2023, 20(3 Suppl.): 1155-1163
https://dx.doi.org/10.21123/bsj.2023.8244
P-ISSN: 2078-8665 - E-ISSN: 2411-7986
Baghdad Science Journal

Assessment of image quality of cervical spine complications using Three Magnetic Resonance Imaging Sequences

Nabaa A. Rasheed Naji

Physiology and Medical Physics Department, College of Medicine, Mustansiriyah University, Baghdad, Iraq.

Received 18/12/2022, Revised 02/06/2023, Accepted 04/06/2023, Published 20/06/2023

Abstract

Examining and comparing the image quality of degenerative cervical spine diseases through the application of three MRI sequences; the Two-Dimension T2 Weighed Turbo Spin Echo (2D T2W TSE), the Three-Dimension T2 Weighted Turbo Spin Echo (3D T2W TSE), and the T2 Turbo Field Echo (T2_TFE). Thirty-three patients who were diagnosed as having degenerative cervical spine diseases were involved in this study. Their age range was 40-60 years old. The images were produced via a 1.5 Tesla MRI device using (2D T2W TSE, 3D T2W TSE, and T2_TFE) sequences in the sagittal plane. The image quality was examined by objective and subjective assessments. The MRI image characteristics of the cervical spines (C4-C5, C5-C6, C6-C7) showed significant differences among the three sequences used $P<0.05$ with the exception of the contrast $P> 0.05$. For the cervical spines (C4-C5), the minimum CNR was noticed with the T2_TFE sequence. For the cervical spines (C5-C6), the CNR and SNR were higher when they were assessed by the 2D T2W TSE sequence as compared to the other sequences. The same findings were observed with the cervical spines (C6-C7). The subjective assessment of the degenerative cervical spine diseases showed that the T2_TFE sequence is excellent in terms of viewing the central stenosis and foraminal stenosis. The best MRI diagnostic imaging can be obtained using the Turbo Field Echo (T2_TFE) and the Three-Dimension T2 Weighted Turbo Spin Echo (3D T2W TSE) sequences to gain detailed diagnostic information regarding the central stenosis and foraminal stenosis of the cervical spines (C4-C5, C5-C6, C6-C7).

Keywords: Cervical Spine Disease, Contrast to Noise Ratio, Image Quality, Magnetic Resonance Imaging, Signal to Noise Ratio.

Introduction

Radiological examinations are an undoubtedly powerful tool for the proper diagnosis of many diseases[1]. The medical image is used for several purposes including treatment, diagnosis, training, remote learning, and medical consultations[2]. Since magnetic resonance imaging (MRI) provides high quality images of the bone structure and soft tissue in various planes, it is frequently utilized as a non-invasive method to evaluate cervical spine pathologies [3]. Superconducting magnets were first introduced as technology advanced, and this resulted in a gradual increase in field strength from 0.15 T to as high as 9.4 T in some conditions. These developments eventually led to the development of high-resolution images used today, which have since made it possible to characterize and identify different spinal degenerative phenotypes like disc degeneration, disc displacement, disc space narrowing, and structural and non-structural endplate abnormalities[4].The cervical spine is one of the most commonly examined areas of the body with MRI [5]. The cervical spine MRI examinations occupy the second degree in the rate of MRI after lumbar spine examinations. Intervertebral Disk

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P-ISSN: 2078-8665 - E-ISSN: 2411-7986
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(IVD) is a hydromechanical system whose functions include flexibility, multi-axial spinal motion, and load transmission to the spine. Intervertebral disks are involved in a variety of pathology disorders. Degeneration, infection, lesions, and trauma are among the examples of pathological changes that can present as changes in the range of signal intensity on an MRI scan [5,6].

Degeneration of IVD is one of the common diseases of the spine, especially in the cervical spine. Cervical degenerative disc disease is a common cause of neck pain and radiating arm pain. A succession of radiofrequency pulses and gradients create a collection of images with a particular appearance in a magnetic resonance imaging sequence. The T2 weighted image (T2WI) is one of the most frequently used MRI pulse sequences. The T2 relaxation period for tissues is highlighted by this sequence weighting[7].

