Comparison of mDixon, T2 TSE, and T2 SPIR Images in Magnetic Resonance Imaging of Lumbar Sagittal Plane

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ABSTRACT

The purpose of this study was to compare and analyze the differences in scan time, signal-to-noise ratio (SNR), and contrast-to-noise ratio (CNR) in the third lumbar vertebral region including the back fat, spinal cord, and cerebrospinal fluid using the mDixon, T2 TSE, and T2 spectral pre-saturation with inversion-recovery (SPIR) techniques. With the factors affecting the SNR fixed, the lumbar sagittal plane images of 30 adults were compared on mDixon, T2 TSE, and T2 SPIR imaging tests. The test times for mDixon, T2 TSE, and T2 SPIR were 115 seconds, 60 seconds, and 60 seconds, respectively. The mDixon T2 images showed higher SNR than the T2 TSE images at the third lumbar vertebral region ($p<0.05$), lower SNR in the back fat and cerebrospinal fluid ($p<0.05$) areas, and comparable SNR in the spinal cord ($p>0.05$). The CNR between the third lumbar vertebral area and back fat was higher in the mDixon T2 images, and the CNR of the cerebrospinal fluid and spinal cord images was higher in the T2 TSE images ($p<0.05$). The mDixon T2 FS images CNR was lower for the 3rd lumbar vertebral body region and back fat than the T2 SPIR images, and higher for the spinal cord and cerebrospinal fluid images ($p<0.05$). The CNR between the third lumbar body and back fat areas was higher in the mDixon T2 FS images ($p<0.05$), and there was no difference in the CNR in the images of the cerebrospinal fluid and the spinal cord ($p>0.05$). It is difficult to determine whether the mDixon technique is superior to the conventional T2 TSE and T2 SPIR techniques in terms of test time, SNR, and CNR. This study was confined to patients with simple lower back pain and was limited by controlled experimental conditions. Studies using clinically applied protocols are warranted in the future.

Keywords: MRI, Fat saturation, mDixon

I. INTRODUCTION

Lower back pain (LBP), a pain felt by 60 to 80% of adults, often disappears over time. However, in some adults, it might indicate the development of acute and chronic diseases[1,2]. It is not easy to determine the exact cause of LBP as it may be triggered by various factors. Magnetic resonance imaging (MRI) is often performed to find the cause of the pain as it produces high-quality images of the muscle and ligament cartilage tissues[3,4]. If the signals of adipose tissues are removed using a fat-suppression technique, an image showing the lesions and structures covered by the fat signals can be obtained[5]. However, if the fat is not adequately cleared, there is a possibility that lesions may be misdiagnosed. Therefore, a fat suppression technique should be used for this purpose. Despite several

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advantages, the test time for MRI tend to increase while using a fat-suppression technique. Furthermore, patients have to maintain their posture so that motion artifacts do not appear in the images. It is, therefore, important to keep test times as short as possible. Hence, this study was conducted to compare and analyze the test times, SNR, CNR, and fat saturation levels in images produced by means of mDixon T2, T2 TSE and mDixon T2 FS, T2 SPIR fat-suppression techniques.

II. MATERIALS AND METHODS

1. Materials and Equipment

A retrospective study was conducted on 30 adults (22 males, 8 females, average age 46.1 ± 16.37 years, average BMI 22.9 ± 3.2) who visited the hospital for lumbar MRI with lower back pain. The equipment used in this study consisted of Achieva Release 3.0T Tx (Philips healthcare, Holland) and a dedicated coil for the spine.

