行政院國家科學委員會專題研究計畫成果報告

超快速成像技術於一般磁振造影系統之研發 (3/3)

Ultrafast imaging techniques on conventional MRI systems (3/3)

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一、中文摘要

本計畫之目的在於比較兩種超快速磁振造影技術，在評估懷孕第二與第三期胎兒腦部發育之情形。我們以 1.5 Tesla 磁振造影儀之 HASTE （目前世界胎兒磁振造影之公認標準技術）及 trueFISP 技術，在共計六位不經麻醉或鎮靜控制的胎兒中樞神經系統中，比較其發育評估之優劣性。發育部分包括白質之髓鞘化、神經遷移、大腦皮質縐折化等均由具有經驗之神經放射科醫師予以辨認。另外，影像之診斷價值則納入模糊程度之考量。實際實驗結果發現，trueFISP 之射頻能量吸收率，在相同影像參數之下，僅約為 HASTE 技術的三分之一。懷孕第三期所見之白質髓鞘化，在 trueFISP 中較能清晰辨認；HASTE 則因白質髓鞘化導致 T2 縮短所引起之 point-spread-function-related 模糊現象，使影像品質略遜於 trueFISP。懷孕第二期則因白質尚未髓鞘化，而使兩技術在影像品質上大致相當。我們因而相信在胎兒磁振造影中，trueFISP 具有比 HASTE 更為安全且能提供高品質影像的優勢，因而可加以取代。

關鍵詞：胎兒、中樞神經系統、超快速磁振造影、脈衝序列、白質髓鞘化

Abstract

The purpose of this project is to compare two fast T2-weighted MR (magnetic resonance) imaging techniques, trueFISP and HASTE, in the evaluation of normal fetal brain maturation during the second and third trimesters of gestation. The central nervous system of six normal fetuses were examined using both techniques without sedation on a 1.5 Tesla MR system. Cerebral developing events, including white matter myelination, neuronal migration, and cortical sulcation were identified. Image quality was graded according to undesirable blurring effects. Specific absorption rate was consistently lower for trueFISP than for HASTE by a factor of three at equivalent imaging conditions. Cerebral white matter myelination that begins at the third trimester was better delineated with trueFISP than with HASTE due to point-spread-function-related blurring effects inherent in HASTE, which hampered visualization of short-T2 structures. In the second trimester when myelination of cerebrum has not commenced, both techniques provide comparable image quality. Early brain stem myelination during the second trimester was better identified with trueFISP compared to HASTE. With superior image quality and lower RF absorption than HASTE, trueFISP is considered a safe and effective alternative to the HASTE sequence in the evaluation of fetal brain.

Keywords: fetus, central nervous system, ultrafast magnetic resonance imaging, pulse sequences, myelination

二、計畫緣由與目的

Magnetic resonance imaging is now considered as an important adjunct to ultrasonography (US) in the evaluation of fetal central nervous system (CNS) abnormalities. Fetal motion, however, had been a major problem necessitating sedation of mother or fetus to obtain high-quality MR images. Fast scanning is therefore a necessary prerequisite for obtaining fetal MR images of diagnostic quality. Due to the sudden death of Dr. Hong N. Yeung, the most important Principal Investigator in our PPG, a rigorous integration of the entire PPG seemed to be difficult. We therefore decided to switch our project direction during this fiscal year toward the theory/applications of some other ultra-fast imaging sequences, fetal MRI in the CNS being our target. The T2-weighted HASTE technique, allowing a scan time of 430 ms to 2 sec, has recently been reported to overcome the scan-time problem in fetal MRI. The CNS anatomy was clearly depicted in fetuses during the third trimester (1-2). The objective of this research, on the other hand, is to compare another option of fast MR imaging sequence, trueFISP, with HASTE in the evaluation of fetal CNS. A theoretical computation of trueFISP contrast is also provided.

HASTE is a single-shot turbo spin-echo (TSE) sequence. With total scan time on the order of a second and TE less than 100 msec, the continuous T2 decaying would cause inevitable point-spread-function blurring (3) detrimental for delineating short-T2 tissues. TrueFISP (4), on the other hand, employs steady-state acquisition which affords equal k-space weighting. Its rapid scanning advantage with high SNR is comparable to HASTE while the use of gradient-echo significantly lowers RF absorption. With automatic shimming achievable nowadays, images acquired with TR of 4-6 msec exhibit no field-heterogeneity artifacts in the spherical shape uterus absent of air cavities. TrueFISP thus seems to be a promising tool for fetal MRI. The remaining question is then whether the inherent T2/T1 weighting of trueFISP could provide sufficient contrast for depiction of fetal CNS.

We examined CNS of six fetuses between 22 and 36 weeks of gestation using both T2 HASTE (TE=64, 130^0 refocusing pulses, 240x256, 1 sec scan) and trueFISP (TR/TE=4.8/2.3, 70^0 excitation pulses, 240x256, 1 sec scan) on a 1.5 Tesla MRI system (Siemens Magnetom Vision plus, Erlangen, Germany). No breath hold of the mothers was utilized. The specific RF absorption rate (SAR) was monitored for both sequences. T1 and T2 relaxation times in the fetal brain were estimated using double contrast turbo spin-echo (TSE) with different TR for a calculation of trueFISP contrast (4) in the fetal brain.