T2 relaxation is also known as transverse relaxation, or spin-spin relaxation. When energy is transferred between dipoles facing parallel and anti-parallel to the external magnetic field in a changing local magnetic field, T2 relaxation occurs. Transverse T2W sometimes has pitfalls in diagnosis such as the flow of the CSF, vertebral artery vascular flow through the foramen of transverse processes on either side, low SNR value due to certain MRI parameters like the effect of the surface coil and the change in the value of the Larmor frequency[8].

Degenerative cervical myelopathy is currently primarily diagnosed clinically because of the limits of current MRI diagnostic alternatives, necessitating the development and continued study of innovative diagnostic approaches with objective quantitative markers[9,10]. For these reasons, other advanced MRI techniques should be examined [11]. There isn't yet a standard MRI procedure for the spine, although it typically entails T1 and T2 axial images, sagittal T2 rapid turbo spin echo, T1 STIR (Short Tau Inversion Recovery) images, and T1 short echo after gadolinium administration. Normal intervertebral discs appear bright (relatively high signal intensity) on T2, although disc degeneration is best diagnosed using sagittal T2 with relatively short echo train lengths (10 ms). The spinal cord and the cauda equina nerve root can also be seen on axial and sagittal T2 images. On T1, lumbar spine fat is highly bright and contrasts well with the dural, sac, and intervertebral disc; the dark postoperative epidural fibrosis contrasts favorably with the high signal intensity of normal epidural fat. In order to distinguish between scar tissue (fibrosis) and recurrent disc herniation, post-gadolinium T1 scans are essential [12]. To determine the degree of spinal stenosis, measurements of cervical degenerative illnesses in the region of interest (ROI) can be made; these measurements have also been used for degenerative disorders and functions [13,14].

Fast or turbo T2W spin echo (FSE/TSE) is a spin-echo (SE) acquisition technique that is intended to cut down on imaging time. Because of the substantially higher imaging speed, it has largely replaced the old spin-echo technique. This is done by transmitting a sequence of 180-degree inversion pulses at regular intervals and measuring the echoes using a slightly altered phase-encoding gradient[15]. The foundation of 3D acquisition techniques is the stimulation of a 3D volume[16]. The term "isotropic" refers to the fact that the voxels produced by the 3D acquisition are the same size in all directions, for example, 0.6mm x 0.6mm x 0.6mm, enabling the images to be reformatted with the same resolution in all directions; otherwise, it can mean to generate 3D data-sets without gaps [7,8]. Turbo Field Echo (TFE) in a Philips MRI scanner (ultrafast gradient echo) is a spoiling gradient echo pulse sequence, which uses a small flip angle of 10^{o} to 30^{o} and a very short echo time (TR) and short excitation time (TE). The turbo field echo sequence is divided into T1_TFE (by prime 180^{o} to obtain T1 contrast image (thrive sequence) and T2_TFE (by a spin echo sequence before it), to obtain the T2 contrast image (it is used in the current study with a flip angle of 5^{o} to 15^{o}) [17].

This study aimed to examine the efficiency of the 2D T2W TSE, 3D T2W TSE, and T2_TFE imaging sequences in producing the best image quality of the cervical spine degenerative diseases.

Materials and Methods

Patients and control

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This study has been performed in the radiology department of Al-Yarmouk Teaching Hospital/ MRI unit/ Baghdad-Iraq. Thirty-three patients who were diagnosed as having degenerative cervical spine diseases were involved in this study. Their age range was from 40 to 60 years old. The MRI images were produced by a 1.5 Tesla MRI system made by Philips Medical System employing eight element phased array sensitivity encoding cervical coil (SENSE, ring width 80 cm. and the Achieva MRI computer software (Achieva application, 2005). The MRI examinations were performed for each patient using three different MRI sequences (2D T2W TSE, 3D T2W TSE, and T2_TFE) in the sagittal plane in order to compare the three sequences to gain the best quality image to give a morphological pattern in the degeneration of the intervertebral disk (IVD) of the cervical spines (C4-C5), (C5-C6), and (C6-C7). The image quality was examined by objective and subjective assessment. The objective assessment was performed by examining the same subject with the three determined sequences to measure the image contrast to noise ratio (CNR) and signal to noise ratio (SNR).The contrast between the different tissues was calculated to evaluate the differences between two tissues A and B, which equates to the difference between the signal intensities for tissue A, S_A, and that for tissue B, S_B, for each sequence using the following formula[17]:

