Abbreviated Turbo Spin Echo T2- and FLAIR-weighted Sequences to Complement Multiplanar HASTE Images in "Quick MRI" Pediatric Brain Imaging at 3 Tesla: A child-tailored approach

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Introduction

The "Quick MRI" approach is rapidly gaining popularity in pediatric neuro imaging to reduce the need for sedation in several conditions including hydrocephalus monitoring, ventricular shunting follow-up, intracranial cysts, minor to moderate head trauma, headaches, and prior to spinal tap procedures.

Single-shot half Fourier (HASTE) T2-weighted sequences are currently the mainstay of "Quick MRI" neuro imaging protocols. Such sequences have clear advantages in allowing brain depiction with minimal or even no motion artifacts. However, certain aspects such as low contrast resolution and a limited sensitivity to intraparenchymal hemorrhage can still present significant drawbacks to further "Quick MRI" applications.

To overcome such limitations and to explore the full potential of new-generation 3-tesla MR scanners (e.g., higher signal-to noise ratio, improved fast shimming, higher density receiver-unit head coils, 20–64 channels, and higher parallel imaging factors), we started testing an abbreviated version of the conventional turbo spin echo (TSE) 2D T2 and FLAIR (DarkFluid) weighted sequence in uncooperative children and all patients under 6 years of age[1].

These sequences were added to the usual HASTE T2-weighted based "Quick-MRI" protocol on our MAGNETOM Vida equipped with XQ gradients and the *syngo* MR XA31 software version. A 20-channel head/neck receiver coil was used. Since each sequence lasts less than a minute (40–55 seconds), the general strategy for each child is to acquire a sufficient number of motion-free images by repeated acquisition of the same sequence if necessary, according to the judgment of the pediatric neuroradiologist. This results in some redundancy in image acquisition, yet images are acquired in a few minutes and contain sufficient diagnostic information.

A tailored individual exam in pediatric neuro imaging is based on the threshold for motion artifacts determined to be acceptable depending on the clinical work-up and the particular diagnostic question.

	HASTE-T2	abbreviated TSE-T2	abbreviated TSE-FLAIR
Acquisition time	46 sec.	52 sec.	51 sec.
TR/TI/TE	2000/90 msec	7300/88 msec	8500/2438/ 97 msec
Concatenations	2	1	2
FOV	230 mm	230 mm	230 mm
phase FOV	75%	75%	75%
In-plane res. acquisition	1.0 × 0.9 mm	1.14 × 0.8 mm	1.73 × 1.44 mm
In-plane res. reconstruction	0.9 × 0.9 mm	0.8 × 0.8 mm	0.7 × 0.7 mm
Slice thickness	4 mm	4 mm	4 mm
Gap	10%	10%	10%
Slice number	23	23	23
GRAPPA	0	2	3
Gradient set mode	fast	fast	fast
Turbo factor	173	16	29
Echo spacing bandwidth	930 Hz/px	126 Hz/px	286 Hz/px
Slice order	ascending	interleaved	interleaved

Table 1: Main parameters of the tested HASTE and abbreviated TSE sequences.

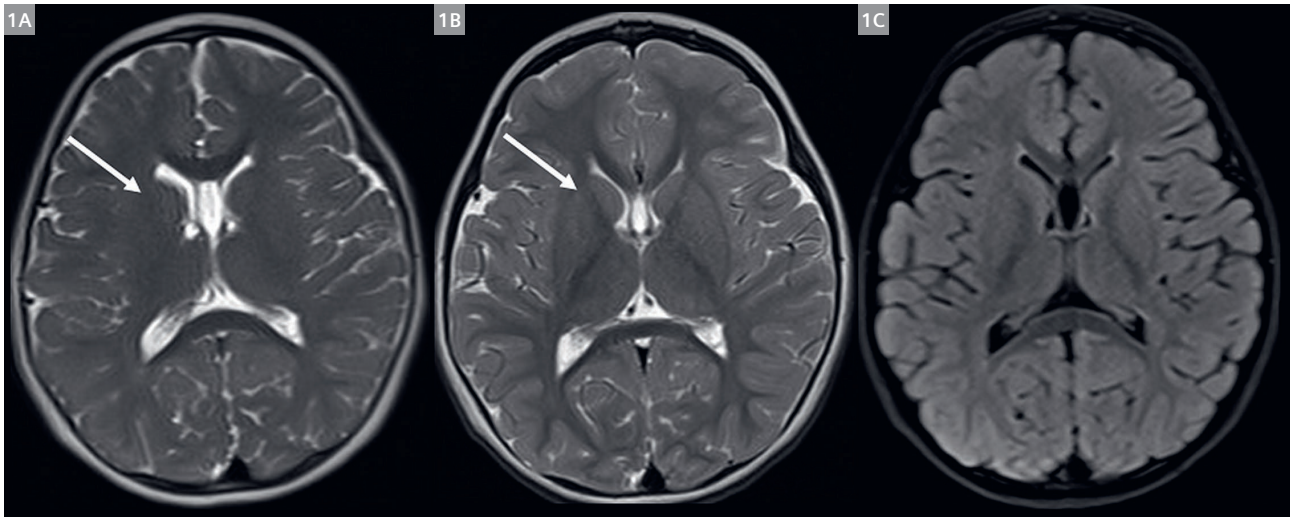
[1] *MR scanning has not been established as safe for imaging fetuses and infants less than two years of age. The responsible physician must evaluate the benefits of the MR examination compared to those of other imaging procedures.*

