

Epilepsy Imaging with Simultaneous Multi-Slice Turbo Spin Echo

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Background

In today's modern pediatric epilepsy protocols, high-resolution, T2-weighted (T2w) imaging plays a very important role in evaluating patients who present with epilepsy. At our institution, the use of 3T combined with high-density receive arrays has improved our diagnostic sensitivity and specificity for the detection of small cortically-based lesions.

Historically, 3D T1-weighted volume acquisitions such as MPRAGE have been integral in identifying small areas of cortical dysplasia. In previous iterations of epilepsy protocols, the T2-weighted imaging has been the Achilles heel of the examination due to inefficient use of the available TR and long scan times but with the increased signal-to-noise (SNR) ratios attributed to modern scanners, T2-weighted acquisitions are improving the diagnostic accuracy of scans.

The ability to reduce the sequence acquisition time has been the ultimate goal for pulse sequence developers since Hennig et al. [1] published their work on RARE imaging. As with most advances in pulse sequence development, clinicians are usually quite reserved in transitioning the current gold standard protocols due to the potential differences in signal intensity and tissue contrasts demonstrated by these acquisitions [2, 3].

The next advancement to significantly reduce T2w acquisition times were techniques proposed by Pruessmann [4, 5] and Griswold [6] using reconstruction algorithms that used

the unique properties coil array geometry to undersample data resulting in reduced scan times at the cost of a reduction in SNR.

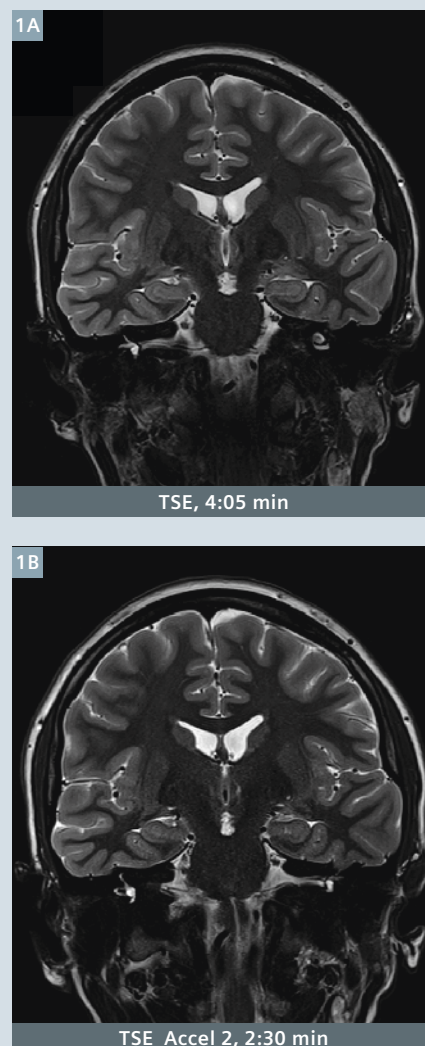
Several authors have proposed modifications to these techniques to reduce the amount of noise encoded

into the images and further reduce scan times, one of the most significant was Breuer [7] with the development of phase and slice-based acceleration – CAIPIRINHA.

Recently several authors [9-12] have proposed the implementation of

Case 1

Figure 1 demonstrates a coronal T2w slice orientated perpendicular to the hippocampus. This slice was chosen to demonstrate the capabilities of the sequence because of the complex anatomy and potential for artifacts originating from physiological sources. It demonstrates the image quality achievable using SMS TSE with a significant reduction in scan time. Importantly, when the images were de-identified, the only reliable factor used by the radiologist in identifying the gold standard TSE was the higher signal intensity of CSF. The reduction of CSF signal was attributed to saturation effects associated with the application of the SMS RF pulse. The overall impression was that the accelerated acquisition appeared slightly sharper and this was probably due to slightly altered noise level associated with parallel imaging reconstruction.



CAIPIRINHA based reconstruction methods into conventional turbo spin echo to accelerate T2w acquisitions without the SNR penalties associated with data undersampling reconstruction methods. The implementation of simultaneous multi-slice (SMS) sequences into routine imaging will enable a more efficient TR-to-slice ratio, the potential to use higher echo train lengths while staying within current SAR restrictions, and reduced scan times. More importantly, these techniques can help overcome some of the limitations of conventional parallel imaging techniques such as *g*-factor penalties and SNR loss with undersampling.