$$Contrast(C) = S_A - S_B \dots\dots\dots\dots\dots 1$$

The mean signal intensity was measured via the Regions of Interest (ROI) option of the MRI device in the two tissues being compared, while the CNR and SNR were measured according to the following eqs [18].

$$CNR = \frac{SNR\ of\ ROI - SNR\ of\ ROI\ 2}{Noise} \dots\dots\dots\dots 2$$

$$SNR = \frac{Mean\ signal\ intensity\ of the\ region\ of\ interest\ signal}{Standard\ deviation\ of\ backgrounds\ signal\ intensity\ (noise)} \dots\dots\dots\dots\dots 3$$

Methods

The signal intensity measurement was expected to change according to the following physical parameters for each sequence: Time of Echo (TE msec), Time of Repetition (TR msec),Flip Angle , Number of Excitations (NEX),and total scan time (sec).The subjective assessment was achieved by demonstrating the patient's image to be assessed and scored for clarity of demonstration of anatomy and pathology according to the different imaging combinations for central stenosis, foraminal stenosis, disc degenerative herniation, and ligament flavum hypertrophy. The evaluation grades of the objective assessment were classified as excellent, very good, and good, as shown in Figs1, 2 and 3.

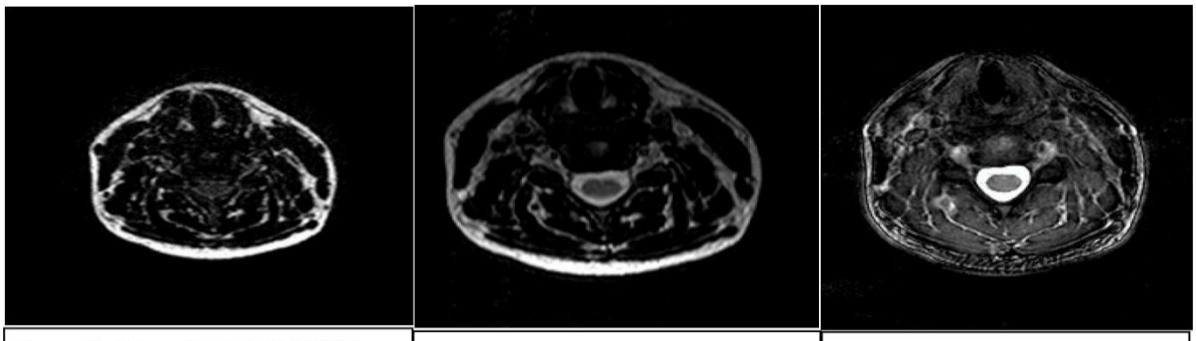

Image 7: Using of 2DT2W TSE MRI sequence for imaging C4-C5