Practical tips

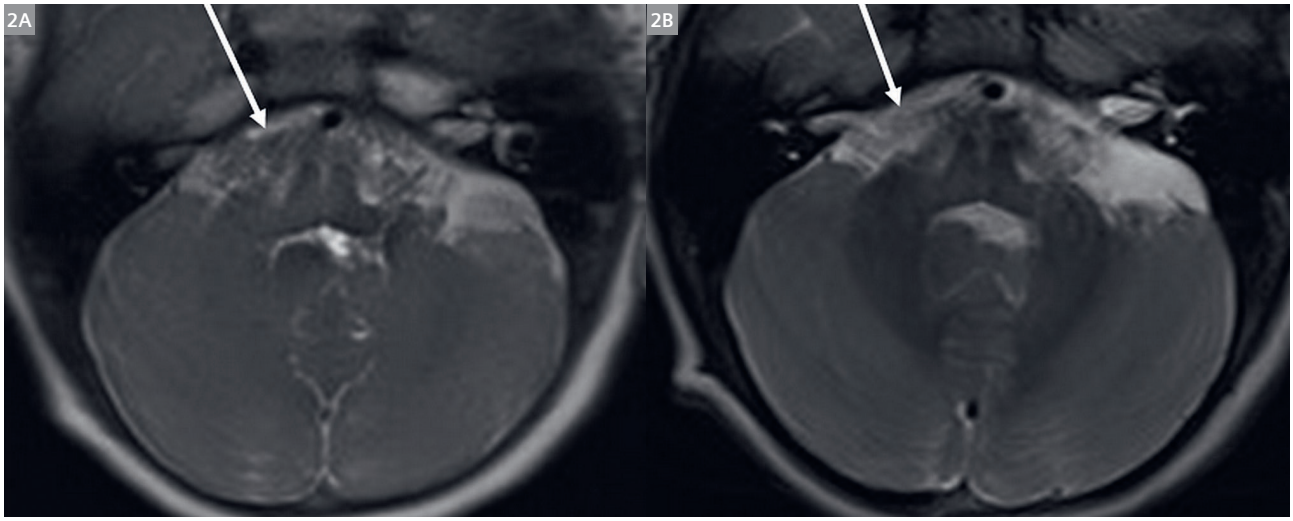
- Position the child's head at the center of the coil and secure it using abundant foam padding. During the exam, a parent should maintain close physical contact with the child to reassure them and to prevent possible leg motion. Play music or fairy tales through the headphones at high volume or allow the child to wear goggles with cartoons to minimize scanner noise and distract the child.
- Start with three-plane HASTE T2 sequences and repeat if there is any significant motion. Then apply abbreviated axial and coronal TSE T2 and FLAIR sequences (Table 1) and repeat if necessary with no further pre-scan adjustment, until the motion artifacts are below the acceptable threshold.
- DWI, T1 VIBE sagittal and axial sections (< 30 sec acquisition time) can be added to the protocol and repeated if needed.

