Development of Portable MRI Systems for Biomedicine and Its Application to MR Microscopy of Biological Samples

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Introduction

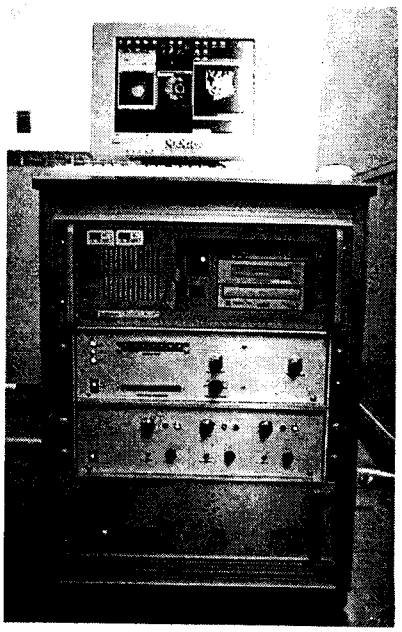
Up to now, about 15,000 clinical MRI systems have been shipped all over the world (about 3,500 MRI in our country). Most of them are whole body MRI because the WB-MRI has the evident advantage of flexibility or versatility. However, now not a few people are not satisfied with the present status of the commercialized WB-MRI.

To overcome this situation and optimize the system performance and cost, several special purpose or dedicated MRI, such as brain MRI, cardiac MRI, extremities MRI, infant MRI, have been developed. In the near future, even more various MRI will be developed and evaluated for medical and non-medical use. For this purpose, we have decided to develop a compact and portable MRI unit which contains essential parts of the electric subsystem of MRI, because any type of MRI can be constructed very quickly by combining it with a magnet, gradient coils, and RF coils.

Portable MRI Units

A typical MRI system can be divided into two subsystems: electric and magnetic subsystems. The magnetic subsystem should be designed for objects to be imaged, but the design of the electric subsystem can be common to all of the MRI systems, though the power units (RF transmitter and gradient drivers) should depend on the object size and property. We call the electric subsystem "MRI unit".

Figure 1 shows our standard portable MRI unit(total weight: ~80Kg, size: 54cm(W) x 77cm(H) x 60cm(D)) developed for many MRI applications. This unit consists of a TFT liquid crystal display, PC, RF modulator & detector, 3-channel gradient driver, and RF transmitter (top to bottom). All of the digital units are assembled in the PC: a commercial DSP board for the MRI pulse



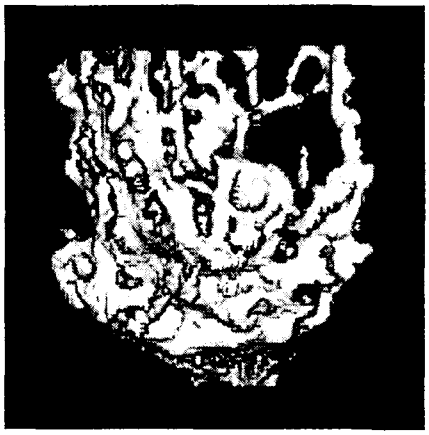
(Fig. 1)

programmer (100 ns time resolution) [1] and ADC board for the data acquisition system [2,3]. Another digital control unit has been developed using a note PC and a PC card to ISA bus extension box. Because the total weight of this unit is about 8 kg and small enough, a more compact system can be built. The RF transmitter and gradient drivers can be made much smaller for this unit.

Compact MRI Systems

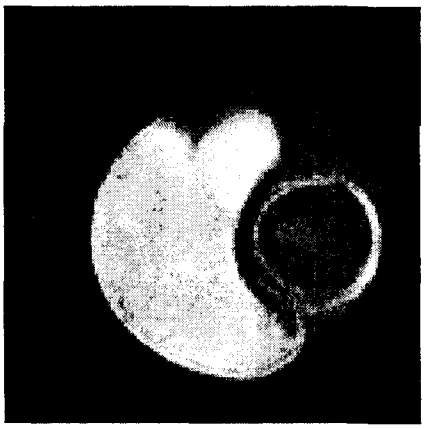
We have developed several compact or portable MRI systems using the MRI unit described above.