三、結果與討論

In both HASTE and trueFISP images the fetal brains were clearly visualized. The T1 and T2 in the unmyelinated immature white matter were found to be 2500+/-600 & 400+/-100 msec, respectively. Note that since the scan time of the TSE sequence was about 20 second, involuntary fetal motion has significantly downgraded the image quality. The T1 and T2 values given in this report are therefore rough estimates only and subject to inaccuracy due to motion artifacts. Adult white matter with myelination had T1/T2 of about 1200/100 (4). These values altogether predicted that myelination could lead to 50% decrease in trueFISP signal at 70^0 flip angle compared with unmyelinated parenchyma (Fig.1). The calculation was consistent with image findings (Fig.2) where the myelination in the peri-Rolandic gyri is clearly depicted in the trueFISP image of a fetus during the third trimester of gestation. By contrast, visualization of mylelination in T2 HASTE image was hurdled by blurring. Figure 3 shows the comparison of two sequences on a fetus at the second trimester of gestation, where white-matter myelination has not commenced. The image quality was

found to be comparable, due to lack of T2 shortening for myelination which causes point-spread-function (PSF) blurring in the single-shot HASTE sequence. Monitoring of RF absorption showed trueFISP to be lower in SAR than HASTE by a factor of three, consistent with our expectation of the difference in RF flip angles. Furthermore, fat-water boundary was conspicuously delineated in trueFISP due to out-phase nature of the TE (2.3 msec) in gradient-echo images.

四、計畫成果自評

We conclude that trueFISP is a promising tool for visualizing fetal brain development. TrueFISP offered unique features of rapid scan, effectively freezing fetal motion, high SNR at short TR, high amniotic fluid signal outlining the fetus, and high T1/T2 contrast to visualize the myelination process. Compared with techniques based on single-shot turbo spin-echo such as HASTE, trueFISP provides high-quality images at a much lower SAR with no PSF blurring. Thus there is essentially no T2-imposed matrix-size limitation in trueFISP. This steady-state imaging technique should therefore be considered as a valuable alternative to the HASTE sequence in MRI evaluation of fetal CNS. Further studies on larger number of normal and abnormal fetal CNS are needed to substantiate the usefulness of trueFISP technique in clinical application.

五、參考文獻

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六、圖表

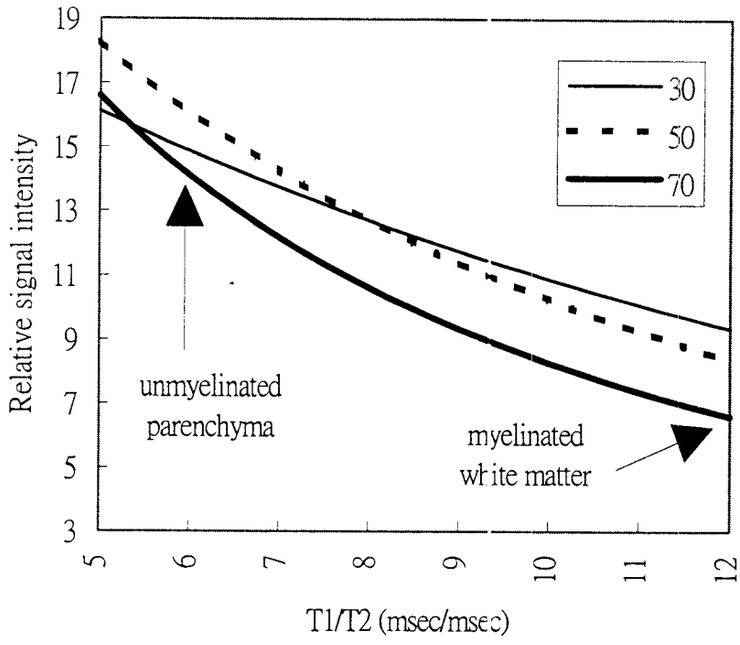

Figure 1. Prediction of signal change in trueFISP with progressing myelination at three flip angles showing the contrast achievable in the fetal brain.

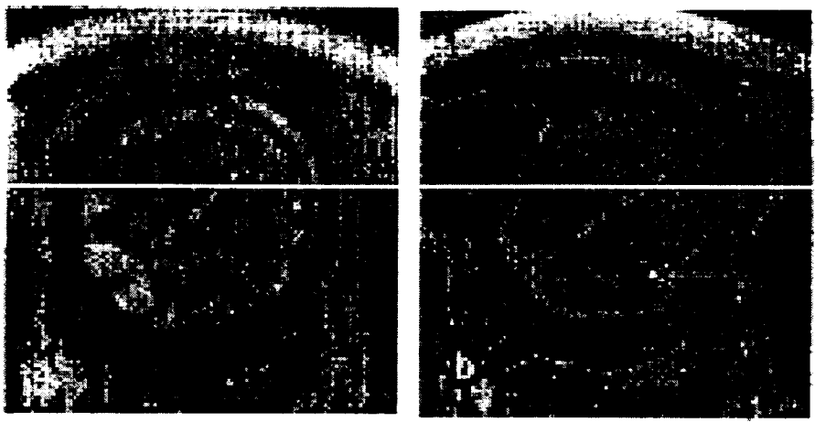

Figure 2. Fetal brain at the third trimester of gestation acquired with HASTE (a) and trueFISP (b) showing depiction of myelination (arrows). Point spread function blurring seen in HASTE was absent in trueFISP

Figure 3. Coronal images of another fetus at 22 weeks' gestation. Both HASTE (left) and trueFISP (right) appear comparable in imaging quality in the supratentorial anatomy depiction during the second trimester due to absence of white matter myelination.