2. Physics and Methods

Each patient had undergone one of the tests under investigation on the lumbar sagittal plane. Chemical shift, selective fat-suppression, is the most commonly used fat-suppression technique. The chemical shift, which defines the resonance frequency of the quantum, is different for each material and is proportional to the main magnetic field. It is used as a method of selectively saturating only a specific material by narrowing the band of high-frequency pulses. The representative method is the CHESS technique using a spoiler gradient. The difference between water and fat is 3.3 ppm at 1.5 T, and this difference can be obtained by separating the signals of water and fat using an RF pulse. However, the chemical shift requires an accurate flip angle and is affected by the uniformity of the magnetic field[6,7]. The mDixon T2 test by W. Thomas Dixon, developed the chemical shift technique further. It produces fat only, and water only, images by post-processing, opposed-phase and in-phase data, using the chemical shift of water and fat. The in-phase image is obtained by adding the water and fat images, and the opposed-phase image is obtained by suppressing the fat image from the water image. Using this method, a fat only image can be obtained by suppressing the opposed-phase image from the in-phase image, and a water only image by adding the opposed image to the in-phase image[8,9,10]. The short-tau inversion recovery (STIR) technique, which is based on the inversion recovery technique, provides a 180 degree inversion pulse, waits for it to relax to equilibrium, and adjusts the inversion time so that the longitudinal magnetization of the tissue becomes zero. Thus, T1 can remove the signal at the null point of two different tissues. The STIR technique has the effect of increasing the T1-T2 contrast while removing the fat signal. Compared to the chemical shift method, STIR has the advantage of not being sensitive to B0 magnetic field non-uniformity and B1 non-uniformity when an adiabatic reversing pulse is used. The limitation of STIR is low SNR and long scan time which may decrease the efficiency of the inversion pulse[11]. The spectral pre-saturation with inversion-recovery (SPIR) technique is a combination of the chemical shift-based CHESS technique and IR. The fat-suppressed image can be acquired at the null point by adding an inversion pulse and spreading the signals of water and fat with the spoiler gradient. The advantage of SPIR is that it only selects local signals; thus, it has a higher SNR than STIR. The disadvantage of SPIR is that it is sensitive to the strength of the magnetic field and requires accurate separation of water and fat. As a result, the test time is longer than that of other examination techniques[12]. During the mDixon T2, T2 TSE, and T2 SPIR tests, factors affecting SNR, TR, TE, TSE, FOV, matrix, thickness, and NSA, were fixed as shown in Table 1, and scan times were compared. As for the scanned images, the signal intensity was measured by setting a circular ROI of 20 mm² for the L3 body region, back fat area, spinal cord, and CSF in the horizontal baseline of the third lumbar vertebra of each patient.

Table 1. mDixon, T2 TSE, T2 SPIR Parameter

Sequence	mDixon	T2 TSE	T2 SPIR
Field of view		280	
TR/TE (ms)		2800/120	
Scan time (s)	115	60	60
S/T (mm)		4	
ACQ Voxel size (mm)		0.76 × 1.37 × 4	
REC Voxel size (mm)		0.55 × 0.55 × 4	
Orientation		Sagittal	
TSE Factor		32	
NSA		1	

3. Data Analysis

SNR was obtained from L3 body, back fat, CSF, and Spinal code, respectively. CNR was calculated between L3 body and back fat, and between CSF and Spinal code. Each of the SNR and CNR values was analyzed through the paired sample t-test (SPSS win 18.0), and a value of 0.05 or less was considered statistically significant. SNR and CNR were calculated as follows:

$$SNR = \frac{Mean\,of\,ROI}{SD\,of\,background\,noise} \quad (1)$$

ROI : Region of interest
SD : Standard deviation

$$CNR = \frac{Mean\,of\,ROI - Mean\,of\,Background}{Background\,noise\,SD} \quad (2)$$

ROI : Region of interest
SD : Standard deviation

III. RESULT

The scan time was 115 seconds for mDixon T2, 60 seconds for T2 TSE, and 60 seconds for T2 SPIR. In the mDixon T2 images, SNR was higher in the L3 body areas than in the T2 TSE images ($p<0.05$), SNR was lower in the back fat and CSF images ($p<0.05$), and there was no difference in SNR in the spinal cord images ($p>0.05$). The CNR of the L3 and back fat areas was high in the mDixon T2 images ($p<0.05$), and the CNR of the CSF and the spinal cord was high in the T2 TSE images ($p<0.05$) [Fig. 1, Table.2].

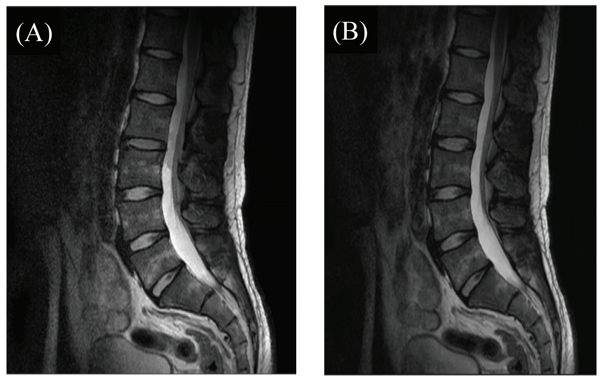

Fig. 1. (A) mDixon, (B) T2 TSE Image.

