Diagnostic Relevant Reduction of Motion Artifacts in the Posterior Fossa by *syngo* BLADE Imaging

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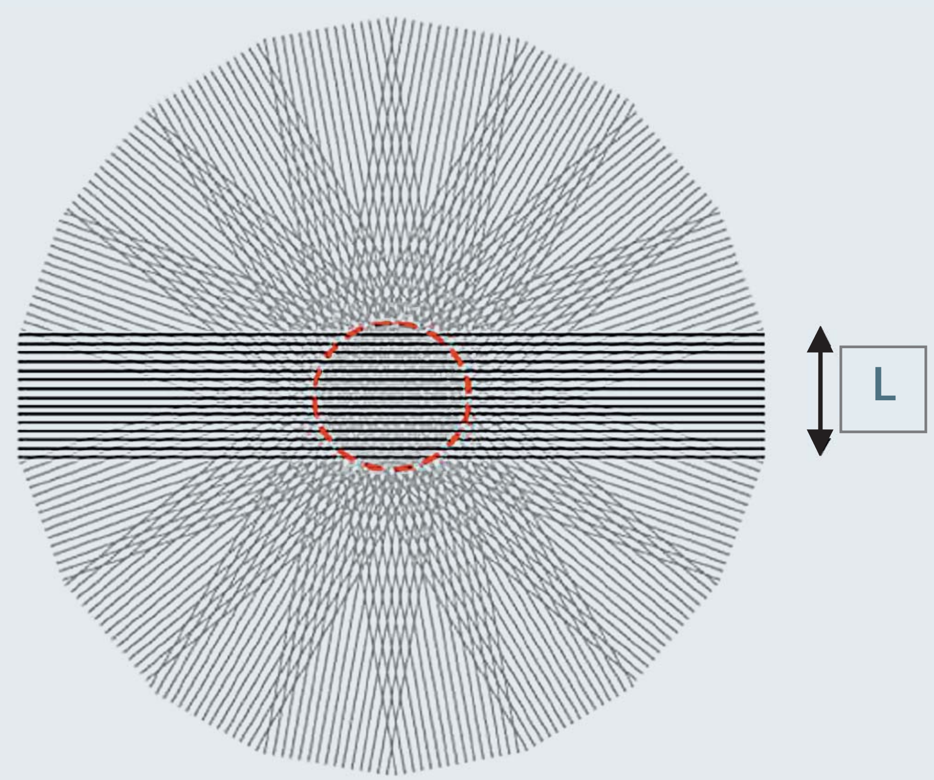

1 k-space trajectory in BLADE imaging. The k-space is covered by a series of blades each of which consists of the lowest phase encoding lines. The centre of the k-space (red circle) with diameter L is resampled for every blade. Data are then combined to a high resolution image.

Although movement and pulsation artifacts are a frequent problem in daily routine [1–4] especially in the diagnostics of pediatric patients, only few articles on this topic can be found in the literature. According to our experience mainly MR images of the posterior fossa, the cerebellum and the brain stem, may be significantly impaired by artifacts from pulsatile flow of blood or cerebrospinal fluid even without patient head movement [5, 6]. Sedation or general anesthesia rarely influence these pulsation or flow artifacts. However, accurate assessment of small brain lesions is essential in many pediatric patients, especially in those with malignant brain tumors.
MR imaging with "rotating blade-like k-space covering" (BLADE) and "Periodically Rotated Overlapping Parallel Lines with Enhanced Reconstruction" (PROPELLER) have been shown to effectively reduce artifacts in healthy volunteers and adult patients [7, 8, 9], as well as in pediatric patients [4, 10] and therefore have the potential to reduce the frequency of anesthesia in children. As these MR techniques reduce motion artifacts by fast segmental image acquisition combined with mathematical algorithms, we assumed that it might at the same time reduce the visibility of small brain lesions. We therefore compared the image quality of two T2-weighted fluid attenuated inversion recovery (T2w FLAIR) sequences with different k-space trajectories (conventional Cartesian and BLADE) with respect to artifacts and depiction of small hyperintense brain lesions [5].