Image 8: Using of 3DT2W TSE MRI sequence for imaging C4-C5

Image 9: Using of T2-TFE MRI sequence for imaging C4-C5

Figure 1.Imaging of the cervical spines (C4-C5) by three MRI sequences

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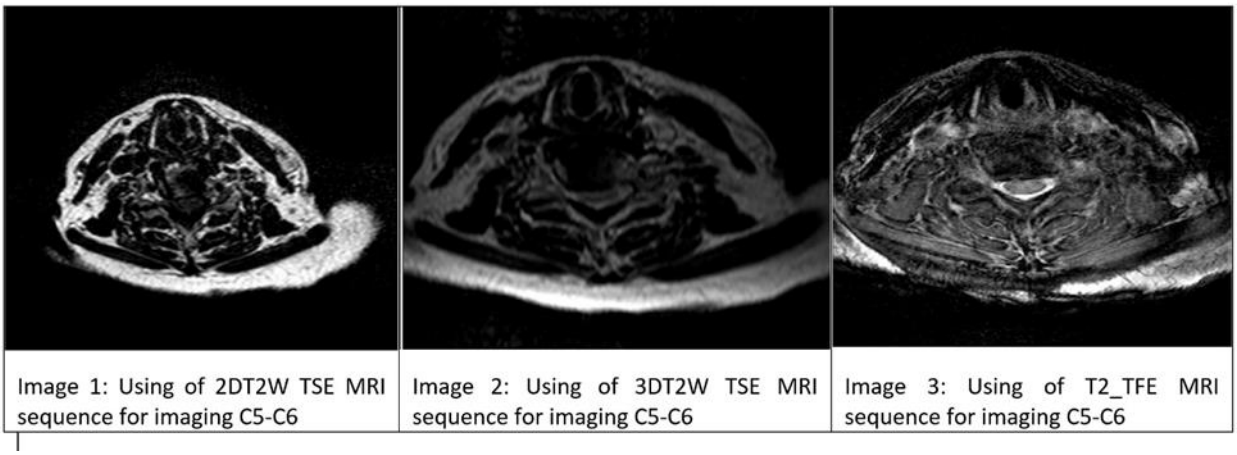

Figure 2. Imaging of the cervical spines (C5-C6) by three MRI sequences

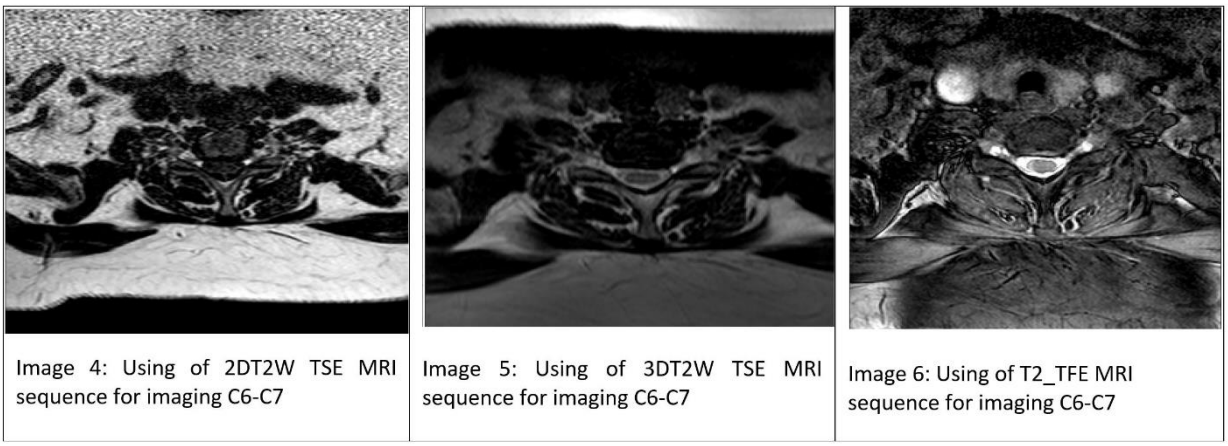

Figure 3. Imaging of the cervical spines (C6-C7) by three MRI sequences

Statistical analysis:

Statistical software SPSS-V24 was used for data analysis (Statistical Package for Social Science-version 24). Simple measurements of percentage, mean, standard deviation, and range were used to present the data (minimum-maximum value). The paired t-test was used to determine whether the difference in dependent mean (quantitative data) was statistically significant. When the p-value was 0.05 or below, the results were deemed statistically significant.

Results and Discussion

Results:

The MRI examination of this study included the cervical spines (C4-C5), (C5-C6), and (C6-C7). The cervical spines (C4-C5) represented 24%, whereas the percentage of (C5-C6) was 46%, and (C6-C7) was 30%. The specifications of each MRI sequence are listed in Table 1.

