Target Audience
Scientists and clinicians interested in fast $T_2$ mapping.

Purpose
Fast spin-echo (FSE) can be used for fast and robust $T_2$ mapping, using either a variable TE spin-echo preparation or by acquiring multiple FSE images with different effective echo times. However, this approach is sensitive to $T_2$- and refocusing flip angle ($B_1$)-dependent image blurring and ghosting artifacts. $T_2$-dependent artifacts have been reduced using joint reconstruction of $T_2$ and equilibrium magnetization ($M_0$), and $B_1$ errors have been compensated in multiple spin-echo imaging by directly fitting echo signals with the extended phase graph (EPG) algorithm. This study combines these two approaches, resulting in a Cartesian FSE $T_2$ mapping protocol that jointly reconstructs artifact-free $T_2$, $M_0$, and flip angle maps.

Methods
Single-slice, 16-echo, 4-shot FSE acquisitions (64 x 64) from a phantom were acquired at 4.7T using 120° prescribed refocusing pulses and with a total of 8 different effective echo times varied according to three acquisition schemes: 1) changing echo number used to sample $k=0$, while minimizing amplitude modulation from line to line across k-space, 2) a multiple spin-echo preparation period, and 3) one which rotated the acquisition modulo the echo train length, to minimize covariance between $T_2$ and high spatial frequency information. Fourier-reconstructed magnitude images from the first two strategies were fitted to $B_1$, $T_2$, and $M_0$ maps using the EPG algorithm. Complex k-space data from the third strategy were Fourier transformed in the read-direction (columns), then jointly fitted row-by-row to $B_1$, $T_2$, and $M_0$ using the EPG algorithm and a least-squares cost function. An analytical expression for the signal’s Jacobian matrix was derived to expedite computation. This analysis was repeated using only 4 and 2 different effective echo times. In the latter case, $B_1$ was constrained to the prescribed value, as there were too few images to fit the third parameter.

Results
Figure 1 shows the three $T_2$ maps created using 4 effective echo times. The proposed method’s map (bottom) contains less artifact than that from the first strategy (top) and is sharper than that from the second strategy (middle) at the cost of increased noise. Similar results were garnered by using 8 images and 2 images, excepting systematic bias caused by the erroneous constraint of $B_1$.

Discussion & Conclusion
The proposed joint reconstruction generated $T_2$ maps that were sharpened relative to voxel-by-voxel fitted FSE data. In addition to using a fast pulse sequence, the joint reconstruction allowed for low-power RF pulses by directly accounting for stimulated echoes in the signal equation. This makes the technique an excellent candidate for clinical translation. Future studies include extending this to larger image matrix sizes, which will increase computation time and may affect computational stability.

References