Imaging techniques

We used a 1.5T scanner (MAGNETOM Avanto, Siemens Healthcare, Erlangen, Germany) and the Siemens 12-channel head matrix coil.
For each patient we compared two sequences with transverse 4 mm sections (gap 10%) that were applied in identical slice positions:
1. The T2w FLAIR standard sequence, a spin-echo sequence with conventional rectilinear Cartesian k-space trajectories (image parameters: TI 2500 ms, TR 9000 ms, TE 100 ms, BW 150 Hz/pixel, turbo factor 19, TA160 s, FOV 230 x 230 mm, matrix 256 x 256).
2. The BLADE FLAIR sequence with rotating blade-like k-space trajectories (image parameters: TI 2500 ms, TR 9000 ms, TE 107 ms, BW 250 Hz/pixel, turbo factor 29, TA 260 s, BLADE-Coverage 130 %, FOV 230 x 230 mm, matrix 256 x 256).
During the acquisition of both sequences children were encouraged not to move their head. They were offered video films or audio programs during the examination.

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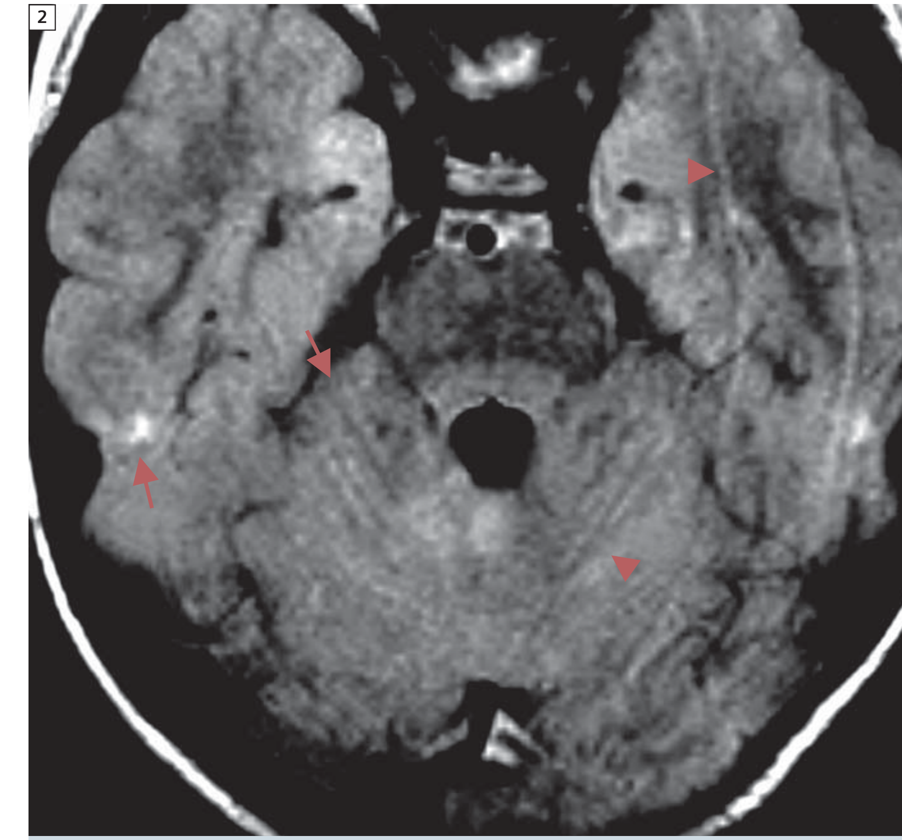


2 Movement artifacts caused by head movements (arrowheads) and pulsation artifacts caused by pulsatile flow (arrows). T2w FLAIR sequence with conventional rectilinear k-space trajectories.

