3D Isotropic Brain Imaging Using Wideband MRI

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Abstract

Using Wideband simultaneous multi-slab 3D MRI we have acquired a whole brain image with high isotropic spatial resolution of 0.78x0.78x0.78mm^3 in only 8m11s. Acquisition time is reduced by 75% compared to conventional 3D MRI with same imaging parameters. This exciting breakthrough has made high-resolution whole brain MR imaging possible to clinical applications; increasing the degree of detail in brain template construction and functional mapping.

Introduction

In wideband MRI, acceleration is accomplished by the extension of signal bandwidth during excitation as well as acquisition. Wideband multi slice/slab factor (*W*) is defined as the factor of by which the signal bandwidth is extended. This method has already been successfully used in 2D scan and easily double the acquisition speed using *W*=2. We are here to extend this bandwidth concept on 3D MRI. High isotropic resolution 3D whole brain MR imaging has always been an unreachable dream to practical applications. It takes almost an hour to obtain an isotropic sub-millimeter brain image even for the best commercial systems [2,3]. For example, to acquire an isotropic whole brain 3D image with image setting FOV=20cmx20cmx20cm, Matrix size=256x256, TR/TE=30/6.3(ms), isotropic resolution requires the number of encoding along slice direction to be 256. The scan time comes out as 33minutes, which is highly impractical. Not only the long scan time gives rise to the uneasiness of the subject, but also increases the risk of motion artifacts. With the introduction of multi-slab excitation used in Wideband 3D MRI, scan time can be reduced easily and dramatically.

Materials & Methods

How Wideband 3D MRI reduces scan time is illustrated in Fig.1. By dividing the large slab covering whole brain by Wideband multi-slice factor (*W*)= 4, the total coverage by a large slab becomes 4 smaller slabs with 1/4 thickness each. The number of slice encodings per slab is divided by 4 to maintain the same spatial resolution, thus decreasing the overall scan time. The 4 smaller slabs are excited simultaneously with a combination of cosine modulated sinc pulses. RF power has been carefully adjusted to remain same SNR and flip angle for each slab. A slab separation gradient is added during the readout to separate MR signal resonating from different slabs at the same time. In our study the whole brain image of a grown male is taken by a Bruker 3T Biospec system, with imaging parameters: FOV=20cmx20cmx20cm, total Matrix size=256x256x256, TR/TE=30/6.3ms. The 4 slabs were simultaneously excited by cosine-modulated sinc pulses that has a Wideband multi-slab factor *W*=4. The actual slice encoding number for 256 images using *W*=4 is 64.

Results

Total scan time of the isotropic 0.78mm head image took 30ms x 256 x 64*(W*=4*)* = 8min11s to complete, 4 times faster compared to 33min45sec using conventional 3D gradient echo. All 256 images possess SNR comparable to conventional 3D MRI by default settings. No visible artifacts or a distortion in the acquired images. The contrast between gray matter and white matter is clear and details such as blood vessels are shown. The change of brain shape is depicted in great detail due to the high isotropic spatial resolution. Several acquired images are shown in Fig. 2.

Conclusion

The multi-slab Wideband MRI worked perfectly with 3D acquisition sequence, the thin slices achieved by 3D MRI provided great image quality. Wideband multi-slab accelerating factor *W*=4 reduced the overall scan time from 32min45sec to 8min11sec. This result is not only an impact to human brain study, but an important breakthrough in clinical brain imaging. More brain precise diagnosis may be possible within reasonable scan time, avoiding the risk of motion artifacts. In this report we have only Wideband 3D MRI. The scan time can be further reduced 2 times with addition of parallel imaging methods. With the success of our present achievements, we are confident to cut the scan time of whole brain imaging with sub-millimeter isotropic high resolution image to fewer than 5 mins within the next few months.

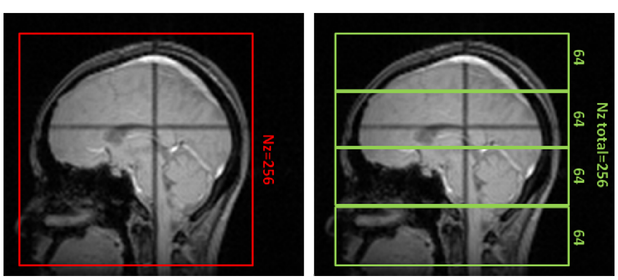

Fig.1 whole brain imaging schematics of conventional 3D MRI with thick slab and 256 steps of encoding (left) and *W*=4 Wideband 3D MRI with 4 thinner slabs and only 64 steps of encoding (right). Total scan time is 32min45sec v.s. 8min11sec, 4X acceleration.

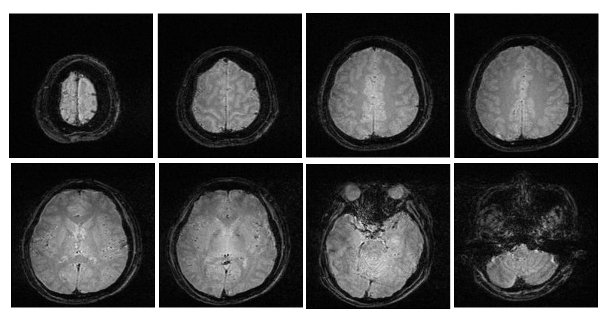

Fig.2 256x256 *W*=4 Wideband 3D MRI whole brain image of grown male. Isotropic resolution =0.78mm, the tissue contrast and details are clear. Slices thinner than1mm are rarely seen in whole brain imaging because of the long scan time using conventional methods.

References

[1] Ultra-fast Brain MR Imaging Using Simultaneous Multi-slice Acquisition Technique, Edzer L.Wu et. al.,Conf Proc IEEE Eng Med Biol Soc. 2007

[2] 3D MDEFT imaging of the human brain at 4.7 T with reduced sensitivity to radiofrequency inhomogeneity, David L. Thomas et. Al, Magn Reson Med. 2005 June; 53(6): 1452–1458.

[3] High resolution MRI of the brain at 4.7 Tesla using fast spin echo imaging, E De Vita, et. Al., British Journal of Radiology (2003) 76, 631-637