Cervical Spinal Cord Lesions in Multiple Sclerosis: Comparison among Different Magnetic Resonance Imaging (MRI) Sequences

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ABSTRACT:

BACKGROUND:

Multiple sclerosis (MS) is a chronic inflammatory, demyelinating and neurodegenerative disease of the brain and spinal cord. The cervical spinal cord is commonly affected in multiple sclerosis ,as many as 90% of MS patients which is often associated with an increase in clinical disability. Though rarely seen in other diseases, asymptomatic lesions of the spinal cord can be present in MS and may help lead to the correct diagnosis. Since the integration of MR imaging into the International Panel (McDonald) criteria in 2001,there is increasing international effort to standardize MR imaging protocols.

OBJECTIVE:

To evaluate MRI imaging protocols for detection of cervical spinal cord multiple sclerosis lesions using 1.5 T MRI scanner.

PATIENTS AND METHODS:

A cross sectional analytical study was conducted at Al-Yarmouk Teaching hospital in Baghdad city. Thirty-one known as MS Patients were examined. from October 2016 till December 2017 by Phillips Achieva Nova Dual 1.5T using a SENSE Neurovascular coil .All patients. underwent sagitta1 T2-turbo spin echo(T2-TSE), Sagittal proton density-turbo spin echo(PD-TSE), sagittal short tau inversion recovery-turbo-spin echo(STIR-TSE)and axial T2-fast field echo(T2-FFE).Comparison was done between the sequences in the means of detectability, conspicuity and number of lesions.

RESULTS:

Total patients were (31),22 were females and 9 were males .The female to male ratio was (2.4:1). The patient ages ranges between 20-61 years with a mean of age of about 38 years.

Mean Lesion to Cord Contrast Ratio (mean LCCR) of STIR and T2WI MR imaging was lower than PD imaging [p value < 0.01].Despite of STIR and T2WI had comparable LCCR (mean= 0.39), STIR imaging had expressively better Lesion Contrast to Noise Ratio (LCNR) [P value < 0.01]. PD had better LCNR (mean=48.8) as compared to T2 and STIR [p value<0.001].

PD-TSE sequence detected a large number of spinal cord lesions as compared to T2-TSE and STIR-TSE sequences [110 vs. 76 , 76; respectively . P value < 0.001].

CONCLUSION:

PD-TSE improves overall lesion detection ,delineation, conspicuity and edge definition, however it cannot give precise cord morphological data, but it prove to be the sequence of choice in cervical MS plaque detection as it has the higher lesion contrast ,and it is beneficial in overcoming artifacts seen in both STIR and T2-TSE.

STIR-TSE have good signal to noise ratio, although have higher CSF flow artifacts.

KEY WORDS: multiple sclerosis, cervical spinal cord, MRI.

INTRODUCTION:

Multiple sclerosis (MS) is a chronic inflammatory, demyelinating and neurodegenerative disease of the brain and spinal cord [(1)].In as many as 90% of MS patients, the spinal cord is involved[(2)].

The cervical spinal cord is commonly affected in multiple sclerosis, which is often associated with an increase in clinical disability.[(3)]

In about 85% of MS cases, the patient presents with a clinically isolated syndrome involving the optic nerve, brainstem, or spinal cord [(4).]

In fact, the presence of cord lesions is more specific for demyelination than in the brain because age related or non-specific ischemic lesions are rare lesions[(5)].

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Since the integration of MR imaging into the International Panel (McDonald) criteria in 2001 there is increasing international effort to standardize MR imaging protocols.[6]

McDonald diagnostic criteria for multiple sclerosis are clinical, radiographic, and laboratory criteria used in the diagnosis of multiple sclerosis. They were originally introduced in 2001 [6], revised in 2005 [7], 2010 [8], 2016 (by MAGNIMS) [9] and most recently in 2017 [10]. The diagnostic value of spinal cord lesions has become increasingly more evident and is apparent in the most recent changes in the diagnostic criteria.[11] Involvement of spinal cord, younger age and male sex at RIS identification were associated with a higher risk of developing neurological symptoms. In cases when MS is suspected and the brain MRI is suggestive but not diagnostic, the presence of spinal cord lesions can be helpful in confirming suspicion of MS.[12]

PATIENTS AND METHODS:

Thirty-one known MS patients were examined at the Radiology Department / MRI Unit of Al-Yarmouk Teaching Hospital from October 2016 till December 2017 by Phillips Achieva Nova Dual 1.5 T using a SENSE Neurovascular coil .

All patients underwent sagittal T2WI-TSE, Sagittal STIR , sagittal PD-TSE , and axial T2-FFE with sequence details listed in table 1.

