^{1}H MR Spectroscopy of the Normal Human Brains: Comparison between Signa and Echospeed 1.5 T system

**Young Hye Kang, M.D., Myung Kwan Lim, M.D., Yoon Mi Lee, M.D. ,
Sun Won Park, M.D, Chang Hae Suh, M.D.**

Purpose : To evaluate the usefulness and reproducibility of ^{1}H MRS in different 1.5 T MR machines with different coils to compare the SNR, scan time and the spectral patterns in different brain regions in normal volunteers.

Materials and Methods : Localized ^{1}H MR spectroscopy (^{1}H MRS) was performed in a total of 10 normal volunteers (age; 20-45 years) with spectral parameters adjusted by the autoprescan routine (PROBE package). In all volunteers, MRS was performed in a three times using conventional MRS (Signa Horizon) with 1 channel coil and upgraded MRS (Echospeed plus with EXCITE) with both 1 channel and 8 channel coil. Using these three different machines and coils, SNRs of the spectra in both phantom and volunteers and (pre)scan time of MRS were compared. Two regions of the human brain (basal ganglia and deep white matter) were examined and relative metabolite ratios (NAA/Cr, Cho/Cr, and mI/Cr ratios) were measured in all volunteers. For all spectra, a STEAM localization sequence with three-pulse CHESS H_2O suppression was used, with the following acquisition parameters: TR = 3.0/2.0 sec, TE = 30 msec, TM = 13.7 msec, SW = 2500 Hz, SI = 2048 pts, AVG = 64/128, and NEX = 2/8 (Signa/Echospeed).

Results : The SNR was about over 30% higher in Echospeed machine and time for prescan and scan was almost same in different machines and coils. Reliable spectra were obtained on both MRS systems and there were no significant differences in spectral patterns and relative metabolite ratios in two brain regions ($p > 0.05$).

Conclusion : Both conventional and new MRI systems are highly reliable and reproducible for ^{1}H MR spectroscopic examinations in human brains and there are no significant differences in applications for ^{1}H MRS between two different MRI systems.

Index words : Magnetic resonance (MR), spectroscopy
Brain, MR

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[1]Department of Radiology, Inha University Hospital College of Medicine

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Address reprint requests to : Myung Kwan Lim, M.D., Department of Radiology, Inha University Hospital
7-206, 3rd st, Shinheung-Dong, Choong-Gu, Incheon 400-103, Korea.
Tel. 82-32-890-2769 Fax. 82-32-890-2743

Single-voxel ^{1}H MR spectroscopy (^{1}H-MRS) has been developed as a noninvasive method for biochemical information. ^{1}H-MRS can detect alteration in brain metabolism not only in patients with abnormal MR imaging findings such as brain tumors, abscesses, and white matter diseases but also with normal or indistinct MR imaging findings which might be in early or subclinical state for MR imaging changes such as hepatic encephalopathy, systemic lupus erythematosus and after cardiac transplantation, etc (1-17, 23, 24).

Despite its usefulness, ^{1}H-MRS application is still limited by the technical difficulties, lack of reproducibility, length of time required for data acquisition. After single-voxel Proton Brain Exam (PROBE/SV; General Electric Medical Systems, Milwaukee, Wis, USA) permits automated shimming, water suppression, and data processing, on-line spectrum display, and it markedly decreased length of time and increased reproducibility of the data acquisition (18, 19). Until now, the analyses in main metabolites on ^{1}H-MRS were usually made by semi-quantitative method with measuring relative metabolite ratios and they are different in various brain regions and in various ages of the patients. Therefore, the normal peak values in different region and ages are important as a reference data for evaluation of intracranial diseases.

Recently, we have upgraded 1.5 T MR machine from Signa Horizon to Echospeed plus with Excite and almost all hardware and software were changed. New MR machine could be more conveniently applied in brain MR imaging and new MR techniques such as perfusion image and diffusion tensor image could be possible. In application of ^{1}H MRS, high signal to noise ratio (SNR) and short prescan and scan time would be expected. The purpose of this study was to evaluate the reliability and reproducibility of ^{1}H MRS in new 1.5 T MR machine using various coils to compare the SNR, scam time and the spectral patterns with conventional 1.5 T MR machine in different brain regions in normal volunteers.