BLADE technique

syngo BLADE is the product name of the motion insensitive Siemens turbo-spin-echo sequence which utilizes the PROPELLER k-space trajectory [11].
The technique is approved for diagnostic MR examinations of patients. It consists of blade-like rotating k-space coverage. During each echo train of a BLADE sequence the lowest phase encoding lines of a conventional rectilinear k-space are acquired. The number of lines, which depends on the length of the echo train, determines the resolution of the image. During the acquisition process the direction of this "blade" is rotated around the k-space centre such that the complete series covers the whole k-space (Fig. 1). Images can be displayed with or without an additional motion correction algorithm.

Patients

The typical hyperintense white matter abnormalities in the cerebellum of patients with neurofibromatosis type 1 (NF 1) [12] served the purpose of our study to assess and compare the visibility of small and low contrast lesions.
We re-evaluated images of children with NF 1, who had been routinely scanned for optic pathway gliomas and who had been examined with T2w FLAIR sequences of both techniques. 26 patients, 10 girls and 16 boys from 2 years 7 months to 17 years (median age 8 years 5 months) were included in the study.

Image evaluation

Four experienced pediatric radiologists independently assessed unlabeled images of both FLAIR sequences of each patient. Structures of the posterior fossa, cerebellum and brain stem, were evaluated according to the presence of movement artifacts (caused by head movements) or pulsation artifacts (caused by pulsatile flow of blood and/or cerebrospinal fluid) (Fig. 2), their differentiation from lesions, and their delineation from the surrounding tissue by contrast (difference in signal intensities) and edge definition (clearly or poorly defined margins) as has been described elsewhere

Table 1: Scores for movement and pulsation artifacts, and the differentiation of artifacts and lesions in the posterior fossa.

	Conventional		*syngo* BLADE	
	yes	no	yes	no
Movement	29	75	4	100
Pulsation	99	5	25	79
Differentiation lesion/artefacts	53	30	81	2

Yes = artifacts present, lesions and artifacts distinguishable. No = artifacts not present, lesions and artifact not distinguishable. Maximum score for each sequence = 104. Last line. Patients with neither artifacts nor lesions were excluded. Results of statistical tests cf Table 2.

[5] The transverse diameters of the largest and smallest lesions were measured in both sequences of each patient. Signal intensities of a representative lesion and the adjacent normal brain tissue were measured. [5]

