as the presence of T2 change in cord substance (AUC, 0.68).
Conclusion This is the first study to demonstrate added clinical value utilising extension MRI. In this cohort of difficult patients, when there was no T2 signal change in the cord, the presence of clinical myelopathy could only be predicted by utilising the data from extension imaging.

Keywords Extension MRI · Cervical spine · Myelopathy

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Introduction

MRI has largely replaced CT myelography as the standard investigation for cervical degenerative radiculomyelopathy. Myelography is performed prone with the neck in forced extension, which may not be representative of normal day to day physiology. MRI is acquired supine with the neck in a position of comfort, usually slight extension. Many factors related to a patient's build will influence the configuration of the neck within the MRI surface coil.

Supine myelographic images can appear almost normal while the corresponding prone images show significant cord compression. This postural change in extension is predominantly due to buckling of the ligamentum flavum and dorsal dura and to increased bulging of the disc annulus. If the spine is unstable, there may also be an increase in anteroposterior slip. Sometimes a few degrees difference at the extreme of the range of movement may dramatically increase the degree of cord compression that is perceived.

MRI in standard and extended positions can replicate the postural changes seen with myelography [1]. Such changes are more likely to be seen in patients with a congenitally narrow canal [2] (Fig. 1).

It has recently been demonstrated that the degree of perceived cord compression may be related to the degree of neck extension achieved [1]. It is also possible to perform dynamic postural MRI of the cervical spine in the erect position, where the weight of the head is likely to increase the degree of disc and ligamentous buckling [3]. The initial reports describing this technology are now a decade old and have had limited impact. The equipment is heavy, expensive, has limited

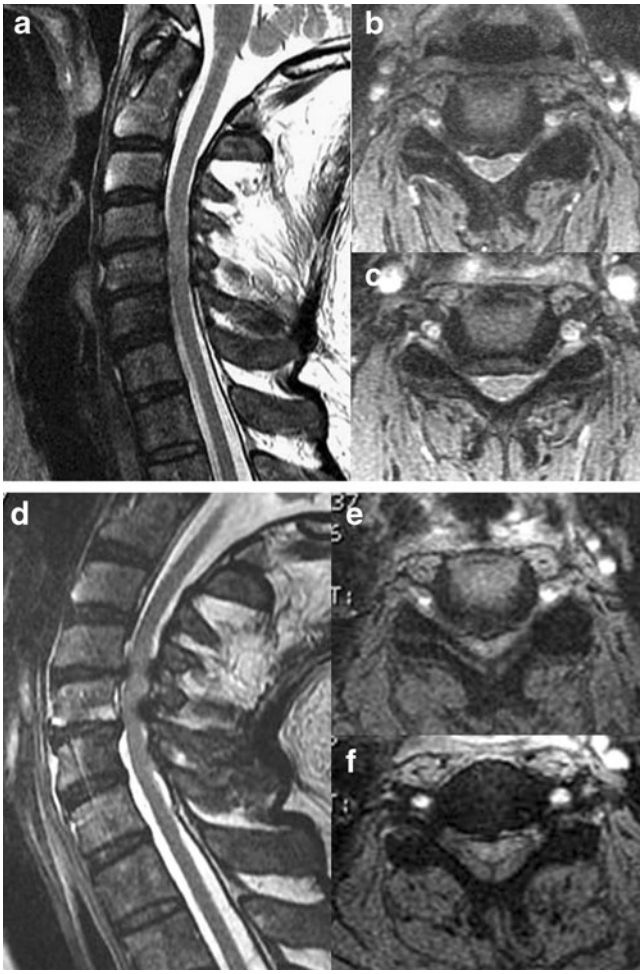

Fig. 1 Sagittal (*a* and *d*) and axial images at C4–5 (*b* and *e*) and C5–6 (*c* and *f*). **a–c** In standard (neutral) position, CSF is visible around cord; no compression. **d–f** In extended position, definite compression at both levels predominantly due to bulging of thickened ligamentum flavum

resolution, and is not readily available. Several new and very compact systems are just reaching the market place. It remains to be shown whether they can produce images of comparable quality to conventional scanners.

Gerigk and colleagues [4] have recently reported a prototype motorised cervical coil that facilitates the acquisition of kinematic data in the supine position. They demonstrated that it can be utilised in postoperative patients and described techniques to minimise metallic artefacts.