Materials and Methods

In 10 normal volunteers aged 20-45 years, we performed ^{1}H MR spectroscopic examinations with spectral parameters adjusted by the auto-prescan routine (PROBE package). In all volunteers, MRS was performed in a three times using conventional MRS (Signa Horizon) with 1 channel head coil and upgraded MRS (Echospeed plus with EXCITE) with both 1 channel quadrature head coil and 8 channel neurovascular coil with 1 receiver. In 5 volunteers, MRS was performed in Signa machine followed by Echospeed machine, and vice versa in the other 5 volunteers. Two regions of the human brain, which were basal ganglia and deep white matter, were examined in all volunteers. The selection of voxel size and position was determined by examining the MR images in the sagittal and axial planes. Voxel size was approximately 8 cm^3 ($2\times2\times2$ cm), voxels were chosen mainly from axial planes, and to avoid tissue contamination from adjacent structures and to keep the technique consistent, all were positioned by an experienced neuroradiologist. Restricting the edge of voxels to positions approximately 5-10 mm from the skull prevented contamination of the spectra by strong signals from scalp fat, which can mask lactate resonance.

MR imaging and PROBE/SV examinations were performed with two different 1.5 T whole-body MR system (Signa Horizon and Echospeed plus with EXCITE; General Electric Medical Systems, Milwaukee, Wis) equipped with active shielded gradients operating with head and neurovascular coils. Before spectroscopy, we obtained conventional MR images using spin-echo T1-weighted axial and sagittal images (TR/TE:484/8-9 msec; NEX:2; matrix size:256 (192; slice thickness: 7 mm; interslice gap: 0 mm) and T2-weighted images (TR/TE: 4000/98; NEX:2; matrix size:256(256; slice thickness:7 mm; interslice gap:0 mm). In no case was contrast enhancement performed.

For all spectra, STEAM (Stimulated Echo Acquisition Method) localization sequence with three-pulse CHESS(Chemical shift selective) H_2O suppression was used with the following acquisition parameters: TR = 3.0 sec, TE = 30 msec, TM = 13.7msec, SW = 2500 Hz, SI = 2048 pts, AVG = 64, and NEX = 2 in Signa and TR = 2.0 sec, TE = 30 msec, TM = 13.7 msec, SW = 2500 Hz, SI = 2048 pts, AVG = 128, and NEX = 8 in Echospeed. The TR, AVG and NEX were different in two machine, as GE company originally recommended. The post-processing was carried out at a SUN SPARC 20 workstation with Spectral analysis/General electric

(SA/GE) software incorporated with low frequency filtering of residual water signal removal, apodization by 0.5 Hz of exponential line broadening, zerofilling of 8 k, FT, and lorenzian to gaussian transformation.

Using these three different machines and coils, SNRs of the spectra and prescan and examination time of MRS were compared. SNR was measured by following equation; SNR = signal intensity/standard deviation of noise. Signal intensities were measured in creatine peak with constant peak width at 3.02 ppm and noises were measured in insignificant peaks at 0-0.5 ppm with same peak width with creatine peaks in both in vitro phantom study and in vivo normal volunteer studies. In all spectra, major brain metabolites, which were N-acetyl aspartate (NAA), creatine (Cr), choline compounds (Cho), and myo-inositol (mI) were measured. Regional differences in relative metabolite ratios to Cr (NAA/Cr, Cho/Cr, and mI/Cr ratios) between different machines and coils were analyzed, using Wilcoxon' s rank sum test.

Results

In all volunteers, successful and reliable spectra were obtained in both basal ganglia and deep white matter using different 1.5 T MR machines and 1- and 8-channenl coils.

Reliable spectra were obtained on both conventional and upgrade MRS systems in both basal ganglia and deep white matters.

The SNRs in Echospeed machine were higher about over 30% than those in Signa machine in both phantom and volunteers studies.

Scan Time was 4 minutes and 42 seconds for ^{1}H MRS in Signa machine and 5 minutes and 4 seconds in Echospeed machines. There were no differences of the scan time between 1- and 8-channel coils. However, the time for prescan was about 1 minutes in Signa and 10-20 seconds in Echospeed machine and total scan time was almost the same with each other.

The predominant signals were N-acetylaspartate (NAA) at 2.02 ppm, creatine and phosphocreatine (Cr) at 3.04 ppm, choline (Cho) at 3.21 ppm, and myo-inositol (mI) at 3.56 ppm (Fig 1). The values of NAA/Cr, Cho/Cr and mI/Cr ratios at various brain sites of the normal volunteers were clearly demonstrated. Although SNRs were higher in Echospeed machine than those of Signa Horizon machine, the relative metabolite ratios were not significantly different between them ($p > 0.05$) (Table 1 and Fig. 2). The spectral patterns in both machines and coils were not significantly different.