Table 1. The MRI parameters of the three MRI sequences

Parameter	2D T2W TSE	3D T2W TSE	T2_TFE
TR (msec)	2642.44	2500	8.3
TE (msec)	120	120	4.1
Flip angle (˚)	90	90	15
NEX	4	1	2
Total Scan Time (sec)	120	140	30

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https://dx.doi.org/10.21123/bsj.2023.8244
P-ISSN: 2078-8665 - E-ISSN: 2411-7986
Baghdad Science Journal

The MRI image characteristics of the cervical spines (C4-C5, C5-C6, C6-C7) indicated significant differences among the three used sequences P<0.05, with the exception of the image contrast, where there was no noticeable significant difference when using these sequences (P= 0.07, 0.1, and 0.07, respectively). For the cervical spines (C4-C5), the minimum CNR was noticed with the T2_TFE sequence, while the lowest SNR was achieved with the 3D T2W TSE, as shown in Table 2

Table 2. The Comparison of MRI image characteristics of (C4-C5) by using three MRI sequences

Parameter	2D T2W TSE	3D T2W TSE	T2_TFE	*p* - value
Contrast	4.7845 ± 2.691	4.8378 ±3.32	3.1744 ± 1.372	0.07
CNR	516.29 ±15.11	304.25 ± 11.05	225.97 ± 13.98	0.00007
SNR	223.64 ± 5.8252	142.83 ± 5.0579	271.19 ± 5.597	0.00003
Minimum Signal Intensity	0.75 ± 0.07	11 ± 3.20	119.428 ± 11.4434	0.00001
Maximum Signal Intensity	27.125 ± 4.3895	214.5 ± 16.8772	286 ± 10.4243	0.00001

For the cervical spines (C5-C6), the CNR and SNR were higher when it was assessed by the 2D T2W TSE sequence as compared to when using the 3D T2W TSE and T2_TFE sequences, as shown in Table 3.

Table 3. The Comparison of MRI image characteristics of (C5-C6) by using three MRI sequences

Parameter	**2D T2W TSE**	**3D T2W TSE**	**T2_TFE**	***p* - value**
Contrast	0.446 ± 0.020	0.559 ± 0.016	0.542 ± 0.0140	0.1
CNR	55.39 ± 3.49	39.39 ± 12.70	35.26 ± 10.48	0.004
SNR	26.15 ± 9.47	17.08 ± 6.69	12.23 ± 4.05	0.00001
Minimum Signal Intensity	1.33 ± 0.82	7.67 ± 8.59	57.73 ± 27.78	0.00001
Maximum Signal Intensity	35.2 ± 2.89	155.6 ± 35.31	244.87 ± 53.46	0.00001

The same findings appeared with the CNR and SNR for the cervical spines (C6-C7), where they were higher with the 2D T2W TSE compared to the 3D T2W TSE and T2_TFE sequences, see Table 4.

Table 4. The Comparison of MRI image characteristics of (C6-C7) by using three MRI sequences

Parameter	**2D T2W TSE**	**3D T2W TSE**	**T2_TFE**	***p* - value**
Contrast	0.35 ± 0.019	0.56 ± 0.023	0.43 ± 0.018	0.07
CNR	55.56 ± 24.13	39.55 ± 12.34	38.15 ± 9.43	0.04
SNR	23.82 ± 6.36	19.41 ± 2.09	10.98 ± 3.23	0.01
Minimum Signal Intensity	1.9 ± 0.92	11.7 ± 1.36	61.8 ± 3.08	0.00001
Maximum Signal Intensity	35.3 ± 15.41	171.7 ± 73.49	204.5 ± 46.20	0.00001

The minimum and the maximum signal intensities were also found to be greater with the T2_TFE sequence as compared with the 2D T2W TSE and 3D T2W TSE sequences with the three groups of cervical spines, as indicated in Tables 2, 3, and 4.