Most patients with clinically apparent myelopathy due to degenerative disease show obvious cord compression on conventional MRI. In many young patients with acute disc extrusion, the pathology is clearly at one level and imaging with the neck extended is not necessary and might even be hazardous. Patients who have a capacious canal are very unlikely to have significant additional findings with neck extension. However, there exists a group of patients in whom standard imaging appearances are equivocal. Many elderly patients with cervical spondylosis have multi-level pathology, and it may be difficult to tell how many levels are likely to be significant and might require surgery.

We hypothesised that if imaging in extension is to have any real value for clinicians and radiologists it will be in patients with a relatively narrow canal showing borderline cord compression on standard imaging. We have sought to answer that question.

Methods

During 2008 and 2009, our technicians were trained to identify patients referred with cervical degenerative disease where the standard scan showed borderline or equivocal cord compression, and the central canal appeared relatively narrow. In essence, this meant patients with little or no cerebrospinal fluid (CSF) visible around the cord at one or more levels, but without clear-cut evidence of displacement and flattening of the cord. A standard saddle-shaped cervical spine coil was utilised in all cases. The patient's shoulders were elevated with robust padding and the neck extended as much as could be comfortably managed [1]. This technique increases the distance between the coil and the spine, and even with good immobilisation, patients are more prone to movement than in the standard position of comfort. The degree of extension that can be achieved is variable and unpredictable and is determined by the patient's habitus, motivation and degree of pain. On some scanners, flexible surface coils are available which might mitigate some of these problems. This approach had become our standard clinical protocol, and ethical approval was not required for this retrospective study.

Of the 60 patients who were analysed, 31 patients were female. The mean age was 55 years (22 –81 years). Patients were scanned on either a General Electric 1.5T Signa or a Philips 1.5T Intera. The routine sequences comprised sagittal FSE 3 mm, 0.3 mm gap. Axial sequences were 2D and 3D MERGE (Multi-Echo Recombined Gradient Echo–GE) or Balanced Turbo Field Echo and Gradient Echo Volume (Philips). Axial images covered C2/3 to C7/T1 and were planned perpendicular to the mid-cervical disc spaces. Sequence data are provided in Table 1. The extension studies comprised the same sagittal and axial sequences.

The scans were reviewed blindly and randomly on a PACS by one investigator (RB) with no access to clinical information. Analyses of the standard and extension studies were separated by 8 weeks. The first 20 patients in the study were independently analysed by a second experienced neuroradiologist (JJ), so as to establish the inter-observer error (Table 2). The initial analysis by the primary investigator comprises the substance of this study.

The extent of radiological cord compression was assessed at each level from C2–3 to C7–T1 using a three-point scoring system which has been previously validated [1]:

Table 1 Scan parameters

Parameter	GE Signa			Philips Intera		
	Sag T2	2D merge	3D merge	Sag T2	BTFE	GE volume
TR (ms)	3,560	1,000	42.6	3,500	8.2	581
TE (ms)	102	17	18.2	130	4.1	9.2
ETL	24			17	256	
Flip angle		30	6	90	45	25
Bandwidth	31.25	31.25	41.67	128.5	217.1	66.3
Matrix	256/384	224/256	192/320	224/288	352/512	224/288
Frequency direction	A/P	R/L	R/L	F/H	R/L	A/P
NEX	6	2	2	4	4	4
FOV (cm)	24	20	24	27.5	22.5	16
Phase FOV		0.75	0.75	1.0	0.8	0.9
Slice thickness (mm)	3	3	3	3	1.5	3
Slice spacing (mm)	0.3	0.1		0.3	0.3	0.6
Foldover suppression	Yes	No	No	Yes	Yes	Yes
Scan time (min)	4.02	5.01	5.44	3.33	5.34	6.13

Sag sagittal, *BTFE* balanced turbo field-echo, *TR* repetition time, *TE* echo time, *ETL* echo train length, *FOV* field of view, *A*/*P* anteroposterior, *R*/*L* right–left, *F*/*H* foot end/head end of the body

Normal (0): CSF visible dorsal or ventral to the cord, which is not indented on sagittal images, and has a normal cross-sectional shape on axial images

Equivocal (1): No CSF visible dorsal and ventral to the cord on sagittal and/or axial images but not indented or displaced on the sagittal image (i.e. "nipped") or considered to be atrophic or flattened but with CSF visible dorsal and/or ventral to the cord

Compressed (2): No CSF dorsal or ventral to the cord, which is also indented or displaced on sagittal images and/or flattened on axial images

This subjective grading scheme is very similar to that employed by Muhle [5] and others.