Discussion

In our study, reliable and successful ^{1}H MRS data could be obtained using different 1.5 T MR machines and different coils in all volunteers, and the relative metabolite ratios in two different regions were not statistically different among them.

After rapid development in ^{1}H MRS, functional and metabolic information about various human brain diseases can now be obtained non-invasively and without the use of ionizing radiation (20). Unfortunately, however, conventional MR spectroscopy examinations are time consuming and operator dependent and involve fairly complex manual post-processing work (18, 19). Using automated (pre)-

Table 1. Relative metabolite ratios with different MR machines and coils. There were no statistical differences of relative metabolite ratios between Signa and Echospeed MR machines and different coils in two brain regions ($p > 0.05$).

		NAA/Cr	Cho/Cr	mI/Cr
BG	Signa 1 channel	1.25±0.21	0.80±0.16	0.55±0.19
	Echospeed 1 channel	1.27±0.12	0.79±0.11	0.50±0.07
	Echospeed 8 channel	1.43±0.22	0.73±0.07	0.47±0.06
DWM	Signa	1.58±0.18	0.87±0.16	0.61±0.09
	Echospeed 1 channel	1.74±0.17	0.95±0.14	0.64±0.10
	Echospeed 8 channel	1.70±0.49	0.83±0.12	0.54±0.17

BG: basal ganglia, DWM: deep white matter, NAA: N-acetylaspartate, Cr: creatine/phosphocreatine, Cho: choline compounds, mI: myo-inositol

scan method, Proton Brain Exam (PROBE), acquisition parameters can be adjusted in 2-5 minutes, including the adjustment of the offsets of x, y, and z shim coils, transmitter radio-frequency (RF) powers, receiver gains, on-resonance frequency, and RF powers used for suppression of the water signal. In addition, automated ^{1}H MRS can immediately post-process data, and displays the crude spectrum on the monitor screen straight after acquisition (25).

Upgraded 1.5 T MR machine, Echospeed plus EXCITE have strong and large hardware and software. The CPU and hard disk in main computer were upgraded, Gradient system and radiofrequency and receiver systems were upgraded and digitalized. New scan parameters were also possible, that is, decreased minimal repetition time and echo time and increased matrix size, etc. It would increase examination speed, increase contrast resolution and increased SNR more than 30%. New MR techniques were also possible with new machine, which included perfusion image, diffusion tensor image, apparent diffusion coefficient (ADC) map image, and single- and multi-voxel ^{1}H MRS. Receive coils with multi-channel were available in new MR machine and they could provide high resolution MR images and decreased scan time.

The reliability and reproducibility on ^{1}H MRS using multi-channel coils, however, were not well established until now, it should be important to examine MRS with new machine and coils and to compare them with those of conventional MR system. Recently, subtle changes of the metabolites in various cerebral diseases could reflect early neuropsychiatric symptoms,

