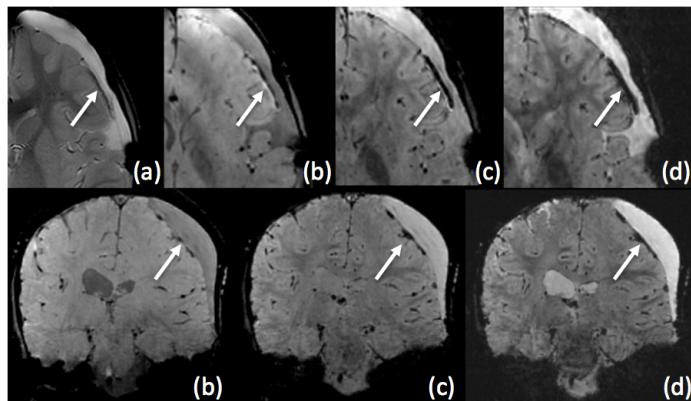


## Evaluating pediatric neuropathologies via multiple TE weighted susceptibility images using a Multi Shot Multi Echo 3D EPI Sequence

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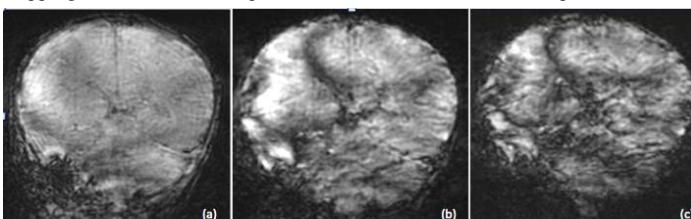
**Introduction:** Susceptibility weighted imaging has been proven clinically useful in a variety of clinical scenarios.[1] However, for any susceptibility weighted imaging, the length of the TE will determine the extent of susceptibility effects depicted.[2] Sequences such as susceptibility weighted imaging (SWI) regularly employ a 3D gradient sequence at a single TE value to obtain isotropic susceptibility weighted images. The multi-shot multi-echo EPI sequence (3D MSME EPI) is an MRI pulse that allows for the acquisitions of images for multiple TE per each TR, and can effectively acquire images for multiple TE's in the same time as a single 3D GRE sequence.[3] We sought to evaluate the utility of multiple TE images for evaluating pediatric pathologies compared to each other as well as against our standard 2D GRE sequence.



**Figure 1:** (a) 2D GRE, and axial reformatted and coronal 3D MSME images at (b) TE=16.8, (c) TE=40.3, and (d) TE=63.76 of 12 year old male demonstrating increasing asymmetric prominence of venous structure under an extracerebral fluid collection. (arrows) Venous structure appears near normal on 2D GRE images, and is suggested to be asymmetrically prominent on TE=63 3D MSME image.

worsen around the paranasal sinuses and mastoid air cells with increasing TE for all cases. 58% (29/50) of cases demonstrated long 3D TE images better-depicted pathologies (such as blood products, post operative changes, or siderosis, vessel prominence) than short or medium 3D TE images or 2D GRE images. In one case, a patient with elevated ferritin levels suspected of having hemophagocytic lymphohistiocytosis demonstrated siderosis on long TE images, while all other sequences appeared to be negative. 22% (11/50) cases demonstrated that the extent of artifact (motion, braces, hardware) worsened with increasing TE (see figure 3), though there was 1 case where despite dental hardware degradation the TE=16.8 image did allow visualization of a cavernous malformation not visible on 2D GRE.

**Conclusions:** Multi-shot EPI images can provide images that demonstrate susceptibility findings better seen on long TE 3D GRE images, can depict findings on short TE images that may be obscured by artifacts on longer TE images, and overall, often can show findings not visible on 2D GRE images, all in the same time as standard 3D GRE sequences (such as SWI). Additionally, this method produces multiple TE images that may be useful for advanced applications such as calculating T2\* values (which may be useful in characterizing neuropathologies), producing phase images or performing quantitative susceptibility mapping. We believe this sequence can serve as a robust tool for pediatric neuroimaging.