Image quality was recorded and graded as good, adequate or poor (non-diagnostic). Intrinsic T2W signal change in the cord was graded at each level as absent, equivocal or definite.

Table 2 Inter- and intra-observer errors

Standard study	Observer A1 vs A2	95 % CI	Observer A vs B	95 % CI
Compression score [*K*]	0.65	0.49–0.81	0.73	0.51–0.91
Cord area	0.66	0.41–0.91	0.74	0.55–0.94
CSF area	0.93	0.88–0.99	0.90	0.82–0.98
Cord sagittal diameter	0.72	0.50–0.93	0.60	0.32–0.88
Lateral quarter compression ratio	0.86	0.75–0.97	0.84	0.75–0.97
Angle of extension	0.97	0.95–0.99	0.61	0.34–0.89
Cord T2 change [*K*]	0.71	0.52–0.96	0.41	0.19–0.63
Cord atrophy [*K*]	0.40	0.19–0.63	0.14	0.00–0.36
Foramina Rt side	0.70	0.54–0.86	0.59	0.43–0.75
Foramina Lt side	0.71	0.51–0.87	0.50	0.35–0.67
Canal diameter at C7	0.82	0.68–0.96	0.82	0.67–0.96
Extension study				
Compression score [*K*]	0.88	0.71–1.00	0.52	0.38–0.67
Cord area	0.78	0.60–0.95	0.75	0.56–0.94
CSF area	0.83	0.69–0.96	0.79	0.65–0.93
Cord sagittal diameter	0.65	0.49–0.90	0.65	0.49–0.90
Foramina Rt side	0.69	0.53–0.85	0.41	0.26–0.57
Foramina Lt side	0.62	0.47–0.79	0.52	0.37–0.68

All other parameters are assessed using the Interclass Correlation Coefficient

K kappa, *Rt* right, *Lt* left

The degree of extension of the spine was measured as the acute angle between a line drawn parallel to the posterior cortex of the C2 vertebral body and a line parallel to the posterior cortex of the C7 vertebral body [1]. The mid-sagittal diameter of the bony spinal canal from mid-C7 vertebral body to the spinous process was measured.

Neural foraminal narrowing at each level from C2–3 to C7–T1 was assessed using sagittal and axial images according to the following criteria:

> Normal (0): Same size as adjacent or contralateral "normal" foramina
> Equivocal (1)
> Compressed (2): >50 % narrowing, displacement or impingement of root complex

We have utilised this grading scheme before [1] and demonstrated good inter- and intra-observer correlation. We did not utilise the foraminal grading scheme of Pfirrmann et al. [6]. Their scheme was described for use in the lumbar spine and is highly dependant upon the presence of intra-foraminal fat. There is very little fat in the cervical exit foramina which are largely composed of epidural venous plexus.

No patients were identified with cord compression at C2–3 or C7–T1 using the subjective scoring scheme described above. Multiple linear and area measurements were obtained at the level of the C3–4, C4–5, C5–6 and C6–7 disc space using the measuring tools available on the PACS (Agfa). These are:

1. Area of the spinal cord on axial images
2. Area of the spinal canal (CSF space) on axial images
3. The anteroposterior (AP) diameter of the cord measured in the mid-line on sagittal images
4. The AP and lateral dimension of the cord on axial images
5. The AP dimension of the cord measured at the junction of medial and lateral quarters of the cord on axial images

These measurements allow calculation of most of the parameters that have been reported to be useful in the quantitative assessment of cord compression, including the central compression ratio of Ogino [7] and the lateral quarter compression ratio of Kanchiku [8]. We calculated the CSF area available around the cord at each level (2 minus 1), and the ratio of the cord area to the CSF area at each level (1/2 × 100 %). It was thus possible to determine a mean value for each of these parameters over the four spinal levels investigated or to identify the "worst" parameters.

In a normal subject, the cord area varies at different spinal levels and is generally considered to be maximal at C6. Thus the significance of an area measurement obtained at C3–4 may be different to a result obtained at C5–6. By utilising measurements at levels where the visual compression score was graded 0, we were able to generate "normal" values of cord area and linear measurements in a population of patients being investigated for symptoms of cervical spondylosis (Table 3). Thus the proportional decrease in cord area relative to the mean "normal" for a particular spinal level could be calculated. All these parameters were ascertained on the standard and extension MRI studies. We also determined the increase in the compression score between the standard and extension studies, the decrease in cord area between standard and extended studies, the decrease in CSF area between standard and extended studies, and the decrease in cord AP diameter between standard and extended studies.