Table 2. Quantitative Evaluation of mDixon T2, T2 TSE

	mDixon T2	T2 TSE	p
L3 body SNR	44.27±16.36	40.84±17.99	.000
Back fat SNR	63.92±19.03	78.41±21.68	.000
CSF SNR	260.04±101.12	296.77±133.39	.000
Spinal cord SNR	106.93±55.71	109.89±68.36	.564
L3 Body-Fat CNR	-19.65±31.71	-37.56±32.19	.000
CSF-Cord CNR	153.10±52.36	186.88±76.62	.000

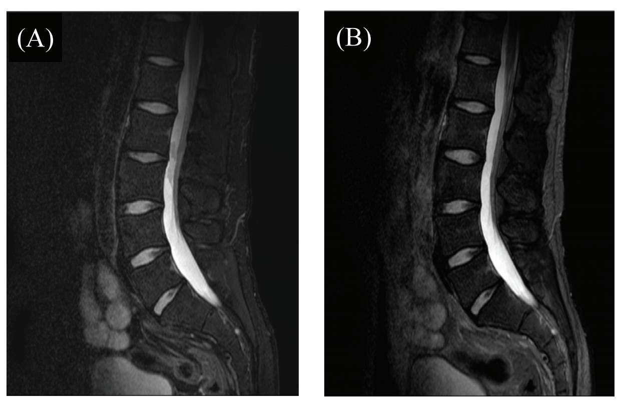

Fig. 2. (A) mDixon T2 FS, (B) T2 SPIR.

Table 3. Quantitative Evaluation of mDixon T2 FS, T2 SPIR

	mDixon T2 FS	T2 SPIR	p
L3 body SNR	11.53±4.37	14.90±7.30	.015
Back fat SNR	4.94±1.57	20.94±8.64	.000
CSF SNR	978.93±331.00	832.18±357.82	.016
Spinal cord SNR	373.07±134.27	272.38±92.06	.000
L3 Body-Fat CNR	6.59±4.75	-6.04±12.16	.000
CSF-Cord CNR	605.85±234.03	559.79±301.70	.257

The mDixon T2 FS produced lower quality images than the T2 SPIR for the L3 body and back fat areas ($p<0.05$), and higher quality images for the spinal cord and CSF ($p<0.05$). The mDixon T2 FS images produced a high CNR of the L3 body and the back fat areas ($p<0.05$). The CNR of the CSF and spinal cord did not differ between the two types of imaging ($p>0.05$) [Fig. 2, Table.3].