Preliminary results

With respect to HASTE, abbreviated TSE images resulted in better contrast between gray and white matter and in sharper depiction of cerebral structures, for example in basal ganglia delineation (Fig. 1). Subcortical and cortical-white matter interface lesions were also better



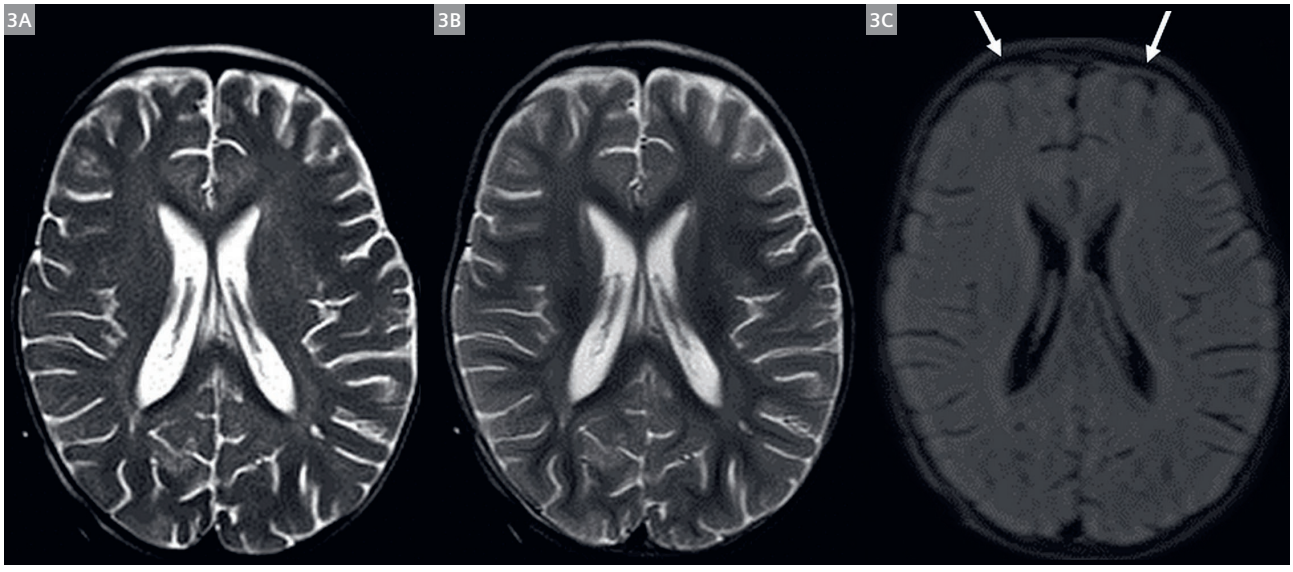
1 Matched axial sections from a 21-month-old unsedated child[1]: **(1A)** HASTE, **(1B)** abbreviated TSE and **(1C)** FLAIR. Gray/white matter contrast and basal ganglia delineation is better on abbreviated TSE with respect to HASTE (arrows).



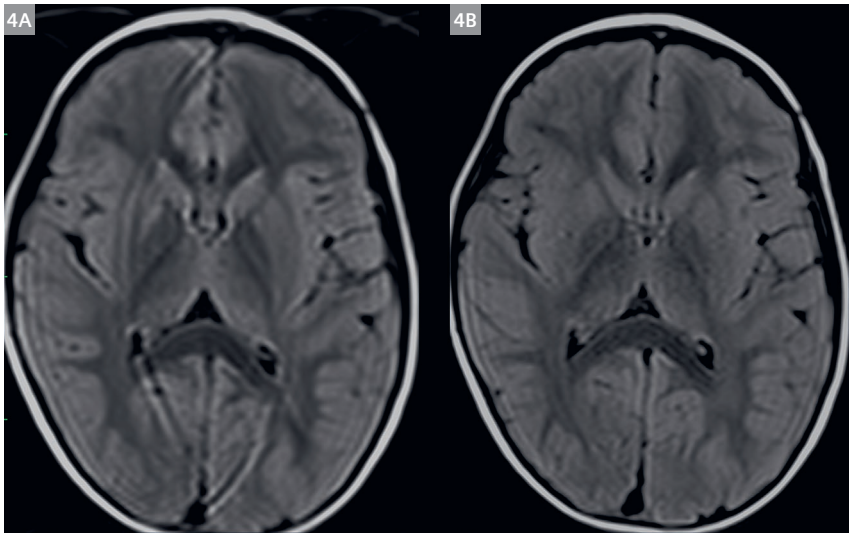
2 Matched axial sections from a 20-month-old unsedated child[1]: **(2A)** HASTE and **(2B)** abbreviated TSE; CSF flow artifacts (arrows) are less evident in abbreviated TSE.

highlighted. They were less prone to CSF flow-related artifacts (Fig. 2), however, anomalies containing CSF (i.e., cysts) were better delineated by HASTE, probably due to the better fluid-parenchyma contrast as is commonly known. The FLAIR sequence provided additional confidence in judging focal parenchymal lesions and peri-cerebral/CSF-abnormal findings (Fig. 3).