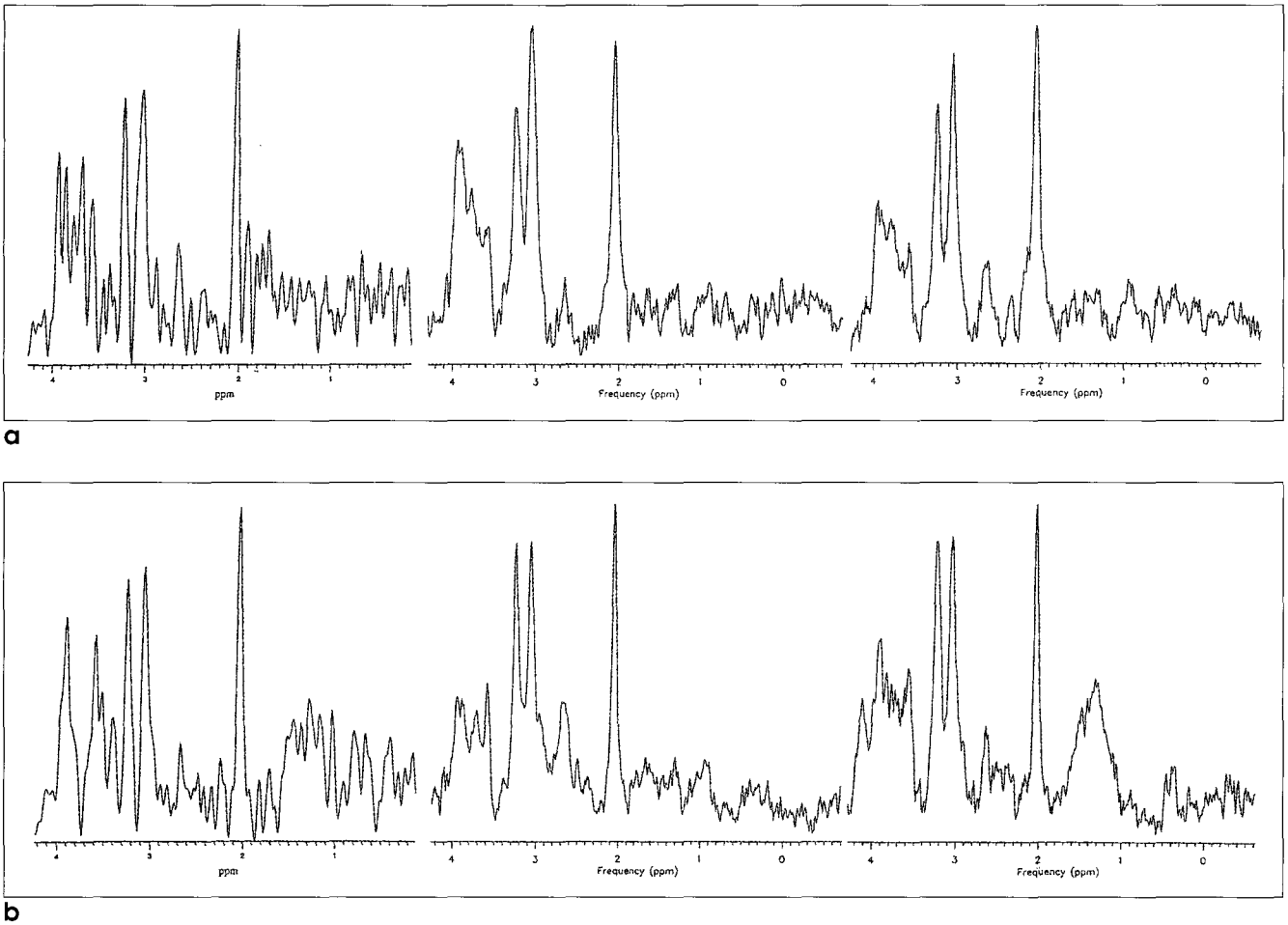

Fig. 1. ^{1}H MR spectroscopy in 29 year-old man with conventional MR machine (Signa Horizon) with 1 channel coil (1) and upgraded MR machine (Echospeed plus with EXCITE) with both 1 channel (2) and 8 channel coils (3). There are no significant differences of the spectral patterns in the various sites of the brain among them.
a) basal ganglia **b**) deep white matter
NAA: N-acetylaspartate, Cr: creatine / phosphocreatine, Cho: choline compounds, mI:myo-inositol

especially in patients with no change was found in MR imagings, the precise normal metabolite ratios in various cerebral regions and ages were very important. Therefore, relative metabolite ratios in this study in addition to success rate and SNR could be the basic reference data for further application of the MRS to various cerebral diseases.

Proton Brain Exam (PROBE) package is new program for totally automatic acquisition of data and dramatic improvement of temporal resolution could be obtained with it (2). Using PROBE/SV, acquisition parameters can be adjusted in 2-5 minutes, including the adjustment of the offsets of x, y, and z shim coils, transmitter radio-frequency (RF) powers, receiver gains, on-resonance frequency, and RF powers used for suppression of the water signal. In addition, automated ^{1}H MRS can obtain immediately post-process data, and display the crude spectrum on the monitor screen straight after acquisition (25). In our study, reliable and reproducible ^{1}H MRS findings could be obtained in all volunteers using PROBE package with different MR machines, it would be reliable and convenient method for further application of ^{1}H MRS study.