The first application is an add-on MR microscope using a magnetic field of a clinical WB-MRI in which the portable MRI unit is working independently of the clinical MRI [4]. By using this system, 2D images with 50 -100 microns square in-plane pixels (Fig.2: human appendix) and 3D images with 150 to 200 microns cube voxels (Fig.3: piece of human femur) were successfully obtained within a practical imaging time. The advantage of this system is that any types of a high field (1.0 - 1.5 T) WB-MRI can be quickly used for MR microscope without any change of hardware and software. In addition, the add-on MRI has possibilities with which various new experiments can be tried by using clinical MRI.



(Fig. 2)

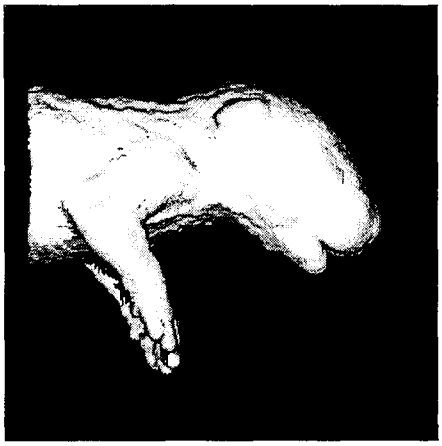
The second application is a compact MR microscope using a 1.0 T permanent magnet (magnetic material: Fe-Nd-B system, gap: 61 mm, homogeneity: 12 ppm over 20 mm dsv, magnet size: 62 cm (W) x 75 cm (H) x 75 cm (D), weight: 1,350 kg) which can be installed within a 1 m2 space [5]. The largest disadvantage of this type permanent magnet is the large temperature coefficient of the magnetic field (-0.1 %/degree, -40 kHz/degree for protons). However, the field-frequency relation has been successfully kept constant by using NMR lock utilizing a commercially available one board DDS synthesizer. Figures 4 and 5 show a 3D surface rendered image and a cross-sectional image of a fixed mouse acquired in 2 hours at the 200 microns cube voxel size.



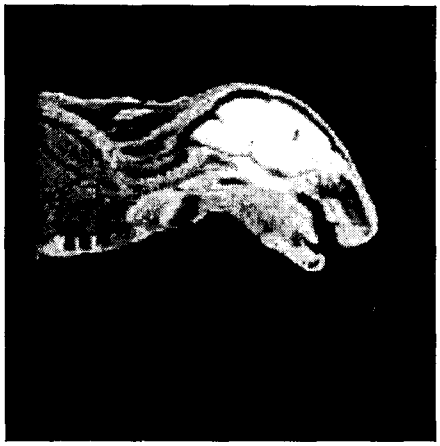
(Fig. 3)

At present, this magnet may be heavy for installation to a conventional room, but our collaborator (Sumitomo Special Metals Company) is now developing a more compact and lighter 1.0 T permanent magnet (magnet size: 36 cm (W) x 28 cm (H) x 32 cm (D), weight: 215 kg) with the same magnetic field profile as that of the present magnet. So this system

can be the real portable MR microscope.



(Fig. 4)



(Fig. 5)

Conclusion

We have developed two types of MR microscopes in a short time using the compact and portable MRI unit. We are now planning to develop several types of special purpose MRI for biomedical use by using the portable MRI unit. In this situation, the compact and portable MRI unit and compact permanent magnet are the key technologies. Many types of MRI will be constructed and evaluated within several years and I believe some of them will extend new possibilities of MRI.

References

1. Kose, T. Haishi, *Spatially Resolved Magnetic Resonance*, p.703-709, WILEY-VCH, 1998.
2. K. Kose, T. Haishi, A. Caprihan, E. Fukushima, JMR,**124**, 35-41 (1997).
3. T. Haishi and K. Kose, JMR, **134**, 138-141. (1998).
4. K. Kose, T. Haishi, N. Adachi, I. Anno, ISMRM abstract book, p.1924. 1998.
5. T. Haishi, Y. Matsuda, T. Uematsu, K. Kose, ISMRM abstract book, p.2035. 1999.