A clinical analysis of the cases was a retrospective review of the case notes undertaken by two consultant neurologists working together and forming a consensus view. In general, the available data were not sufficient to make a categorisation of myelopathy using the modified JOA score, and the less specific Ranawat classification was utilised [9]. Radiculopathy was classified as: 0=absent, 1=equivocal with no localisation, 2=equivocal with localisation, i.e. no clear objective signs but symptoms indicating specific root dysfunction, 3=definite, i.e. clear objective myotomal/dermatomal deficits, either clinically or neurophysiologically. Only a minority of patients had electrophysiology and those data were not incorporated in the assessment of myelopathy.

Statistical analysis of inter- and intra-observer error was analysed with the kappa statistic; and for continuous data using interclass correlation coefficient (ICC) (StataCorp statistical software release 10, 2007). Discrimination of patients with and without myelopathy was made by non-parametric ROC curves [10, 11]. Five per cent statistical significance (two-tailed) was assumed.

Results

Of the 90 cases identified, 16 did not have any axial extended images due to patient discomfort. In ten cases, extended images (usually the axials) were considered of "poor" quality. One patient had an imaging diagnosis of intrinsic cord tumour and one a diagnosis of transverse myelitis. One patient showed possible cord compression at C2–3 level, not covered on axial sections. A 64-year-old patient with a history of previous stroke and systemic lymphoma became hypotensive

Table 3 "Normal" measurements of the cord in the neutral position

Level	Cord area (cm^2)	Sagittal diameter (cm)
3/4	0.81	0.68
4/5	0.85	0.68
5/6	0.82	0.66
6/7	0.73	0.63

and vomited after attempts to position him in extension, which was abandoned. He was admitted for observation for a few hours and discharged without a specific diagnosis. Thus in total, 30 cases were rejected, leaving a study population of 60.

Forty-four patients had standard and extension studies performed at the same attendance. The remaining 16 were recalled for the extension study after 2–53 days (mean, 26 days). Eleven of these were rescanned on the same machine.

Twenty-four patients were myelopathic (Ranwat grade 2 or more), of whom 12 also had radiculopathy. Of the 36 patients who were not myelopathic, 23 were considered to have true radiculopathy and 13 to have non-specific neck or arm pain. The mean estimated duration of symptoms was 6.8 months.

Many patients complained of a transient exacerbation of neck pain after the examinations had been completed, but none reported weakness or persistent symptoms.

The primary observer assessed image quality on the standard studies as good: 32, adequate: 28 and for the extension studies good: 22, adequate: 38.

The degree of spinal angulation on the standard studies was mean, 9.7 deg (−12 to 35); and on extension mean, 28.3 (5 to 49). Mean AP canal diameter at C7 was 11.8 mm (0.94–1.47). Only a small number of patients in this study showed definite evidence of T2 signal change in the cord; four in the myelopathic group, one in the non-myelopathic group.

Observer variance

Inter- and intra-observer variance is shown in Table 1. The interpretation of ICC values is generally held to be similar to the interpretation of kappa. Thus, inter- and intra-observer variance was usually satisfactory for both categorical and continuous data. Most comparisons (>0.6) would be considered as “substantial”, or “almost perfect”, agreement [7]. Exceptions are the assessment of T2 change in the cord and identification of cord atrophy, which showed very poor correlation between observers. The assessment of foraminal narrowing between different observers was in the range of “moderate agreement”. It is notable that agreements on the extension studies were generally satisfactory, even though image quality tended to be less good due to patient movement.

Normal cord measurements

Results are shown in Table 3.

Predictors of clinical myelopathy

For most parameters that were investigated, values were calculated for the "worst" level (for example at the level of minimum AP cord diameter), as well as a mean value for the four levels that were investigated. Large changes in the compression score in the different neck positions were observed (Table 4).

In general, data obtained from measuring specific parameters were of no value in discriminating between myelopathic and non-myelopathic patients. These non-discriminatory measurements comprise CSF+spinal cord area, spinal cord area, the difference between these areas, the AP diameter of the cord and the central compression and lateral compression ratios. This applies whether calculated for the "worst" level or the average of four levels and on either the neutral or extension studies. All demonstrate an area under the curve (AUC) value of <0.45.