Because it allows for short TE acquisition at the price of a lower signal-to noise ratio, only STEAM pulse sequence were used in our study. ^{1}H MR spectroscopy using PRESS (Point Resolved Spectroscopy) at long echo times (135 and 270 msec) allows the detection of only four types of metabolite: choline compounds, creatine/ phosphocreatine, N-acetylaspartate, and lactate (2, 21). In contrast, using a short echo time (20–30 msec), other resonance peaks such as myo-inositol, glycine, glutamine/glutamate, macromolecules, and lipids can be distinguished (2, 22). When examining abnormalities of the human brain such as tumors and cerebral infarctions, we may be seeking not only the four major metabolites with a long echo time, but also others; if so, a short echo time should be applied. However, PRESS has higher SNR than STEAM and consequently application in small voxel size is possible. Moreover, it is reported that PRESS method at short echo time was possible, further ^{1}H MRS studies in

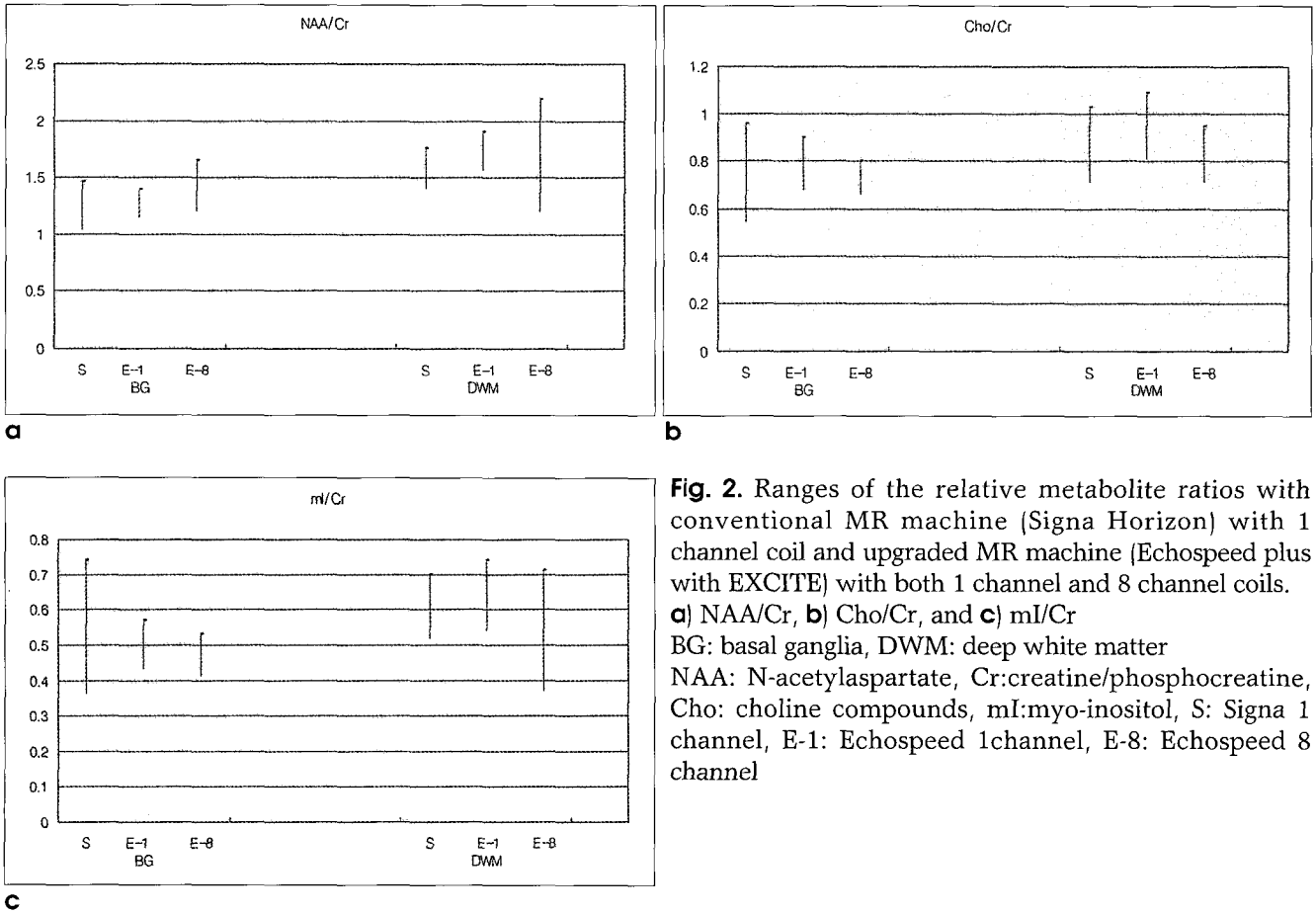

Fig. 2. Ranges of the relative metabolite ratios with conventional MR machine (Signa Horizon) with 1 channel coil and upgraded MR machine (Echospeed plus with EXCITE) with both 1 channel and 8 channel coils.
a) NAA/Cr, **b**) Cho/Cr, and **c**) mI/Cr
BG: basal ganglia, DWM: deep white matter
NAA: N-acetylaspartate, Cr:creatine/phosphocreatine, Cho: choline compounds, mI:myo-inositol, S: Signa 1 channel, E-1: Echospeed 1channel, E-8: Echospeed 8 channel

fields of cerebral regions with PRESS methods would be necessary.

NAA is understood to be a neuronal marker, and a decrease in NAA is due to loss of neurons or neuronal activity as a result of myelin breakdown. Cho appears to contain contributions from phosphorylcholine and glycerophosphorylcholine, which are precursors to cell membrane and the breakdown products of cell membrane, especially the myelin sheath, respectively. An increased Cho signal is thought to be a tumor