The subjective assessment of the degenerative cervical spine diseases showed that the T2_TFE sequence is optimal in terms of viewing the central stenosis and foraminal stenosis (P=0.0001 and 0.02, respectively), where 92% of the MRI images produced by T2_TFE were evaluated by the radiologists with excellent scores for this sequence, and very good for the 3D T2W TSE sequence. The same results were found when evaluating the disc degenerative herniation, and bulging and ligament flavum hypertrophy, where the radiologists' opinions pointed to a 100%excellent view of the MRI images produced

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https://dx.doi.org/10.21123/bsj.2023.8244
P-ISSN: 2078-8665 - E-ISSN: 2411-7986
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with the T2_TFE and 3D T2W TSE sequences(P=0.001 and 0.003, respectively).

Discussion:

The T2_TEF is considered the most useful MRI sequence for cervical spine imaging. This sequence of gradient echo imaging allows for rapid imaging with very short repetition times (TR) intrinsic to good image quality [19]. In the current study, the image quality indicators of the T2_TFE sequence were represented by a significant decrease in the CNR and SNR of the cervical spines (C4-C5) as compared to 2D T2W TSE and 3D T2W TSE. This can be explained by the strong minimum and maximum signal intensities of this sequence, as the MRI signals traverse a region of the neck that has only a small surface area. This result was confirmed by the radiologists' assessment for the central and foraminal stenosis of the cervical spine, where they evaluated the images produced by T2_TFE as being the clearest.

The 2DT2WTSE and 3D T2W TSE sequences are the most sensitive for detecting disc degeneration via MRI. Reducing the 2D T2W TSE and 3D T2W TSE signals within the intervertebral disc, some of the issues that may impair image quality include a decrease of intervertebral disc height, loss of the typical distinctness between the nucleus pulposus and annulus fibrosus, and others[20].

These findings are in parallel with the results of this study, especially when examining the cervical spines (C5-C6) and (C6-C7), where the minimum and maximum signal intensities of the 2D T2W TSE and 3D T2W TSE were lower than those signals of the T2_TFE, in spite of the fact that the CNRs and SNRs recorded for the two dimensions and three dimensions turbo spine echo sequences were higher than those obtained by the T2_TFE. The location of (C5-C6) and (C6-C7) in the large surface area part of the neck beside the presence of regional vascular anatomy may produce motion artifacts which compromise image quality. Furthermore, T2_TFE is distinguished by a shorter echo time (4.1 msec) in comparison to the echo time of the 2D T2W TSE and 3D T2W TSE (120 msec), which may come at the price of reducing the SNR of the T2_TFE and which, importantly, can lead to increased motion sensitivity [21,22].

Furthermore, the findings of the present study are consistent with those of Hossein et al [23], who sought to compare T2-weighted three-dimensional isotropic turbo spin-echo (SPACE) sequences with T2-weighted two-dimensional turbo spin-echo (TSE) sequences for the comprehensive evaluation of lumbar spine pathologies in terms of diagnostic value and image quality.

The author came to the conclusion that, with the exception of the vertebrae and disc, all lumbar spine regions displayed greater SNR, CNR, and visibility in the 3D SPACE sequence for lumbar spine MRI. Also, they indicated that there were significant inter-observer and inter-method agreements for pathologic indexes between 2D TSE and 3D SPACE sequences, with 3D SPACE having a better inter-observer agreement and requiring a shorter scan time. Hence, in the sagittal, axial, and coronal planes, T2 weighted 3D SPACE sequence and its MPR might be a great replacement for 2D TSE, particularly for patients with aberrant lumbar spine curvature[23].

Conclusion

The stronger maximum and minimum signal intensities produced by applying the T2_TFE MRI sequence and the highest contrast value of the 3D T2W TSE MRI sequence contribute to the best image quality for the central stenosis and foraminal stenosis of the cervical spines (C4-C5), (C5-C6), and (C6-C7), where more accurate diagnostic details can be obtained when using one of these sequences for the imaging of degenerative cervical spine diseases.

Acknowledgment

The researcher would like to express her gratefulness to the College of Medicine/ Mustansiriyah University, for their support and helps.