IV. DISCUSSION

In MRI, fat-suppression techniques are used to observe a lesion by removing fat signals when the lesion of the overlapping tissue is not visible due to the signals from the fat tissues[13]. SPIR and mDixon T2 techniques are representative fat-suppression techniques. The SPIR technique combines the CHESS technique using chemical shift, with the STIR technique obtained at the null point after inverting the fat component with RF pulses. The mDixon T2method of acquiring data from the water and fat suppressed images uses an algorithm that adds and subtracts signals, both from when the water and fat signals are in-phase, and from when they are in the opposed-phase[14]. This method is known to provide a uniform image in a fat suppressed image and can reduce artifacts caused by metal objects. According to Kishida's study, the mDixon T2 technique is beneficial for patients with metal implants, spinal tumors, and fractures than SPAIR[15]. However, there are insufficient studies comparing the advantages of mDixon T2 with those of other techniques. According to the results obtained in this study, the scan times of mDixon T2 were not lesser than those of the alternative techniques focusing on the spinal cord and CSF. The SNR was higher in the L3 body area of the mDixon T2 images than that in the T2 TSE images. The SNR was lower in the back fat areas and in the CSF, and the SNR in the spinal cord was comparable to that of the other techniques. The CNR of the L3 body and back fat areas was higher in the mDixon T2 images, and the CNR of the CSF and spinal cords was higher in the T2 TSE images. The mDixon T2 FS images of the L3 body and back fat areas was lower in quality than the T2 SPIR images, but superior in images of the spinal cord and CSF regions. The CNR of L3 body and back fat areas was higher in the mDixon T2 FS images, however the CNR of the CSF and spinal cord revealed no differences between the two images. In terms of the scan time of the lumbar sagittal MRI of LBP patients using the mDixon T2 method was 60 sec and 55 sec, which was similar to the T2 TSE and T2 SPIR test times of 60 seconds. The results of T2 TSE and T2 SPIR techniques were better for the CNR of back fat and CSF images. This challenges the view that the mDixon T2 test takes longer than other test methods but obtains higher quality data. The T2 TSE and T2 SPIR tests showed better results in CNR depending on the test site. However, the SPIR using the CHESS technique gave rise to magnetic susceptibility artifacts due to the air layer, a chronic problem of the CHESS technique[16]. The mDixon T2 technique was superior when the fat-suppression technique was applied, in that it reduced magnetic susceptibility artifacts in the examination of bones and the torso when metal implants were present. From this point of view, it is suggested that imaging tests be chosen according to the context for which they are required. The T2 TSE and T2 SPIR techniques are most useful in the examination of back fat and CSF. The mDixon T2 test is more appropriate for investigations of the bones and torso. However, in this study, these tests were performed under controlled conditions. These may differ from the actual clinical situation. Hence, further studies in less-controlled, clinical scenarios are warranted.

V. CONCLUSION

A comparison of the fat-suppression techniques of mDixon, mDixon T2, T2 TSE and T2 SPIR imaging tests showed no significant difference in scan times. The differences in the SNR and CNR of the images were also not significant. Therefore, the appropriate test technique should be selected in accordance with the area to be examined. Since the study was conducted under controlled conditions, additional studies using uncontrolled clinical protocols are required to confirm these findings. It is believed that the results of this study will serve as basically data for future works.

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요추 시상면 자기공명 영상검사에서 mDixon과 T2 TSE, T2 SPIR 영상의 비교 연구

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요 약

본 연구에서는 mDixon 기법과 T2 TSE, T2 SPIR 기법을 비교하여 3번 허리뼈 체부, 등 지방, 척수, 뇌척수액 위치에서 검사 시간, 신호대잡음비, 대조도대잡음비의 차이를 알아보고자 하였다. 성인 30명을 대상으로 신호대잡음비에 영향 인자를 고정하고 요추 시상면을 mDixon검사와 T2 TSE, T2 SPIR 검사를 한 후 비교하였다. mDixon의 검사 시간은 115초, T2 TSE는 60초, T2 SPIR는 60초였다. mDixon T2영상은 T2 TSE 영상보다 3번 허리뼈 체부에서 신호대잡음비가 높았고, 등 지방과 뇌척수액에서는 SNR이 낮았으며($p<0.05$), 척수에서는 비슷한 신호대잡음비을 가졌다($p>0.05$). 3번 허리뼈 체부와 등 지방의 대조도대잡음비는 mDixon T2영상이 높았으며, 뇌척수액과 척수의 대조도대잡음비는 T2 TSE가 높았다($p<0.05$). mDixon T2 FS영상은 T2 SPIR영상보다 3번 허리뼈 체부, 등 지방에서 낮았고, 척수, 뇌척수액에서는 높았다($p<0.05$). 3번 허리뼈 체부와 등 지방의 대조도대잡음비는 mDixon T2 FS영상이 높았으며($p<0.05$), 뇌척수액과 척수의 대조도대잡음비는 두 영상이 차이가 없었다($p>0.05$). mDixon 기법이 기존의 T2 TSE, T2 SPIR 기법에 비해 검사 시간, 각 부위의 신호대잡음비, 대조도대잡음비에서 보다 우수한 영상이라 하기 어려웠다. 하지만 본 연구는 단순 요추통증환자를 대상으로 제한하였다는 한계로, 기존의 연구에서 보고된 금속물 삽입, 척추 종양, 골절 환자 등 특정 환자군의 설정을 통한 추가 연구들이 필요할 것으로 사료된다.

중심 단어: MRI, Fat saturation, mDixon

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