marker or an indicator of active demyelination. Cr appears to be a phosphate reservoir that is related to cell and energy metabolism and regarded as reference metabolite because it has been assumed to be constant in healthy adults. As a carbohydrate metabolic intermediary as a precursor of compounds in intracellular signaling pathways, as a constituent of membrane phosphatidylinositol and as an osmoregulator, mI peaks are thought to play central role in the brain (7, 8, 16).

In conclusion, new MRI systems are highly reliable and reproducible for ^{1}H MR spectroscopic examinations in human brains and with some differences in SNR and scan time, the spectral patterns and relative metabolite ratios were not significantly different between two different MRI systems.

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정상 뇌의 수소 자기공명분광 소견: 1.5T Signa와 Echospeed 자기공명영상기기에서의 비교

[1]인하대학교 의과대학 진단방사선과학 교실

강영혜 · 임명관 · 이윤미 · 박선원 · 서창해

목적: 정상인 뇌에서 측정한 신호대잡음비율, 주사 시간, 그리고 대사물질의 상대 비율을 이용하여 서로 다른 1.5T 자기공명영상기기에서의 수소자기공명분광법의 유용성과 차이점을 알아 보고자 하였다.

대상 및 방법: 총 10명의 정상인 (20-45세)에서 PROBE (PROton Brain Exam) 라는 자동화된 방법을 이용하여 수소 자기공명분광술을 시행하였다. 수소 자기공명분광술은 1 channel 코일의 기존의 자기공명영상기기(Signa Horizon)와 1 channel 및8 channel 코일을 이용한 다른 자기공명영상기기(Echospeed plus with EXCITE)에서 3번씩 시행하였다. 각각 방법에서 팬톰과 생체에서의 스펙트럼의 신호 대 잡음비와 주사 시간을 측정하였다. 모든 정상인에서 뇌의 2 부분, 즉 기저핵과 심부백질 부위를 위의 방법으로 각각 검사하였고 각 부위에서 대사물질의 상대적인 비율의 차이(NAA/Cr, Cho/Cr, mI/Cr)를 측정하였다. 모든 스펙트럼에서 STEAM(Stimulated Echo Acquisition Method) 방법을 이용하여 다음과 같은 조절치로 검사하였다: TR=3.0/2.0 sec, TE=30 msec, TM=13.7 msec, SW=2500 Hz, SI=2048 pts, AVG=64/128, NEX=2/8 (Signa/Echospeed).

결과: 신호대잡음비율은 Echo speed 기계에서 약 30%이상 더 높았고 주사 시간은 거의 같았다. 각각의 방법에서 모두에서 믿을만한 스펙트럼을 얻었고 정상 뇌의 2부분에서 얻은 스펙트럼 모양과 대사물질의 상대적인 비율의 차이는 서로 의미있는 차이를 보이지 않았다 ($p > 0.05$).

결론: 새로운 자기공명영상기기와 코일을 이용한 수소자기공명분광소견은 매우 믿을만 하였고 높은 신뢰성과 재현도를 보였으며 기존의 자기공명영상기기의 수소자기공명분광소견과 의미있는 차이는 없었다.

통신저자 : 임명관, (400-711) 인천시 중구 신흥동3가 7-206
Tel. (032) 890-2769 Fax. (032) 890-2743