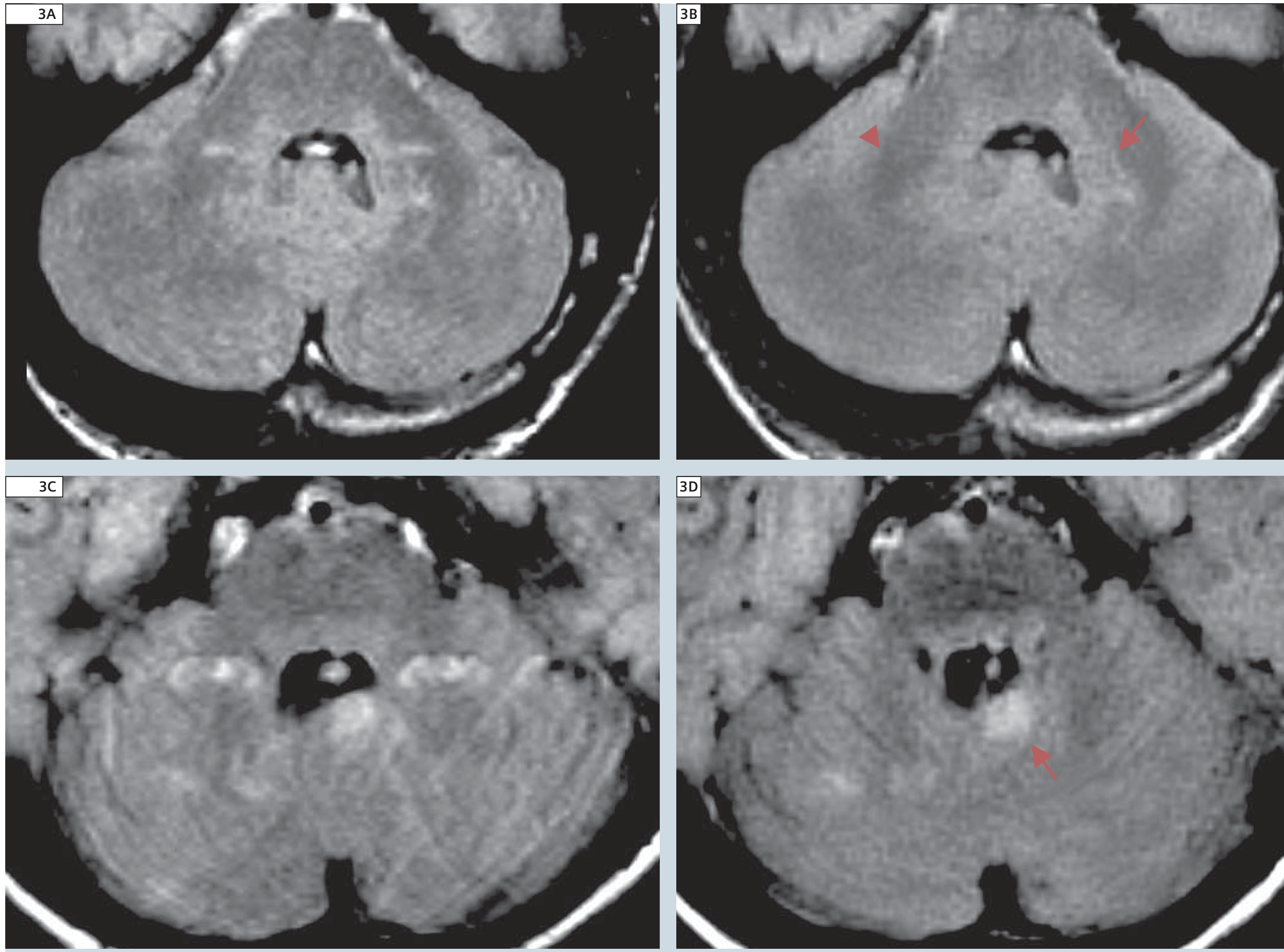
Discussion

Techniques with rotating blade-like k-space covering (BLADE) [9], with periodically rotated overlapping parallel lines with enhanced reconstruction (PROPELLER) [8,10], and with k-space alignment similar to a trellis [13] have been shown to effectively reduce artifacts in T1- and T2-weighted images. Studies on pediatric [4] and adult patients [7] found a comparable detectability of lesions in contrast-enhanced T1-weighted images of FLAIR BLADE sequences and conventional spin-echo sequences. However, image quality and delineation of small or poorly delineated lesions in MR images in T2-weighted FLAIR acquired with these techniques have not been systematically studied.

