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The clinical results described in this paper are the experience of the authors.
Results may vary due to clinical setting, patient presentation and other factors.

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Multiband SPEEDER: Proven Reduction of Time on DTI and Multiple b Values

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High-end neuro work such as Diffusion Tensor Imaging (DTI) and Body imaging with multiple b-values can provide more detailed information for radiologists, such as diffusional anisotropy and tissue microstructure and integrity. These techniques come at a price like longer scan times. Longer scan times can increase issues such as patient discomfort, claustrophobia and motion. The application of Multiband SPEEDER (MB SPEEDER) is a proven technique that will reduce these scan times significantly by simultaneously acquiring multiple slices. This reduction in scan time can also achieve an increase in volume coverage and/or more diffusion directions. Thus, depending on the application, MB SPEEDER can be used to optimize these advanced imaging techniques to achieve better clinical diagnosis. This article introduces some possibilities to improve scan time and image quality of DTI, DWI, and multi-b diffusion scans in clinical practice.

Brief description of diffusion techniques

Diffusion Weighted Imaging (DWI), Echo Planar Imaging (EPI) scans with diffusion-sensitized gradients in the three directions are performed to estimate the trace of the diffusion tensor, which is average diffusivity. This technique detects water molecules in Brownian motion within the body. These images have proven to be very effective in diagnosing strokes in the brain.[1] DWI revolutionized the evaluation of patients with suspected stroke by providing exquisite sensitivity to the presence of brain infarction, virtually immediately after onset instead of several days later.[2]

Diffusion Tensor Imaging (DTI) is a variation of the diffusion method. DTI measures at least six different directions and visualizes the flow of water along the white matter tracts of the brain, and muscles including the heart and other nerves in such a way that requires no new equipment, contrast agents, or chemical tracer.[3] While DWI can be used to measure average diffusivity, DTI exploits the directional property of water flow in the white matter tracts that can provide useful biological information of the tissue's microstructure.

How Multiband works compared to conventional scanning with other time reduction techniques

By choosing more diffusion directions in DTI, the better biological detail of a tissue's microstructure can be utilized. However, for the price of more diffusion directions is longer scan times. MB SPEEDER offers the best ratio of time versus signal compared to other techniques of time reduction such as parallel imaging or compressed sensing because there is no additional under-sampling.

In conventional 2D acquisitions utilizing traditional parallel imaging such as SPEEDER, each slice is excited individually. The reconstruction unfolds the obtained

signal of that specific slice using a coil sensitivity map.[4] This process is repeated for all the slices until the full volume is obtained. For single-shot EPI used in DWI and DTI, the use of parallel imaging helps to reduce effective echo time (TE), which in turn leads to increased SNR and reduced distortion. However, parallel imaging does not result in overall scan time reduction because it only shortens the data acquisition duration but not effective repetition time (TR). Modest scan time reduction may be possible by optimizing your number of averages per b value, however this optimization can also be used in conjunction with Multiband.

When MB SPEEDER is activated the scanner will ***simultaneously*** excite two slices (i.e., MB factor of 2) within one TR using a multiband RF excitation pulse, thereby cutting the scan time in half. MB SPEEDER maintains image quality by simultaneously exciting slices that are furthest apart to mitigate cross-talk. An additional benefit of this slice order is that the coil sensitivity profiles will be most unique to aid in the sensitivity-based unfolding. During the MB-SPEEDER acquisition, the signals from multiple excited slices are superimposed and then separated and unfolded in a similar fashion to traditional SPEEDER reconstruction. The unfolding is done during the reconstruction process using the previously acquired coil sensitivity map. In summary, by implementing MB SPEEDER, scan time is halved by the simultaneous acquisition of two slices at one time—in the same amount of time traditional scanning would require for a single slice. In addition, MB SPEEDER does not suffer from the SNR reduction associated with traditional parallel imaging. The decreased scan time as well as higher SNR can be employed to increase the number of diffusion directions, b values, and/or volume coverage.

