Coronal whole body diffusion imaging with 2D spatially selective excitation (FOCUS)

Maggie M Fung[1], Lloyd Estkowski[2], Dan Xu[3], Suchandrima Banerjee[2], Pauline Worters[2], Gaohong Wu[4], John Skinner[4], and Ersin Bayram[5]
[1]Global MR Applications and Workflow, GE Healthcare, Jersey City, NJ, United States, [2]Global MR Applications and Workflow, GE Healthcare, Menlo Park, CA, United States, [3]Global MR Applications and Workflow, GE Healthcare, Waukesha, WI, United States, [4]MR Engineering, GE Healthcare, Waukesha, WI, United States, [5]Global MR Applications and Workflow, GE Healthcare, Houston, TX, United States

Target audience: Radiologists, Technologists, Physicists

Purpose:

Diffusion weighted whole body imaging (DWIBS) is being increasingly used for comprehensive tumor assessments in various malignant diseases[1]. Conventionally, DWIBS is acquired axially to reduce image distortion due to B0 inhomogeneity in the SI direction. However, axial DWI acquisition requires longer scan time, as compared to coronal acquisition, and also suffers from stair-steps artifact in the reformatted coronal view. Direct coronal DWI using higher acceleration factors (up to 5 fold) has recently been demonstrated[2] but SNR loss due to high acceleration factor may have an impact on image quality. Therefore, we propose an alternative method for coronal diffusion imaging using 2D spatially selective excitation (FOCUS)[3] that can reduce distortion even at a lower acceleration factor.

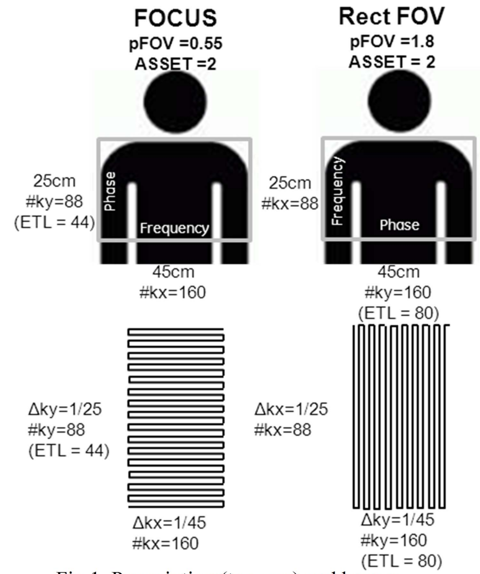

Fig 1. Prescription (top row) and kspace trajectory (bottom row) of a) rectangular FOV & b) reduced FOV FOCUS imaging.

Theory:

In coronal whole body DWI, the left-right(LR) FOV should span the width of the shoulders (~45cm) to enable lymph node visualization, and superior-inferior(SI) FOV is limited to ~25cm because of B0 field inhomogeneity; as a result, a rectangular FOV (LR>SI) is often prescribed. In this conventional rectangular FOV acquisition (Fig 1a), frequency direction must be in SI direction to avoid phase wrapping. And in order to maintain similar resolution in both phase & frequency direction, the number of phase encodes (ky) in LR is often much higher than that of frequency encodes (kx) in SI. Long echo train length (ETL) causes distortions due to phase accumulation of the off-resonance field. As a result, high acceleration factors (e.g. ASSET Acceleration factor (R) of 4 or more) are needed to reduce ETL and therefore reduce distortions.

In FOCUS DWI acquisition (Fig. 1b.), the 2D selective excitation pulse can excite a small extent in the phase encoding direction without giving rise to aliasing artifacts[3]. So phase encoding direction can be in SI when using the FOCUS technique[4]. Since SI coverage (~25cm) is usually much smaller than LR coverage (~45cm), the number of phase encodes/ETL can be much reduced, leading to less distortion even at moderate acceleration (e.g. R=2). Compared to conventional imaging, FOCUS DWI will employ higher number of frequency encodes in the LR direction, however, since the Δkx steps (equals to $1/FOV_{LR}$) are relatively smaller than Δky (equals to $1/FOV_{SI}$), the echo spacing is only slightly increased in the FOCUS acquisition (4µs increase in our study), and does not have a significant impact on distortion.