The cases presented here are our initial experience with SMS TSE¹ in clinical epilepsy cases. All acquisitions were anatomically matched to an equivalent standard T2w TSE acquired on a MAGNETOM Trio or MAGNETOM Verio 3T (with software version syngo MR B17) using the product 32-channel head coil. A whole-brain high-resolution T2 coronal with non-interpolated resolution of 0.5 x 0.6 x 2.5 mm³ was achieved in all acquisitions. All images were evaluated for signal-to-noise, contrast-to-noise, image sharpness, artifacts, reconstruction faults, diagnostic confidence and lesion detectability.

Conclusion

Our initial experience with SMS TSE with a slice acceleration factor of 2 in conjunction with in-plane parallel imaging acceleration factor of 2 is very encouraging, producing scans of a similarly high diagnostic quality when compared to our gold standard TSE (with in-plane parallel imaging acceleration factor of 2) in much shorter scan times. Modifications to the protocol have enabled our team to incorporate slice accelerated TSE into protocols developed for our pediatric² epilepsy program.

As with many variations to pulse sequences, our team had concerns

¹ The product is still under development and not commercially available yet. Its future availability cannot be ensured.

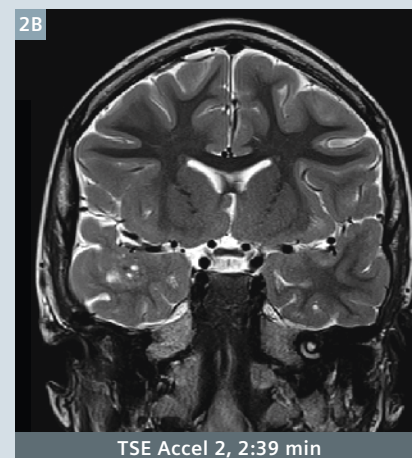
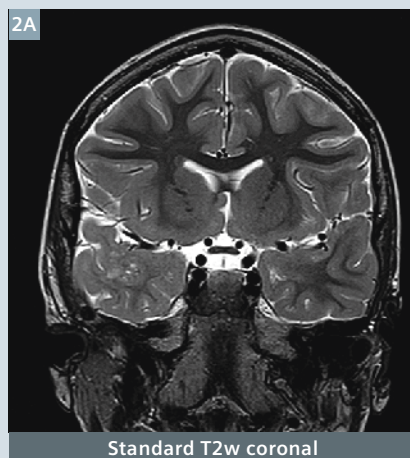
Case 2

10-year-old patient presented with seizures. Preliminary imaging demonstrated a dysembryoplastic neuroepithelial tumour (DNET) in the right anterior temporal lobe.

The images demonstrate a complex lesion involving the anterior component of the right temporal lobe.

Both sequences equally demonstrate the complex nature of the lesion including small cysts, calcification including blurring and loss of grey and white matter.

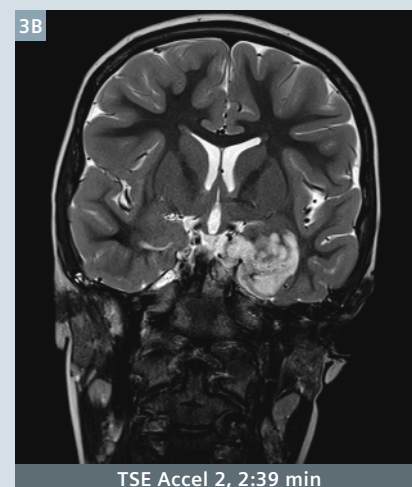
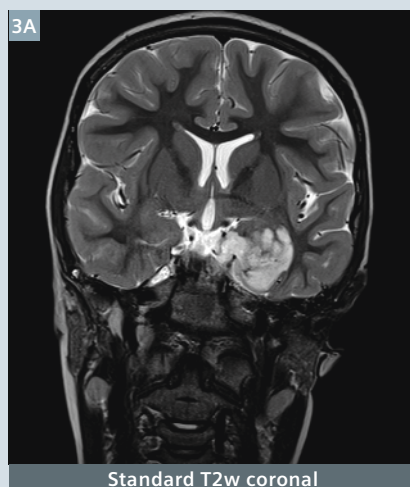
There is slight anatomical disparity with the comparative images as there was patient movement between the acquisitions.