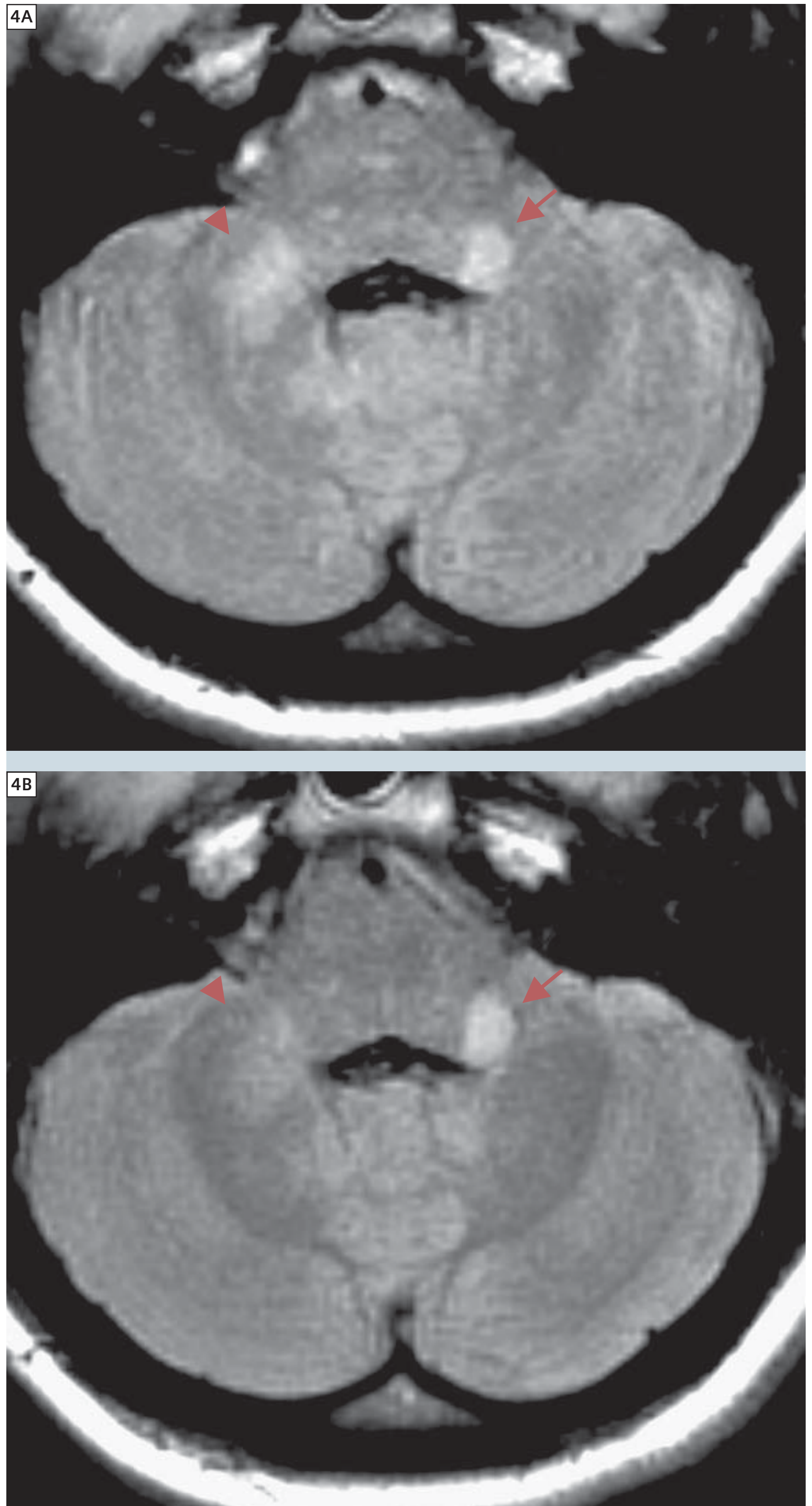
In our study, all observers found more pulsation artifacts than movement artifacts in images of both the conventional and the *syngo* BLADE sequence (Table 1). Artifacts were reported significantly less often in images acquired with BLADE technique than in images with rectilinear k-space trajectory (Table 1 and 2). These results confirm that artifacts caused by pulsation, flow and motion are significantly reduced by the BLADE technique in comparison to the standard sequence with conventional rectilinear k-space covering. As the children were encouraged not to move during the examination, there were only moderate to minor movement artifacts even in conventional T2w FLAIR images. Pulsation artifacts were more frequent and more severe in conventional images and sometimes also present in BLADE images. Ratings of subtle movement artifacts in conventional images and subtle pulsation artifacts in BLADE images led to an only fair interobserver agreement (Cohen's kappa < 0.4, Table 2). These artifacts did not disturb the depiction of lesions.
There was good observer agreement (Cohen's kappa 0.74, Table 2) that artifacts compromised the assessment of lesions more often and more severely in conventional T2w FLAIR images than in BLADE images. In 6 of all 26 patients (23%) observers agreed that in conventional T2w FLAIR images they could not differentiate lesions from artifacts in the posterior fossa, rendering nearly a fourth of the examinations with conventional k-space trajectory inadequate for a reliable diagnosis. In none of the BLADE sequences more than one observer considered artifacts and lesions to be indistinguishable (Fig. 3).

Table 2: Posterior fossa. Comparison of conventional vs. BLADE images. McNemar's test. p-values for each observer. Cohen's kappa for interobserver agreement.