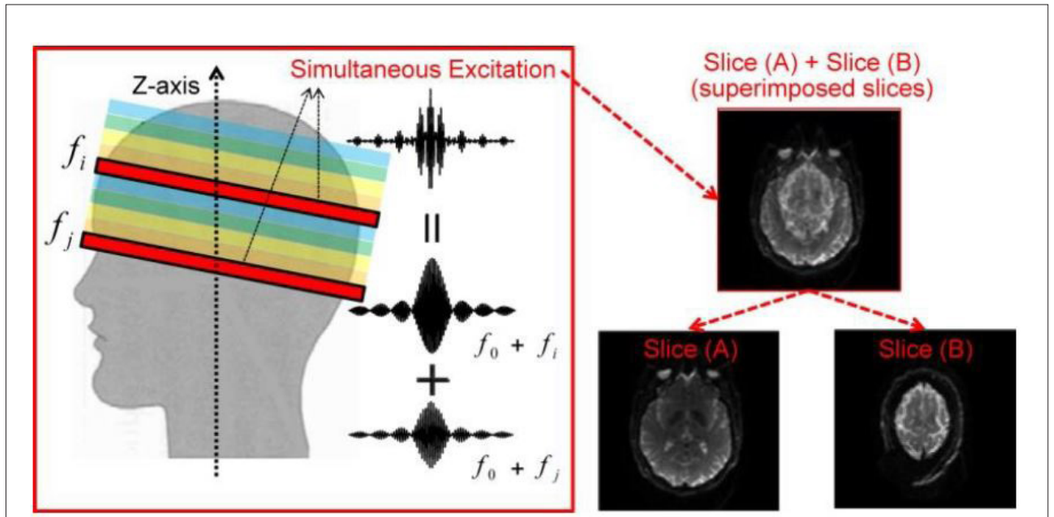


Figure 1 Illustrates how the simultaneous excitation occurs: the superimposition and separations of the slices

Recommendations for Multiband SPEEDER in the Brain

- Use the 32 channel head coil for better coil sensitivity
- Increasing the number of TE-echoes results in the following
  - Sharper images
  - Possible restrictions on the minimum TE, maximum number of slices, b-value, etc.
  - Deterioration of the SNR or increase of high-frequency N/2 artifacts
- Shimming is critical for the best image quality
- SPEEDER of 2 is recommended but a SPEEDER factor of 3 should reduce distortion, allows more slices and higher TR minimum to accomplish this
- Number of slices: it works best to have an odd number when the number of slices is divided in two
- Phase Encode Direction—The reverse direction of PE is recommended in order to weaken the eyeball distortion which is the cause of slice leakage artifacts. (i.e., AX/PA -> AX/AP) but this can cause midbrain distortion
- If the excited slices are too close together this could result in aliasing or slice bleed

Clinical Applications and Examples of Multiband SPEEDER

Brain

30 Directions

Figure 2 illustrates the long scan time due to an increased number of directions in DTI (bottom row). For the same number of directions, that scan time is cut in half with MB SPEEDER (top row). The parameters for all scans have remained the same—a FOV of 25x25 cm^2, 2.0x2.0 mm^2 and a NAQ of 1. While the image quality remains the same qualitatively, the time is reduced by around 50%.

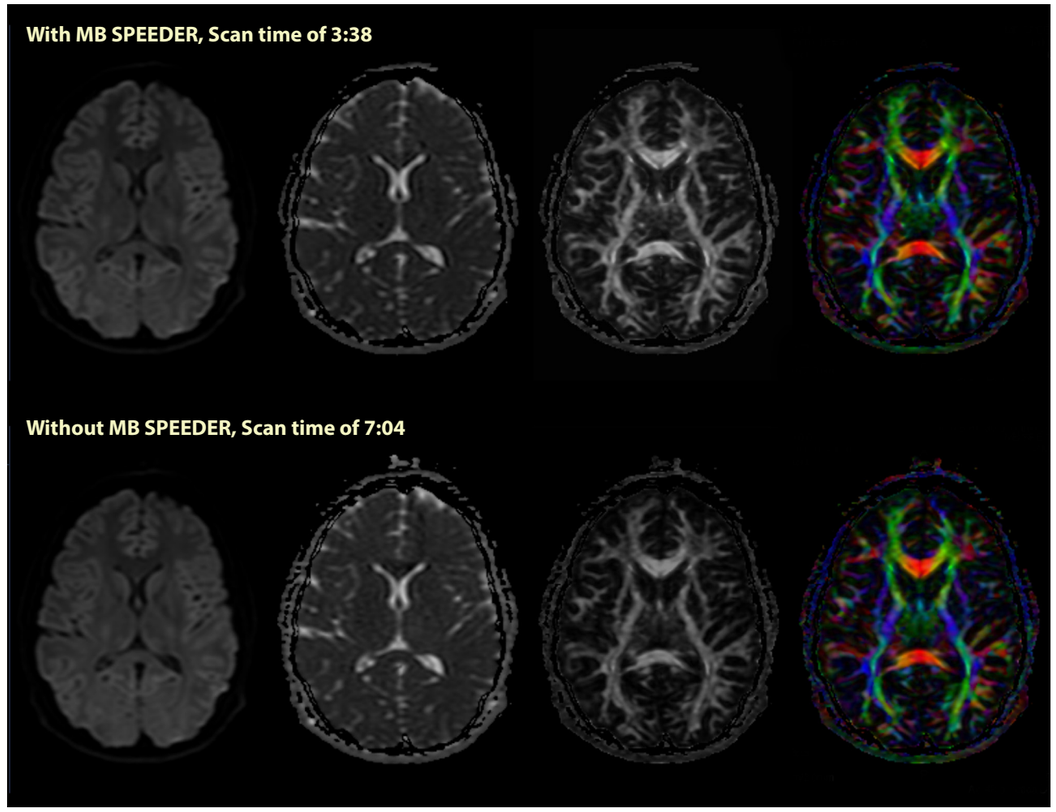


Figure 2 30 directions. Top row scan time of 3:38 with Multiband, bottom row scan time of 7:04 without Multiband.