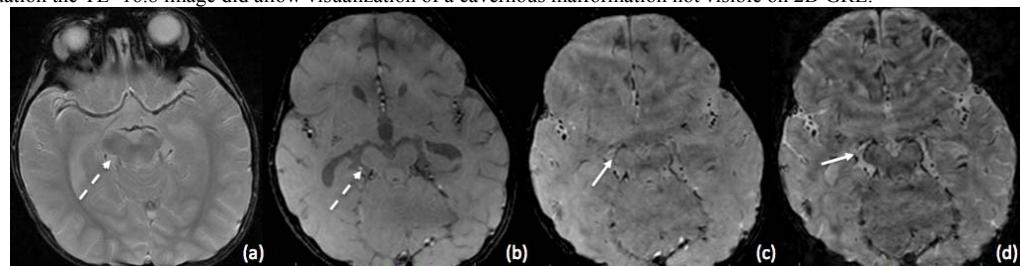


**Figure 3:** 3D MSME images (a) TE=16, (b) TE=40, and (C) TE=63 images demonstrating worsening motion degradation with increasing TE.

**Methods:** 50 pediatric patients imaged as part of our clinical practice had multi-shot EPI sequences and 2D GRE sequences performed under an IRB approved protocol using a 3T MRI with an 8-channel head coil (MR750, GE Healthcare, Waukesha, WI) using TE's of approximately= 16.8, 40.3 and 63.76, (TR=95, matrix 256x256, slice thickness 1 mm). Patients included in the study ranged from 2 months to 21 years in age and demonstrated various stages of tumors, hemorrhage, postoperative changes, or no abnormalities. A board certified pediatric neuroradiologist and a second year neuroradiology fellow reviewed all images.

**Results:** 66% (33/50) of cases demonstrated findings on 2D GRE images, and 18% (6/33) of these cases showed new findings not seen on the initial 2D GRE images (such as previously nonvisualized portions of tumor, additional subependymal nodules, siderosis, areas of hemorrhage, and post operative changes). 27% (9/33) of the initially positive cases showed findings more prominently compared to the 2D GRE cases. 6% (2/33) of cases demonstrate findings more poorly than the 2D GRE cases. Susceptibility artifacts from the sinuses obscured both of these findings in the pituitary gland and orbit respectively. 45% (15/33) of the cases initially positive on 2D GRE showed no change in on 3D MSME EPI images. In considering the 34% (17/50) of cases that had no findings on 2D GRE images, 22% (4/18) showed clinical findings not seen on the initial 2D GRE sequence. These new findings included portions of residual tumor, siderosis, hippocampal asymmetric susceptibility, and suggestion of venous prominence (see figures 1 and 2). Susceptibility artifacts were seen to

worsen around the paranasal sinuses and mastoid air cells with increasing TE for all cases. 58% (29/50) of cases demonstrated long 3D TE images better-depicted pathologies (such as blood products, post operative changes, or siderosis, vessel prominence) than short or medium 3D TE images or 2D GRE images. In one case, a patient with elevated ferritin levels suspected of having hemophagocytic lymphohistiocytosis demonstrated siderosis on long TE images, while all other sequences appeared to be negative. 22% (11/50) cases demonstrated that the extent of artifact (motion, braces, hardware) worsened with increasing TE (see figure 3), though there was 1 case where despite dental hardware degradation the TE=16.8 image did allow visualization of a cavernous malformation not visible on 2D GRE.



**Figure 2:** (a) 2D GRE, and 3D MSME (b) TE=16.8, (c) TE=40.3 and (d) TE=63.76 images in a 1 year old patient with elevated ferritin levels and suspected hemophagocytic lymphohistiocytosis. TE=40.3 and TE=63.76 images suggest siderosis around cerebral peduncles (solid arrows), while other images demonstrate no abnormality in this area (dashed arrows). These findings helped confirm the clinical diagnosis.

### References

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2. Gorno-Tempini, M.L., et al., *Echo time dependence of BOLD contrast and susceptibility artifacts*. *Neuroimage*, 2002. **15**(1): p. 136-42.
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