Table 1: Parameters of MR images sequences.

Sequence / Parameter	sagittal T2WI-TSE	Sagittal STIR-TSE	Sagittal PD-TSE	Axial T2-FFE
TR(ms)	3130	1982	2500	366.9
TE(ms)	96	80	31	9.2
FOV(mm)	160*232*39	160*220*52	160*252*39	120*120*49
Echo spacing	7	5.6	8.6	10.4
Acquisition time(min)	1:55	1:31	3:07	2:46

The cervical cord was divided into 7 segments, each segment includes the vertebral level and its lower corresponding disc. Two Trained specialist radiologists independently identified MS plaques as hyperintense compared to normal appearing background cord in all sequences. Lesions appear on one of the mentioned sequences were included only if were detected on the axial T2WI-FFE.

Along lesion defined as contiguous involvement of more than 2 segments detected on sagittal T2WI-TSE , sagittal PD-TSE, sagittal STIR-TSE were included.

Spinal cord AP dimension were calculated at 3 levels C1,C3 and C6 vertebral body levels and compared to normal values published by RSNA 2014.[13]

Lesion detectability was assessed quantitatively by using a normalized lesion-to-cord contrast ratio (LCCR) and a lesion-contrast to-noise ratio (LCNR).

The LCCR was calculated for each lesion in each sequence by applying the mean signal intensities generated in the regions of interest (ROI) in the equation below, A small ROIs were obtained within MS lesions, normal-appearing cord. Signal Lesion denotes to the signal intensity of the lesion and Signal Normal Cord is the signal intensity of normal-appearing cord[14]:

$$LCCR = \frac{(Signal\ Lesion\_Signal\ Normal\ Cord)}{Signal\ Normal\ Cord}$$

For evaluation of lesion contrast-to-noise ratio (LCNR), a small region of interest (ROI) was manually placed , Mean signal intensity (SI) and standard deviation (SD) were recorded within MS lesions, normal-appearing cord, and background air; the **Signal Lesion** and **Signal Normal Cord** against the level of background noise expressed as the standard deviation (SD) of background air ($\mathbf{SD}_{air}$) as measured in the equation below[14]:

$$LCNR = \frac{Signal\ Lesion\ -\ Signal\ Normal\ Cord}{SDair}$$

Each patient assigned a serial identification number. The data were analyzed using Statistical Package for Social Sciences (SPSS) version 20.

RESULTS:

In this study, the patient's ages range were from 20-61 years with a mean of age of about 38 years.

About 22 were females and 9 were males. The female to male ratio was (2.4:1).The (20-39 years) age group was the most affected of about 51.6% (16 patients).

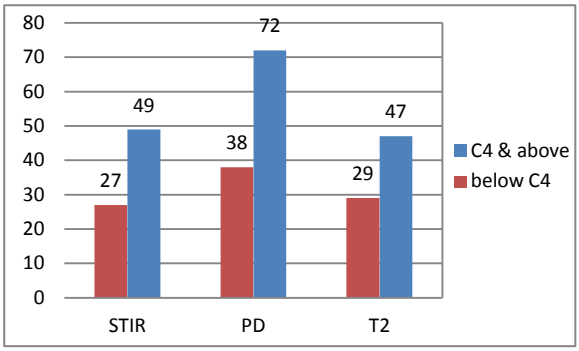

Figure 1 :Comparison of the number and distribution of MS lesions of cervical cord in T2WI, PD and STIR MR imaging.

Distribution of the lesion was noted to be higher in the upper segments (C4 segment and above) than in the lower segments(below C4), PD-TSE shows the largest group at C4 level(n=72) (i.e. 1.9 times) compared to that of the lower segments number of lesions(n=38), which was near that of STIR-TSE (1.8 times ,n=49,n=27) and slightly higher than that of T2-TSE (1.6 times ,n=47,n=29).

Table 1:Quantitative cervical cord MS lesion detection in T2WI, PD and STIR MR imaging.

Parameter	MRI sequence			P value		
	T2WI	PD	STIR	PD vs. T2WI	T2WI vs. STIR	PD vs. STIR
Number of lesions	76	110	76	< 0.001	N.S.	<0.001

N.S. statistically non-significant

T2WI and STIR MR imaging had equal detection rate for spinal cord lesions (n=76); P value is statistically non-significant (> 0.05).

PD detected a large quantity of spinal cord lesions as compared to T2WI and STIR [PD n= 110, versus T2WI n= 76, STIR n= 76; P value < 0.001].