48 Directions

When comparing figure 3 to figure 2, the parameters used are the same with an exception of the number of directions from 30 to 48. As expected, scan time increased significantly from seven minutes to almost eleven minutes when not using MB SPEEDER and when MB SPEEDER is employed, the scan time is reduced from eleven minutes to a little over five and a half minutes.

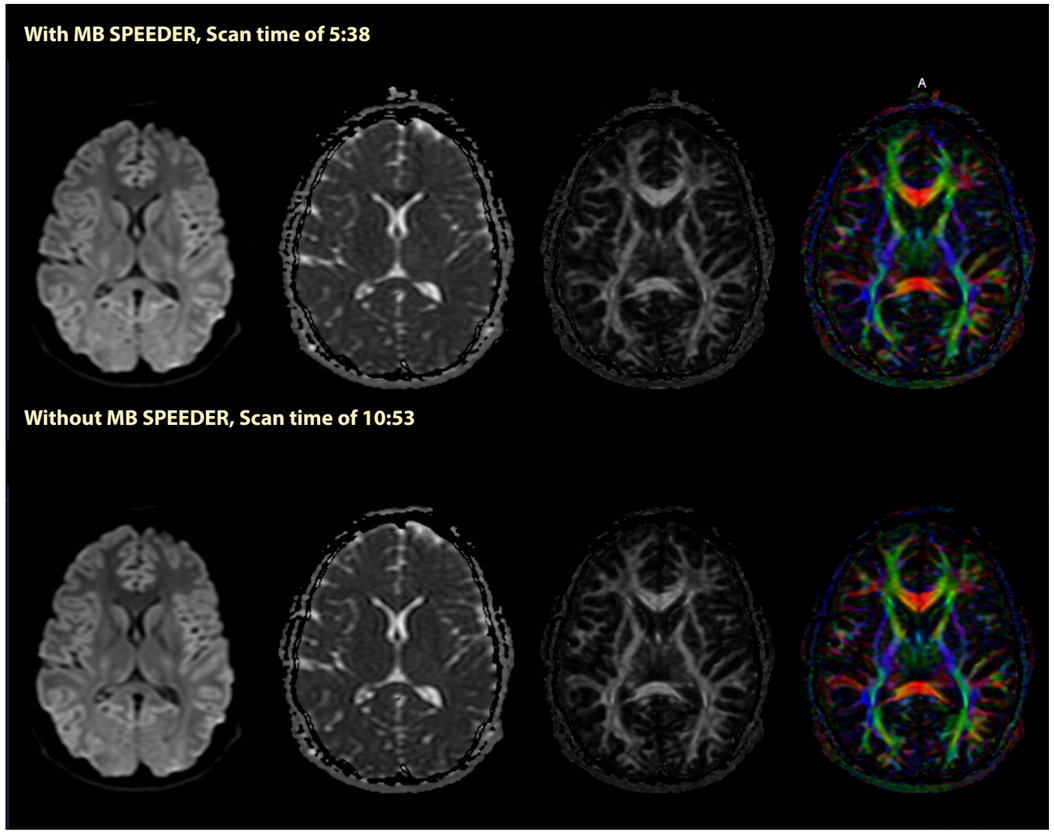
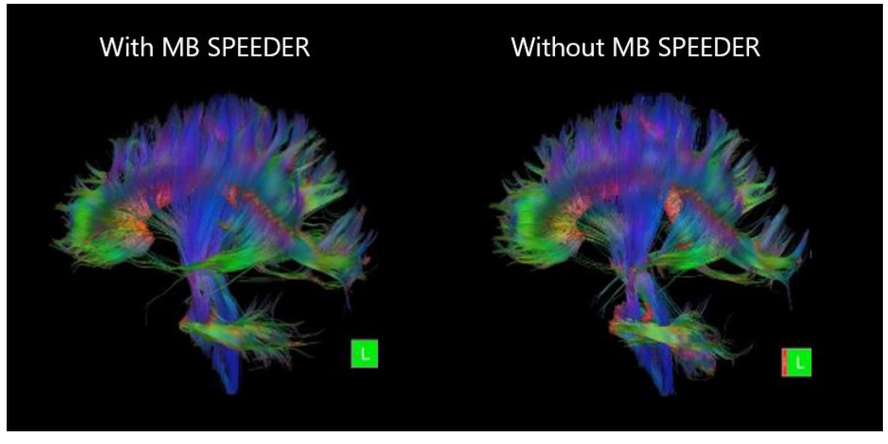


Figure 3 48 directions. Top row scan time of 5:38 with Multiband, bottom row scan time of 10:53 without Multiband

Figure 4
The image on the left is from 48 direction DTI with MB SPEEDER and the image on the right is 48 directions without MB Speeder.