The cord compression score was discriminatory (Table 4) but only on the extension scans. Thus, extension sequences were able to distinguish between myelopathic and non-myelopathic patients (AUC, 0.60), whereas in this patient population, the standard sequences were virtually non-discriminatory (AUC, 0.52). As might be expected, the best discriminator was the presence of T2 signal change in cord substance (AUC, 0.68) (Table 5). The change in compression score between the standard and extended studies was no better than looking at the extended studies alone (AUC, 0.62). The only quantifiable measurement that seemed to be of value was the ratio of cord area/CSF area at the level of maximum cord compression (AUC, 0.71) (Table 4).

Radiculopathy

Of 35 patients with radiculopathy, 19 were clinically graded 2 or 3, and thus had clinical localisation which could be compared with the imaging. If strict criteria are used (grade 2 imaging abnormality) a sensitivity of 47 % and specificity of 90 % are found for conventional MRI. The use of extended imaging makes little difference to the sensitivity (53 %) at the expense of worse specificity (86 %).

Discussion

Compressive cervical myelopathy is a relatively common disease that leads to chronic disability. It is thus a cause for concern that radiologists are not very reliable at diagnosing the condition. Stafira [12] and colleagues assessed the degree, cause and level of cervical stenosis on standard MR and CTM. No specific criteria were utilised. Observer agreement for the degree of stenosis on MRI was very poor (inter-observer kappa, 0.31; intra-observer, 0.37). Braga-Baiak [13] used seven observers to review a small number of patients with cervical myelopathy, with and without specific guidelines, and still found generally poor inter-observer agreement.

The current study utilised specific qualitative and quantitative parameters and obtained much better agreement within and between observers, and it was therefore valid to analyse the full data from observer A.

Table 4 Compression score

MR study	Worst level or average	Myelopathic group	Non-myelopathic group	AUC	95 % CI
Standard (neutral) study	Worst	0.83	0.77	0.52	0.38–0.65
	Average	0.28	0.28	0.52	0.27–0.66
Extended study	Worst	1.87	1.66	**0.58**	0.48–0.67
	Average	1.02	0.84	**0.60**	0.45–0.75
Difference between neutral and extended	Worst	1.04	0.88	0.55	0.42–0.69
	Average	0.73	0.56	**0.62**	0.47–0.76

Comparison of myelopathic and non-myelopathic scores (means) and ROC analysis of the ability of the scans to differentiate the two groups. Important values in bold type

The normal values for spinal cord sagittal diameter established from this study are not entirely consistent with previously published values. Hulcelle [14] reported normal values in 50 healthy volunteers and quoted values obtained from gaseous and opaque myelography which were respectively greater and less than on MRI, presumably due to the density of the adjacent contrast material. One might assume that modern CT myelography would give accurate measurements of soft tissue structures in the cervical canal, unaffected by the susceptibility issues that affect MRI, but their paper indicates that is not necessarily the case. Our "normal" (non-compressed) values are less than those previously quoted, but they are obtained in patients with symptomatic myeloradiculopathic cervical spondylosis, rather than asymptomatic volunteers. It raises the possibility that some of our patients had subtle cord atrophy, either due to previous cord compression that had spontaneously resolved, or to other causes. Such factors may complicate the assessment of spinal cord compression and the need for surgery.

Many subjective and objective methods to quantify cord compression have been described, which suggests that none of the techniques is entirely satisfactory [8, 15]. The presence of T2W signal change in the cord is clearly important, but it is not necessarily present in early or borderline cases [16–18]. When present, it is not always associated with ongoing compression at the level of signal abnormality and may indicate old irreversible damage or a completely different pathology. Similarly, the presence of a small or focally flattened cord may just indicate that it is atrophic and may have been compressed in the past rather than at the time of scanning.

Table 5 Ratio of cord area/CSF area and presence of T2 signal change in cord for neutral and extended studies—ability to distinguish myelopathic and non-myelopathic groups: ROC analysis

MR study	Level	AUC	95 % CI
Neutral	Worst	0.53	0.35–0.65
Extended	Worst	**0.71**	0.58–0.85
T2 change in cord	Total score	**0.68**	0.54–0.83

Important values in bold type. The presence of T2 signal change in the cord is a summation of the score (1 or 2) at all four levels

Despite measuring almost every parameter that has been described for assessing spinal cord or spinal canal compromise, we did not find any single measurement which was of value on standard scans. The ratio of cord area/CSF area was of value in predicting myelopathic patients but only on extension imaging studies. Subjective assessment of cord distortion was almost as useful but only on the extension studies or when looking at the change between standard and extension studies. This is probably not surprising. However sophisticated a quantitative measurement is, it cannot encapsulate all the anatomical features that can be identified by an experienced radiologist looking at a full set of sagittal and axial images. Most radiologists will be relieved that there seems to be no real value in performing difficult and tedious linear or area measurements.