In about half of the cases, either abbreviated T2- or-FLAIR-weighted sequences had to be repeated because there were deemed too heavily affected by motion. However, this only resulted in an increased global scanning time of 2–3 minutes. Moreover, we noticed that the repeated sequences were usually less or not at all affected by motion compared with the previous ones, probably due to a sort of "lullaby effect" from the rhythmic scanner noise (Fig. 4).

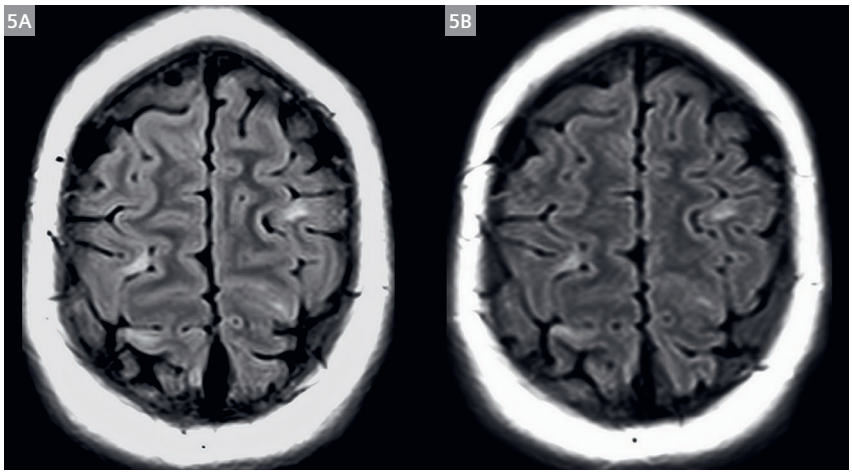


3 Matched axial sections from a 12-month-old unsedated child[1]: **(3A)** HASTE, **(3B)** TSE, and **(3C)** FLAIR. Abnormal meningeal signal due to pneumococcal meningitis is noticeable in FLAIR (arrows).



4 Matched axial abbreviated FLAIR sections from a 6-year-old unsedated child with intellectual disability: **(4A)** shows marked motion artifacts, while on **(4B)** the consecutive repeated acquisition is not affected.

[1] *MR scanning has not been established as safe for imaging fetuses and infants less than two years of age. The responsible physician must evaluate the benefits of the MR examination compared to those of other imaging procedures.*



5 Matched axial FLAIR sections from a 12-year-old patient with tuberous sclerosis. **(5A)** 3-minute long conventional sequence and, **(5B)** the abbreviated version. Cortical tuber identification is acceptable.

Discussion

A similar approach was recently successfully tested by Jaimes et al. [6, 7]. They compared abbreviated versions of TSE sequences with conventional longer ones and found a good correspondence in diagnostic yield. Their sequence duration was longer than one minute, which might limit a strategy of potential iterative repetition of the sequence as used in our setting.

We believe that the addition of abbreviated FLAIR could expand the use of "Quick MRI" protocols to chronic conditions that require follow-up starting from pre-school age, such as cortical tubers and subependymal giant cell astrocytoma monitoring in tuberous sclerosis (Fig. 5).

Abbreviated TSE sequences would benefit from further improvement by using even higher density coil elements (i.e., 64-channel head/neck coil with a higher GRAPPA factor) or specially designed smaller coils carrying more elements (i.e., 32 channels) for children between 12 months and two years of age. In addition, using Simultaneous Multi-Slice (SMS) in TSE imaging could further reduce scan times. FLAIR- and T1-weighted 3D wave-CAIPI may also be helpful, although they are likely to be quite susceptible to motion artifacts.

In summary, we believe that the use of abbreviated versions of TSE sequences is feasible in uncooperative children or those under six years of age. It could provide some advantages in diagnostic pediatric work-up and complement HASTE techniques in current "Quick MRI" imaging, at least for some indications. Meanwhile, in conditions such as neuro oncology, complex brain malformations, or epilepsy such an approach is not suitable. Repetitive iterative sequence acquisitions of lower resolution TSE imaging may represent a valuable strategy to achieve a diagnostic target tailored to an individual child's condition.

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The .exar1 protocol file is available for download at
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