Case 3

5-year-old patient presented to our Epilepsy unit with aphasia and seizures originating from left anterior temporal lobe. A comprehensive epilepsy protocol was undertaken including comparative TSE and SMS TSE high-resolution T2-weighted coronal images aligned perpendicular to the hippocampus.

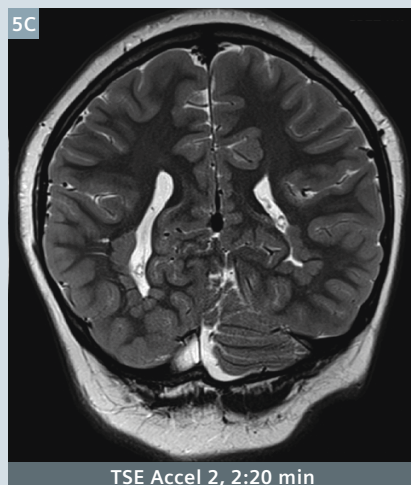
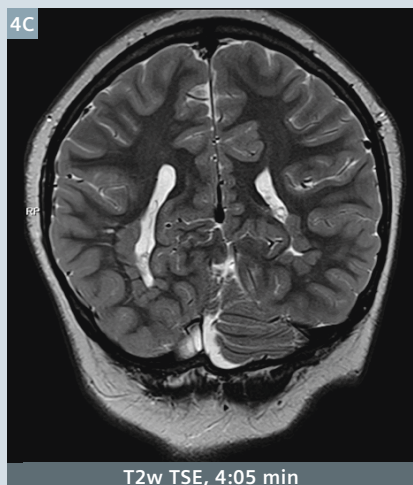
The images demonstrate a complex lesion adjacent to the left MCA involving the left anterior temporal lobe and amygdala. Based on the imaging characteristics, the lesion probably represents a dysembryoplastic neuroepithelial tumor (DNET).



Case 4

11-year-old with periventricular nodular heterotopia (PVNH) for further evaluation of the PVNH and to demonstrate any right occipital focal cortical dysplasia.

The images demonstrate a complex malformation of cortical development with clear delineation of multiple areas of PVNH and occipital polymicrogyria.



over a number of factors that would potentially impact on the diagnostic quality of the scans:

1. Sequence RF pulse techniques to reduce the SAR of the acquisition would influence image sharpness. The concern related to the implementation of low SAR VERSE pulses would increase echo-spacing has been unfounded and the general impression is that the accelerated T2 acquisitions appear sharper.
2. The reduction of CSF signal, potential loss of grey matter / white matter ratio and general SNR were highlighted as potential areas that would limit clinical integration. A number of scans on complex cerebral infections were undertaken to evaluate the diagnostic accuracy of the sequence and this comparison demonstrated equal diagnostic quality between the two sequences, with no significant difference in contrast to noise ratios in grey matter and white matter or CSF pulsation artifacts. The initial comments were that these concerns were similar to the transition from spin echo to TSE and then TSE with hyper-echo.
3. The acquisition and reconstruction strategy could invoke interslice leakage that could influence image quality. This has not been demonstrated to affect image quality as we expect a maximum leakage factor of less than 5%.
4. SMS TSE would have limited clinical utility due to SAR limitations. As with all MR sequences, there are numerous options to facilitate SAR management and we have obtained scans using low-SAR and normal RF pulses. The goal is to operate the system in normal operating mode and as such we tend to use low SAR RF pulses in the majority of cases.

² MR scanning has not been established as safe for imaging fetuses and infants under two years of age. The responsible physician must evaluate the benefit of the MRI examination in comparison to other imaging procedures.

The team has also started using the sequence in brain tumor imaging with very encouraging results. We have developed acquisition strategies to obtain high-resolution thin slice whole-brain coverage using acceleration factors of 3 in under 24 seconds for a limited clinical indication.

Acknowledgements

The authors wish to acknowledge the expertise of the Children's MRI Centre Staff, the assistance of Dr Simone Mandelstam for reviewing images, Dr Dingxin Wang and Siemens Healthcare for access to VB17_sliceaccel_WIP1003.

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