Initial Experience with Isotropic 3D-FSE-XETA (eXtended Echo Train Acquisition) Imaging of the Cervical Spine

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Objective: Conventional imaging of the cervical spine typically includes multiple 2D fast spin echo (FSE) acquisitions in different orientations, as well as gradient echo axial images, with the latter chosen for the possibility of thin sections. The large number of separate acquisitions leads to prolonged imaging times, limitations in registration between the image sets, and motion artifacts. We propose an approach based on acquiring a single three dimensional isotropic fast spin-echo dataset of the cervical spine, with reformatting into axial and coronal projections.

Materials and Methods: We employed a new technique, 3D FSE XETA (eXtended Echo Train Acquisition) to obtain contiguous 1 mm sagittal images of the cervical spine with acquisition parameters that produced heavily T2-weighted contrast. XETA uses refocusing flip angle modulation to restrain blurring over very long readout trains (>100 echoes) [1], making 3D T2 weighted imaging possible with reasonable acquisition time.

For this project, we acquired contiguous 1mm sagittal images with timing parameters intended to reproduce the contrast characteristics conventional fast spin echo T2 weighting. Acquisitions were performed without and with peripheral pulse cardiac gating, using a 24 cm sagittal FOV, 384 frequency encodes and 256-384 phase encodes in the anterior-posterior direction and three averages. Echo train length (ETL) varied from 109-218, using either square or 50% rectangular fields of view. When rectangular FOVs were used, saturation bands using very selective saturation (VSS) pulses [2] were placed over the anatomy anterior to the relevant spinal anatomy to prevent aliasing artifacts. The effective TE's ranged from 80 to 120 ms and with peripheral gating of 3xRR, TR was approximately 3 s. There were 44 acquired 1 mm thick slices in each 3D volume and zero-fill interpolation yielded 88 slices with a reconstructed voxel size of $0.5x0.5x0.5mm^3$. The 3D-FSE-XETA data set was then reformatted into 1.5mm axial and 3 mm sagittal and coronal images for review. Images were compared to a conventional fast spin echo sagittal acquisition with TR/TE of 3 s/110 ms, FOV 24 cm, 384 frequency encodes, 224 phase encodes, 80 % rectangular FOV, ETL 19, BW ± 31.25 kHz, three averages and 3 mm section thickness. Since we employed parallel imaging, we could not meaningfully measure SNR in the conventional or XETA images. Experienced neuroradiologists subjectively assessed image quality for noise, sharpness, and contrast characteristics.

Results: Figure 1 shows a comparison of sagittal cervical spine images acquired with the standard FSE protocol and the high resolution XETA protocol. The contrast and spatial resolution of these images are strikingly similar. The rightmost images show axial reformats of the same data sets shown on the left. The XETA reformat is vastly superior due to the much lower slice thickness allowed by the XETA protocol.

The differences between the 3D-FSE-XETA and conventional 2D FSE images were obvious, and it was not possible to blind the radiologists to the image acquisition technique. Because fluid appears exceptionally bright, FSE-XETA acquisitions appeared to be more heavily T2-weighted than the conventional 2D-FSE acquisitions at the same nominal effective TE. Adjusting the TE to shorter values (80 msec) produced similar contrast characteristics to routine 2D fast spin-echo acquisitions. The acquired images displayed increased noise due to the thin sections. When reformatted to comparable section thickness, the apparent noise was similar to the 2D images. There was an increase in apparent edge enhancement at interfaces between CSF and short T2 structures such as ligaments and spinal cord, presumably due to the long echo train. The XETA images demonstrated less pulsation artifact, likely due to the long echo train and cardiac gating, but motion during acquisition presented as image blurring. While the square FOV images with higher echo train length exhibited some blurring, the rectangular field of view sets, obtained with a reduced echo train length, reduced blurring seen on the higher ETL images. Axial reformatted images were exquisite with clear demonstration of the nerve roots throughout their intradural course. Coronal images were most useful for analyzing alignment, articular pillars, and cervicocranial ligaments. Since the axial images were obtained by reformatting, cervical kyphosis was easily handled by changing the orientation of the reformatted images. Acquisition time was similar to a 2D run, but since thin-section XETA also produced axial images without further imaging, this strategy reduced overall imaging time.

CONCLUSION: 3D-FSE-XETA produces diagnostic quality sagittal images and outstanding axial and coronal reformats of arbitrary section thickness and obliquity without further acquisition, thus saving imaging time. Due to the isotropic acquisition, we retrospectively display images in any desired orientation without loss of quality, thus overcoming limitations of spinal deformities.

Reference: 1) Busse RF, MRM 2006, 55: 1030-1037. 2) Le Roux P, JMRI 1998 8:1022-32.