	Presence of movement artifacts	Presence of pulsation artifacts	Differentiation of lesions and artifacts	Delineation of lesions	
				Edge definition	Contrast
Observer 1	0.03	0.02	0.04	> 0.05	> 0.05
Observer 2	0.02	0.00002	0.002	0.0027	0.0009
Observer 3	0.041	0.000007	0.001	> 0.05	> 0.05
Observer 4	0.013	0.00002	0.013	> 0.05	> 0.05
Cohen's kappa	0.34	0.37	0.72	0.11	0.01



3 T2w FLAIR images of the posterior fossa of two different patients. Rectilinear k-space coverage (left), BLADE (right). Lesions typical of neurofibromatosis type 1: low contrast confluent (arrowhead), high contrast round (arrow). Artifacts and lesions not reliably distinguishable in conventional images (left).



4 Absence of major artifacts and comparable visibility of lesions in images of both techniques (T2w FLAIR: rectilinear k-space top, BLADE bottom), low contrast confluent (arrowhead), high contrast round (arrow).

As Gill et al. reported for their sample [12], most hyperintense lesions in the thalami, brain stem and cerebellum were confluent or diffuse with poorly defined edges. A smaller number of lesions were well circumscribed with edges that were distinct from the adjacent normal tissue. Mean ratios of signal intensities were only slightly lower in the posterior fossa than in cerebrum and midbrain.

If lesions were not obscured by artifacts, visibility of lesions with both clearly and poorly defined edges appeared to be comparable in images of both techniques (Fig. 4). Observers' comparisons of both imaging techniques according to contrast and edge definition did not reveal consistently significant differences for lesions of the posterior fossa (Table 2). There only was a tendency to better edge definition in BLADE images. Visibility of lesions also was independent of size. Even the smallest lesions of our sample (2–3 mm) were equally depicted by both techniques.

BLADE technique is based on standard image acquisition techniques and therefore has the advantage of providing image characteristics equal to standard sequences. As an alternative to *syngo* BLADE imaging, pulsation artifacts may be identified by a second data acquisition after changing the phase encoding direction [1] or the slice orientation, with the disadvantage of a longer examination time and the higher risk of movement artifacts. Reduction of motion artifacts in non-sedated children can also be achieved by rapid sequences (e.g. single shot techniques) which, in neuroimaging, have the disadvantages of a poorer differentiation of gray and white matter [3, 10,14] and a lower spatial resolution [15].

Observers of our study had the subjective impression that the appearance of FLAIR BLADE images differed slightly from that of conventional images which did not impair image quality and lesion detectability (Figs. 3 and 4). These subtle differences have already been reported for PROPELLER technique [2]. BLADE images might therefore be identified by experienced radiologists despite "blinding". We have, however, not identified bias due to this fact in our study.

In our study, data acquisition time and image reconstruction time together were approximately 2–3 minutes longer for *syngo* BLADE sequences than for conventional FLAIR sequences. The advantage of artifact reduction by the BLADE technique clearly outweighed the prolonged duration.

There are limitations of our retrospective study: We were not able to measure the degree of patients' movements. Therefore, like other investigators [2, 4, 9], we can only assume that these parameters were similar in statistical mean throughout the examination. As both sequences were performed successively, pulsation and flow artifacts were also assumed as unchanged for both acquisitions. For our retrospective analysis we had to accept that in addition to the k-space trajectory some of the parameters of both sequences were not identical. As the BLADE technique benefits from long echo trains, a turbo factor had been chosen that was larger than that of our routine T2w FLAIR sequence. However, a change of these parameters would have had only minor influence on motion artefacts, and presumably would not have changed the quality of results. Prospective studies of a larger patient group could avoid these shortcomings.

Conclusion

BLADE technique reduces movement and pulsation artifacts in T2w FLAIR images without relevant loss of image quality. It therefore markedly improves depiction of small and low contrast brain lesions in children in the posterior fossa of pediatric patients. This can be crucial especially in patients after surgery of malignant brain tumors. In the absence of major artifacts lesions of all sizes were depicted in comparable quality by both techniques.

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