Table 2: Qualitative cervical cord MS lesion detection in T2WI, PD and STIR MR imaging.

Parameter	MRI sequence			P value		
	T2WI	PD	STIR	PD vs. T2WI	T2WI vs. STIR	PD vs. STIR
LCCR (mean)	0.39	0.42	0.39	< 0.01	N.S.	<0.01
LCNR (mean)	22.5	48.8	36.2	<0.001	< 0.01	<0.001

N.S. statistically non-significant

LCCR (mean) of STIR and T2WI MR imaging was lower than PD imaging (p value < 0.01).
Despite of STIR and T2WI had comparable LCCR (mean= 0.39), STIR imaging had expressively better LCNR (P value < 0.01).PD had better LCNR (mean=48.8) as compared to T2 and STIR (p value<0.001).

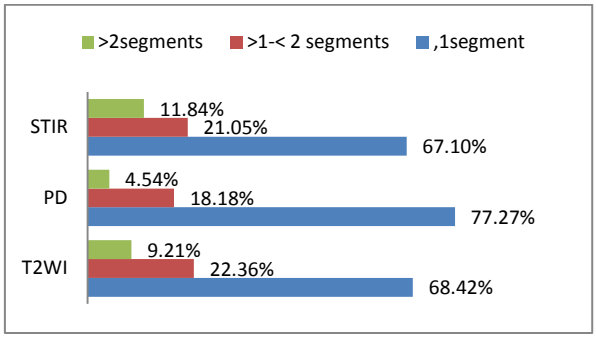

Figure 2: Lesion length in T2-TSE, PD-TSE and STIR-TSE MR imaging.

The length of the lesions which were more than 2 vertebral segments (long lesions) on PD (n=5, 4.5%), on T2 (n=7,9.2%) and STIR (n=9,11.8%). Majority of lesions don't affect the cord morphological contour, swelling of the cord noted in 2 patients (n=5 lesions, 6%) and atrophy was identified in association with (n=4 lesions, 5%) in 3 patients in T2-TSE and STIR . cord contour were more obvious at T2 and STIR sequences and poorly defined by PD.

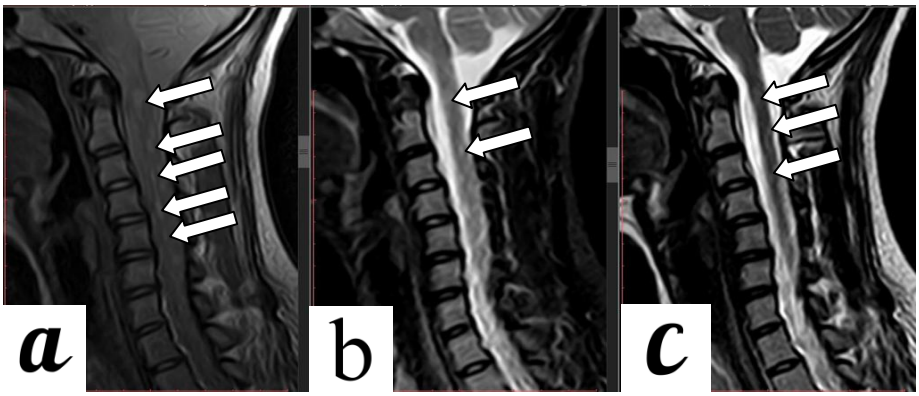

Figure 4: 20 Yrs female cervical MRI multiple tiny lesions noted at PD(a) while STIR shows only 2 lesions (arrows at b) and three lesions at T2(c).

DISCUSSION:

Improving detection of focal MS lesion in spinal cord MRI is important as it increases confidence when making diagnosis of MS because cervical cord is less affected by age related changes as in brain also cord lesion may be used in quantification of disease activity in known MS cases and early prediction of RIS conversion into definitive MS.[15]Distribution of the lesion was noted to be higher in the upper segments than in the lower segments(Fig 1), PD-TSE shows the largest group at C4 level, this is due to imaging heterogeneity between these 2 regions that arises from field inhomogeneity, artifacts and dielectric effects. [16] These factors affect the image quality of the lower cervical region more than the upper region, mostly due to increased body thickness at the shoulders, which can potentially confound evaluation.The current study revealed that STIR-TSE is similar to T2-TSE in LCCR ratio with same number of lesions but a higher lesion to cord noise ratio (LCNR) making the conspicuity of the lesion to be more in STIR-TSE which was comparable to a local study by Fahad et al [17] who stated that STIR-TSE improved detection of MS plaque compared to T2-TSE and many other international studies as Nayak et al [18] whom study showed STIR- TSE sequence imaging provides better detection, contrast and conspicuity of visible lesions, and two earlier studies by Rocca et al [19] who found that STIR-FSE has the best sensitivity compared to T2-TSE and Hittmair et al [20] who found that lesions showed the higher contrast ,appeared larger and were better delineated on STIR-TSE compared to T2-TSE,this is attributed to synergistic effect of the prolonged T1 and T2 relaxation times and its ability of fat suppression ,this has an advantage in lesions with slightly increase T2-TSE as in chronic lesions.PD-TSE gives a higher detectability and conspicuity of lesion compared to T2-TSE,this coincides with a previous study by Chong et al[21] who states that PD-TSE was superior to T2-TSE for cervical MS plaque as PD-TSE detects cord lesion in whom T2- TSE appears normal , which was due to higher signal to noise ratio and lower artifacts, this was discordant to what Hittmair et al[20] found in his study that PD-CSE and T2-CSE were equal in lesion detection. This is may be due to that the image quality of CSE is more affected by the pronounced image noise and ghost artifacts than TSE sequences. Small sample and the old MR scanner used in their study might affect their result. Proton density PD-TSE shows higher detectability and conspicuity in comparison with STIR-TSE which was disagreed to what Sudarakumar et al[22] who had stated that STIR-TSE has detectability (2 times) higher than that of PD-TSE which is due to higher field strength (3T) and different sequence parameters used in their study.Due to its high LCCR and LCNR the PD-TSE ,significantly higher no. of lesions were detected in PD-TSE; which is attributed to higher edge definition and lower artifacts of PD-TSE, Artifacts related to CSF pulsations are known to produce focal changes on the T2-TSE and STIR sequence, which can be mistaken for real abnormalities[23].That explains why some long lesions in STIR-TSE and T2-TSE appeared to be multiple contiguous discontinuous lesions in PD-TSE and explains the lower percentage (4.5%) of long lesions in PD-TSE compared to STIR-TSE- and T2-TSE(11.8% and 9.2%).Similarly, the higher signal of gray matter and the central canal on STIR& T2-TSE cause spurious hyperintense foci or can obscure the central lesions[24] .Better edge demarcation and lesser(cerebro-spinal fluid) CSF artifact made the researcher and the observers more comfortable with PD-TSE sequence lesion interpretation but cord morphology was hard to judge in this sequence.This result is very important since sagittal T2-TSE sequences are the most commonly used in clinical institutions for cord MS lesion detection.Majority of lesions did not affect the cord morphological contour, swelling of the cord noted in 5 lesions (6%) in 2 patients .Atrophy was always identified in association with lesions and was seen in 4 lesions (5%), swelling and atrophy were more obvious at T2 and STIR sequences and poorly defined by PD due to the lower contrast between the CSF and the nearby cord margins ,this was close to what Rocca et al [19] study found in which swelling was associated with 11% and atrophy with 2% of the lesions. This is an important predictor since several groups reported strong association between atrophy correlated to loss of cervical cord axons and clinical disability[25].**CONCLUSION:**PD-TSE improves overall lesion detection ,delineation, conspicuity and edge definition, however it cannot give precise cord morphological data, but it prove to be the sequence of choice in cervical MS plaque detection as it has the higher lesion contrast ,and is beneficial in overcoming artifacts seen in both STIR and T2-TSE.STIR have good signal to noise ratio, providing good cord morphological data , despite higher CSF flow artifacts .Minority of the lesions associated with morphological changes of the cord.

REFERENCES:

1. Geurts J, Calabrese M, Fisher E, et al . Measurement and clinical effect of grey matter pathology in multiple sclerosis. The Lancet Neurology. 2012;11:1082-92 .
2. Bot JC, Barkhof F, à Nijeholt GL,et al . Differentiation of multiple sclerosis from other inflammatory disorders and cerebrovascular disease: value of spinal MR imaging. Radiology. 2002;223:46-56.
3. Bergers E, Bot JC, De Groot CJ, et al. Axonal damage in the spinal cord of MS patients occurs largely independent of T2 MRI lesions. Neurology. 2002 ;59:1766-71.
4. Noseworthy J, Lucchinetti C, Rodriguez M, et al. Multiple Sclerosis. New England Journal of Medicine. 2000;343:938-52.
5. Trip SA, Miller DH. Imaging in multiple sclerosis. Journal of Neurology, Neurosurgery & Psychiatry. 2005 ;76(suppl 3):iii11-8.
6. McDonald WI, Compston A, Edan G, et al . Recommended diagnostic criteria for multiple sclerosis: guidelines from the International Panel on the diagnosis of multiple sclerosis. Annals of neurology. 2001;50:121-7.
7. Polman CH, Reingold SC, Edan G, et al . Diagnostic criteria for multiple sclerosis: 2005 revisions to the "McDonald Criteria". Annals of neurology. 2005;58:840-46.
8. Polman CH, Reingold SC, Banwell B, et al . Diagnostic criteria for multiple sclerosis: 2010 revisions to the McDonald criteria. Annals of neurology. 2011;69:292-302.
9. Filippi M, Rocca MA, Ciccarelli O, et al . MRI criteria for the diagnosis of multiple sclerosis: MAGNIMS consensus guidelines. The Lancet Neurology. 2016 ;15:292-303.
10. Thompson AJ, Banwell BL, Barkhof F, et al .Diagnosis of multiple sclerosis: 2017 revisions of the McDonald criteria. The Lancet Neurology. 2017.
11. Ulrike W. Kaunzner and Susan A. Gauthier. MRI in the assessment and monitoring of multiple sclerosis: an update on best practice. Ther Adv Neurol Disord. 2017; 10: 247–61.
12. Okuda DT, Siva A, Kantarci O, Inglese M, et al. Radiologically isolated syndrome: 5-year risk for an initial clinical event. PloS one. 2014;9:e90509.
13. Ulbrich EJ, Schraner C, Boesch C,et al. Normative MR cervical spinal canal dimensions. Radiology. 2014 ;271:172-82.
14. Geurts JJ, Pouwels PJ, Uitdehaag BM,et al. Intracortical lesions in multiple sclerosis: improved detection with 3D double inversion-recovery MR imaging. Radiology. 2005;236:254-60.
15. Kidd D, Thorpe JW, Thompson AJ, Kendall BE, Moseley IF, MacManus DG, McDonald WI, Miller DH. Spinal cord MRI using multi-array coils and fast spin echo II. Findings in multiple sclerosis. Neurology. 1993;43:26-32.
16. Fries P, Runge V, Kirchin M, et al. Magnetic Resonance Imaging of the Spine at 3 Tesla. Seminars in Musculoskeletal Radiology. 2008;12:238-52.
17. Fahad Q . , Hadi A., Obaid S. et al . A Comparison of Sagittal Sections of Short T1inversion Recovery and T2 Weighted Fast Spin Echo Magnetic Resonance Sequences for Detection of Multiple Sclerosis Spinal Cord Lesions. Al-Kindy College Medical Journal 2016;12:60-63.
18. Nayak NB, Salah R, Huang JC, et al. A comparison of sagittal short T1 inversion recovery and T2-weighted FSE sequences for detection of multiple sclerosis spinal cord lesions. Acta Neurologica Scandinavica. 2014;129:198-203.
19. Rocca MA, Mastronardo G, Horsfield MA, et al. Comparison of three MR sequences for the detection of cervical cord lesions in patients with multiple sclerosis. American journal of neuroradiology. 1999;20:1710-16.
20. Hittmair K, Mallek R, Prayer D, et al . Spinal cord lesions in patients with multiple sclerosis: comparison of MR pulse sequences. American Journal of Neuroradiology. 1996;17:1555-65.
21. Chong AL, Chandra RV, Chuah KC, et al. Proton density MRI increases detection of cervical spinal cord multiple sclerosis lesions compared with T2-weighted fast spin-echo. American Journal of Neuroradiology. 2016 ;37:180-84.
22. Sundarakumar DK, Smith CM, Hwang WD,et al. Evaluation of Focal Cervical Spinal Cord Lesions in Multiple Sclerosis: Comparison of White Matter–Suppressed T1 Inversion Recovery Sequence versus Conventional STIR and Proton Density–Weighted Turbo Spin-Echo Sequences. American Journal of Neuroradiology. 2016;37:1561-66.
23. Bot JC, Barkhof F, à Nijeholt GL,et al. Comparison of a conventional cardiac-triggered dual spin-echo and a fast STIR sequence in detection of spinal cord lesions in multiple sclerosis. European radiology. 2000 ;10:753-58.

24. Yiannakas MC, Kearney H, Samson RS,et al. Feasibility of grey matter and white matter segmentation of the upper cervical cord in vivo: a pilot study with application to magnetisation transfer measurements. Neuroimage. 2012;63:1054-59.

25. Valsasina P, Rocca MA, Horsfield MA, Absinta M, Messina R, Caputo D, Comi G, Filippi M. Regional cervical cord atrophy and disability in multiple sclerosis: a voxel-based analysis. Radiology. 2013;266:853-61.