High Field MRI Research Activities in Korea

Heung-Kyu Lee [a,b]

[a] SOL Technology Inc., 203 Neungpyung-ri, Gwangju-city, Gyunggi-do, 464-892, Korea, [b]Dept. of Biomedical Engi neering, Catholic University of Korea, 505 Banpo-dong, Seocho-gu, Seoul, 137-701 Korea

e-mail: heunglee@isoltech.co.kr

INTRODUCTION

During the last 25 years, we have witnessed so, rapidly changing evolution of MRI technology from the first primitive images in the laboratory to the so advanced anatomical, physiological, biochemical and brain functional images in the clinical applications. In this presentation, the technical progress of MRI over the last 25 years and the experiences of high field MRI in Korea will be reviewed.

Technical Progresses of MR Imaging

Physicists, F. Bloch and E. Purcell independently discovered the phenomenon of nuclear magnetic resonance(NMR) in 1946. Since then, their discovery has been converted into invaluable results in laboratories of physics and chemistry in both of academic and industrial realms. However, such a discovery could be intensively used in the medical applications only recently due to the engineering difficulties. In 1971, R. Damadian proposed NMR principle to the medical application and Dr. P. Lauterbur proposed the Zeugmatography, which provided the basic principle of MR imaging in the 3D spatial domain in 1973. Since then, the first image of human torso was demonstrated in 1977. In that period, there were only low field resistive MRIs from 0.1 to 0.15T mainly for the human brain imaging. In the early of 1980s, low and mid field superconducting MRIs were developed and installed at university hospitals for the better signal to noise ratio, which provides prettier quality images.

In the mid of 1980s, GE and Siemens introduced the 1.5T MRIs which gave rise to the debating issue of optimum magnetic field strength for the clinical imaging.

Although there were severe debates for the, so called, optimum magnetic field strength, owing to the technical refinements year by year, any of 0.5T. 1.0T and 1.5T MRIs could provide improved and acceptable clinical images at the 1 mm spatial resolution until 1990.

In the early of 1990, scientists in the academic realm introduced many ideas such as MR angiography, Diffusion/Perfusion, MR spectroscopy and even functional MRI mainly based on the 1.5T magnet.

Since that time, all those research ideas were refined and improved to expand the clinical uses and the patient populations. It should be noted that a couples of 4T magnets were already used as research systems to overcome the inherent limits of poor SNR at 1.5T for the advanced applications.

In late 1990s, scientists started to recognize that the existing 1.5T MRI may not be even enough for the advanced MRI researches and looked for another higher field magnets such as 3.0T, 4.0T and even higher 8.0T for the human whole body examinations. In September 1996, the FDA in USA finally approved the maximum field strength up to 4.0T. Since then, many vendors started to push the high field research MRIs into the fully commercial MRIs.

In parallel with the increasing magnet strength, the gradient coil and amplifier have been improved significantly and became the technical break through. In 1980s, the whole body gradient coils were winded discretely and a max. strength were less than 10mT/m with a rising times of 1ms.

In the early of 1990s, the gradient coils based on the distributed winding technique were proposed and it brought the technical break through for the MRI advanced applications. The new high performance gradient' coil provides the maximum gradient field strength as high as 40mT/m with the rise times as short as 150us nowadays.

With such a gradient performance break through comes many benefits such as higher resolution with a smaller FOV, thinner slice, faster spin echo images with the increased number of echo trains, even single shot EPI less than 100ms scan time which truly opened a unprecedented door to the clinical applications of fMRI, perfusion/diffusion physiological imaging and MR spectroscopy.

Proton spectroscopy of the human brain has advanced rapidly since early of 1990s and become reliable in vivo measurements. However, still many confusing and conflicting results are shown due to the difficulties of inherent low

sensitivity and complicated peaks within a narrow spectral bandwidth. Even the minimum voxel size of $(1.5cm)^3$ appears to be too large. The situation of other nuclei such as phosphorus spectroscopy is even worse.
Due to such an inherent limitation of sensitivity and a poor spectral resolution, scientists have tried to overcome such limitations by increasing the magnet field strength from 1.5T to 3.0T or 4.0T and even higher such as 7.0T and 8.0T at boutique sites in USA.
It is hoped that with such efforts with high field MRIs, the edge potential of MR spectroscopy can be assessed and proved to be a vital tool to detect the early change of bio-chemicals in the course of disease progress and monitor the response of new therapies in the clinical applications.

MR Research Activities in Korea

The experience of MRI in Korea for the medical imaging has started from 1980. One may claim the Korean MRI experience could be very close to those of worldwide MRI research communities.
With the co-operative research efforts of two groups, KAIST and LG, the first commercial 0.15T MRI was developed and installed at the local community hospital in 1984.
The continuing efforts had been made toward higher field MRIs such as 0.5T and 2.0T and those two MRIs were installed at the Seoul National University hospital in 1986. In spite of such a frontier achievement, the commercial MRI program was shutdown in 1990 due to the limited demands of MRI in Korea. In 1997, the same research group reinitiated the MRI program and commercialized the 1.0T MRI. In 1998, the first 3.0T MRI was developed and installed at the Catholic Medical School using a world first active shielded 3.0T magnet and the second 3.0T MRI was followed at the Brain Research Center of Korean Advanced Institutes of Science and Technology. Now, more than 10 research institutes are actively participated in the brain studies.

In conjunction with the high field fMRI, it is noted that the research of magnetic source imaging(MSI) has been also performed for the additional and supplemental biological information. The preoperative mapping of sensory-motor cortex in neurosurgical patients, the characterization and localization of epilepsy activity and the characterization of abnormal signals which are prominent in a wide range of neurological disorders are a few of them.

CONCLUSION

The advanced techniques with a higher magnetic field strength and a powerful gradient coil have the potential to extend dramatically the types of MR examination that can be performed in the MR scanner from anatomic images to those that include functional, biochemical and physiological images. In the presentation, the review of MRI progress during the last 25 years and the introduction of brain research activities including the acupuncture study with high field 3.0T MRI will be given.

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