Abdomen

Diffusion

Multiband can also be used to decrease the scan time in standard DWI. Figure 5 illustrates an example of scan time reduction in DWI in the liver. The left column demonstrates a typical DWI scan (without MB) with 4:48 mins scan time. On the right column the scan time is reduced to 2:36 mins using MB SPEEDER. This scan time reduction is achieved without any compromise in the image quality. Both scans have the same parameters, such as b-value = 800 (top row), FOV = 32x35 cm^2, and resolution = 1.4x1.4 mm^2. The Iso DWI and Iso ADC are shown in the middle and bottom rows, respectively.

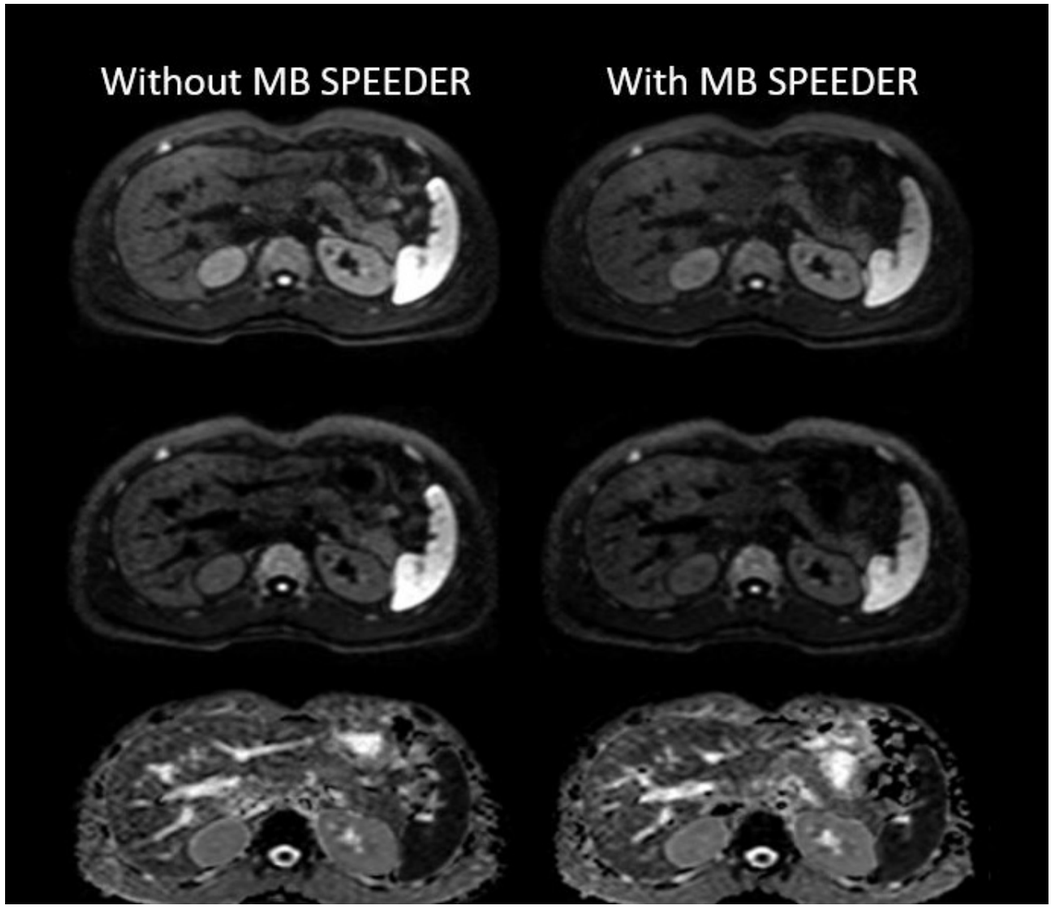


Figure 5 The left side is without Multiband and a scan time of 4:48, while the right side with Multiband shows a reduced scan time of 2:36.

Summary

The use of MB SPEEDER for DTI has shown its ability to greatly reduce scan time without degradation in image quality as other conventional time saving techniques. Alternately, this scan time reduction can be translated into increasing the number of diffusion directions in DTI, assisting more accurate visualization of white matter tracts. While there are exceptions and considerations to follow when using this technique, they are straightforward. These time reductions have made the use of DTI a more viable imaging option by giving doctors more opportunity for higher quality imaging or adding additional sequences for further diagnostic information within a given time frame.

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