2023, 20(3 Suppl.): 1155-1163
https://dx.doi.org/10.21123/bsj.2023.8244
P-ISSN: 2078-8665 - E-ISSN: 2411-7986
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Author's Contribution Statement

- Conflicts of Interest: None.
- I hereby confirm that all the Figures and Tables in the manuscript are ours. Furthermore, any Figures and images that are not ours have been included with the necessary permission for re-publication, which is attached to the manuscript.
- Author sign on ethical consideration's approval
- Ethical Clearance: The project was approved by the local ethical committee in Mustansiriyah University, the ethical approval number 258, on 30-10-2021.

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2023, 20(3 Suppl.): 1155-1163
https://dx.doi.org/10.21123/bsj.2023.8244
P-ISSN: 2078-8665 - E-ISSN: 2411-7986
Baghdad Science Journal

تقييم جودة الصورة لاضطرابات الفقرات العنقية باستخدام ثلاثة متسلسلات للرنين المغناطيسي

نبأ عبد اللطيف رشيد ناجي

قسم الفسلجة والفيزياء الطبية، كلية الطب، الجامعة المستنصرية، بغداد، العراق.

الخلاصة

اختبار كفاءة الصورة لاضطرابات الفقرات العنقية باستخدام تسلسلات الرنين المغناطيسي، (Two Dimension T2 weighing Turbo Spin Echo)، (Three Dimensional T2 Weighting Turbo Spin Echo)، (T2 Turbo Field Echo "T2_TFE"). تضمن البحث ثلاثة وثلاثون مريضا يعانون مناضطراباتالفقرات العنقية، مدى اعمارهم 40 – 60 عاما. تم انتاج الصور باستخدام جهاز الرنين 1.5 تسلا باستخدام المتسلسلات Two Dimension T2 weighing Turbo Spin Echo، Three Dimensional T2 Weighting Turbo Spin Echo، T2_TFE "T2 Turbo Field Echo". وتم تقييم جودة صور الفقرات العنقية (C3-C4, C5-C6, C6-C7)بواسطة المعلمات الفيزيائية لتباين الصورة، نسبة الإشارة الى الضوضاء (SNR)، التباين الى نسبة الضوضاء (CNR)، شدة الإشارة القصوى ، الحد الأدنى من شدة الإشارة بتطبيق منطقة الاهتمام (ROI)، كما تم تقييم جودة الصورة من قبل اختصاصي الاشعة التشخيصية بناءا على وضوح الصورة (ممتاز، جيد جدا، جيد) للتضيق المركزي و الثقبي والفتق التنكسي للقرص وانتفاخ وتضخم الاربطة. اظهرت خصائص صور الفقرات العنقية (C3-C4, C5-C6, C6-C7) اختلافا عنداستخدام المتسلسلات الثلاثة $P<0.05$، ما عدا وضوح الصورة $P>0.05$ ، بالنسبة الى الفقرات C4-C5 فان اقل تباين الى نسبة الضوضاء (CNR) لوحظ مع التسلسل "T2_TFE" T2 TurbO Field Echo ، اما نسبة الإشارة الى الضوضاء (SNR)للفقرات C5-C6 و التباين الى نسبة الضوضاء (CNR) كانت الاعلى باستخدام Two Dimensional T2 Weighting Turbo Spin Echo . ولوحظت النتيجة نفسها مع الفقرات C6-C7.كما اظهر التقييم الشخصي الذي اجراه اختصاصي الاشعة التشخيصية ان التسلسل "T2_TFE T2 Turbo Field Echoهو الأكثر امتيازا في تشخيص التضيق المركزي والتضيق الثقبي للفقرات العنقية. الحصول على افضل صورة تشخيصية باستخدام"T2_TFE" T2_Turbo Field Echo و Three Dimensional T2 Weighting وTurbo Spin Echo للتضيق المركزي والتضيق الثقبي للفقرات العنقية C3-C4, C5-C6, C6-C7).

الكلمات المفتاحية: امراض الفقرات العنقية، نسبة الوضوح الى الضوضاء، جودة الصورة، التصوير بالرنين المغناطيسي، نسبة الإشارة الى الضوضاء