The use of flexion/extension MRI in the elucidation of cervical cord compression has largely been advocated by Muhle's group using a purpose built positioning device [5]. Chen [2] questioned whether dynamic MR needs to be performed in every patient. Using standard equipment, they found similar results to Muhle with 31 % of patients showing functional cord impingement on extension and only 3 % in flexion. They considered that a sagittal canal diameter of 10 mm or less at C7 reflected severe canal stenosis, and showed that the chance of demonstrating dynamic cord impingement on extension rose to 79 % in this patient group. However, they did not determine whether positional MR imaging correlates with patient symptomatology any better than standard imaging.

A more physiological assessment of the dynamic changes occurring in the degenerate cervical spine would be obtained by scanning the patient erect. Unfortunately, the quality of erect MR images is often disappointing.

Presumably, patients with a narrow canal are much more likely to become symptomatic once degenerate changes develop; however, the mechanism by which degenerative changes lead to spinal cord dysfunction may be much more complex than just the degree of mechanical distortion that

ensues, and involve vascular and other factors. Recently Diffusion Tensor Imaging has been used to assess spinal cord physiology. Kara [19] assessed 16 patients with clinical evidence of myelopathy but with no evidence of T2 change in the cord. He showed a decrease in fractional anisotropy and an increase in apparent diffusion coefficient at levels of compression. He utilised a non-compressed level in the same patient as the control. This may, or may not, be valid. Such work is in its infancy and holds considerable promise, but future research needs to take dynamic factors into consideration as well.

If the role of MR imaging in myelopathy is complex, the assessment of patients with radiculopathy is even more difficult. Since the early days of spinal MR, it has been known that MR is poor at identifying the cause of foraminal compromise, either osteophyte or soft tissue [20]. The main problem with MR is the very high incidence of anatomical foraminal narrowing that has no clinical relevance. Nardin [21] showed poor correlation with electrophysiology. Kuijper [22] reported much better inter-observer agreement for foraminal compromise than has been shown in this study.

A poster reported in Spine in 2007 [23] utilised weight-bearing dynamic MR and suggested that the technique might be valuable in patients with cervical radiculopathy and unimpressive standard MR. The data from our study do not support their conclusion. The only consequence of extension MRI is to increase the already high incidence of false positive irrelevant foraminal abnormalities.

Conclusion

To obtain good quality white CSF images in a spondylytic patient with a narrow canal and little fluid to generate image contrast has always been one of the greatest technical challenges for MRI. Anatomical criteria that radiologists should use to identify cord compression are difficult to define. If there is no CSF visible around the cord and it is flattened, or distorted, it is often considered to be compressed. However, patients with cervical spondylosis often demonstrate localised or diffuse areas of cord atrophy; perhaps due to previous mechanical compression that has resolved. These factors may complicate the identification of compression. Indeed radiologists are known to show poor reproducibility in their diagnosis of cervical cord compression.

The problem with a technique such as extension MRI, which seeks to maximise the factors contributing to mechanical cord compression, is that it may increase the incidence of false positive results. Our study utilising an ROC analysis addresses this concern. The degree of extension obtained when a patient is placed in a standard MR scanner is unpredictable, and no one knows what the "best" position is. We sought to investigate the standard position of comfort that the patients adopted and the position of maximum extension that could be maintained.

One might ask why it is worth trying to predict myelopathy radiologically if the issue can be answered simply by clinical examination or electrophysiology. In the spondylytic population, radiological cord compromise often occurs at multiple levels. Indeed one of the most valuable uses of extension imaging is to show which level, or levels, are worst. Plain X-rays in flexion and extension may be helpful, especially if there is obvious instability, but minor movements on plain X-rays are much more difficult to be confident about than the changes seen with dynamic MR. The clinical diagnosis of myelopathy is not always clear cut. In the post-operative population in particular, previous cord damage means that a clinical diagnosis of myelopathy does not necessarily mean that there is cord compression.

For all these reasons, it is important to improve the radiological criteria for cord compression in patients undergoing cervical imaging. This is the first study that has shown a definite clinical benefit in examining such patients in the extended position.

The technique appears to be safe. No significant complications have occurred in any of our patients, and none are reported in the literature. However, this is a potentially vulnerable group of patients, and the technique is pointless, and ill advised, in those with obvious high-grade cord compression.

Conflict of interest We declare that we have no conflict of interest.

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