Methods:

Diffusion weighted imaging using 2D selective RF excitation (FOCUS) was performed on healthy volunteers on a GE 3T 70cm bore scanner (MR750w) using the Geometry Embracing Matrix (GEM) coil suite. Parameter optimization was performed to compare various acceleration factors, and the effect of dual vs. single spin echo on the appearance of distortion. We also compared the conventional rectangular FOV imaging with FOCUS imaging. The optimized FOCUS imaging parameters were used to perform 4-station imaging. Optimized FOCUS imaging parameters were: FOV: 45cm(LR)x25cm(SI), Matrix: 160x80, pFOV = 0.55, TR/TE:6300ms/80.8ms, dual spin echo, BW:250kHz, Slice thickness:12mm, # slices:16, STIR, TI=250ms, ASSET Acceleration factor R:2, b-value=50s/mm^2(3 nex), 500s/mm^2 (6 nex), diffusion encoding: ALL, scan time: 2:56min per station (5:20min for 3rd station with respiratory navigator). ASSET calibrations for each station were performed with an SI extend that matched with the reduced SI extend in FOCUS.

Results & Discussion:

Fig 2 shows a comparison of a) conventional rectangular FOV imaging and b) FOCUS imaging. Both are acquired with R of 2. Severe distortion is observed in conventional imaging in the phase direction (LR) due to long ETL while FOCUS imaging shows much less distortion. In the comparison of various R factors in FOCUS imaging, we found that R of 3 and above shows no significant changes in distortion, but suffer from SNR loss. This is due to the limited coil separation in the small SI coverage. Fig 3 shows a 4-station coronal DWI imaging using FOCUS with the optimized parameters described above. One drawback of this technique is that the number of interleaved slices acquired per "pass" or "TR" is limited to 16 due to the concern of partial saturation from the periodic side lobes of the 2D selective RF pulse. As a result, we have used thicker slices in this feasibility to cover the anatomy within one TR. Alternatively, separate passes can also be used to acquire the full AP coverage with thinner slices.

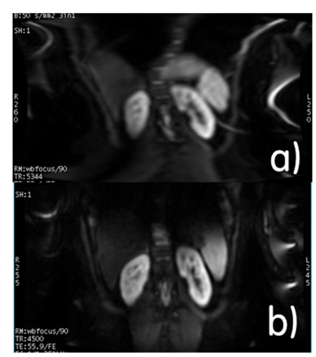

Fig 2. Severe distortion is observed in conventional rectangular FOV imaging (a) comparing to FOCUS imaging (b), both with R=2.

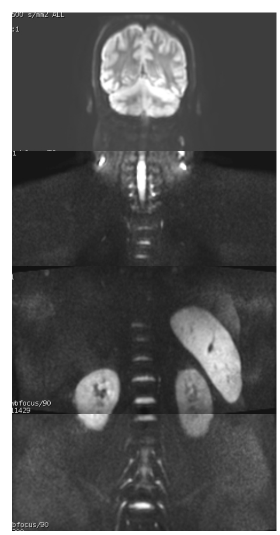

Fig 3. 4-Station FOCUS DWI (R=2, b=500)

Conclusion:

In this work, we demonstrated whole-body coronal DWI using FOCUS 2D selective excitation technique. This technique can reduce distortion caused by long ETL by switching the phase direction to the shorter dimension (SI) in the acquisition. This technique also reduces the reliance on high acceleration factors to reduce the ETL as described in other direct coronal DWI techniques and could be clinically viable at systems with lower channel count surface coils.

References: 1. T.Kwee et al, Eur Radiol 2008;18: 1937–1952, 2. T. Kwee, T. Takahara: SPR 2012. 3. Saritas E et al, MRM 2008; 60:468-73, 3. Saritas E et al, MRM 2008; 60:468-73 4. Karampinos DC et al, NMR in Biomedicine 26:630-637, 2013