

First Clinical Experiences with Simultaneous Multi-Slice Accelerated Diffusion-Weighted Imaging Throughout the Body

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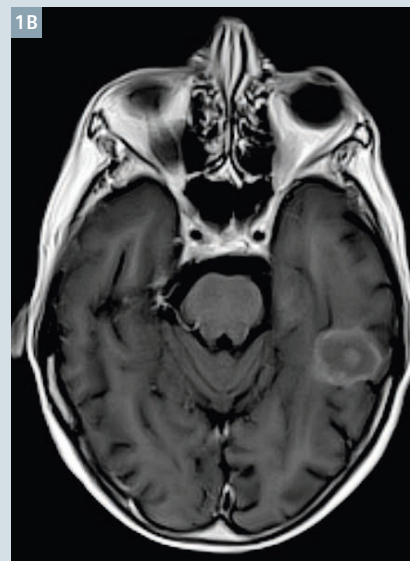
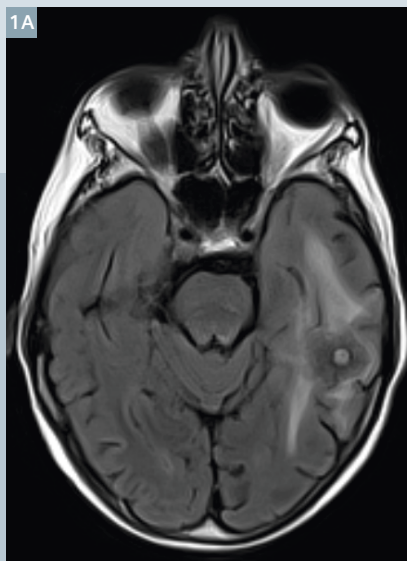
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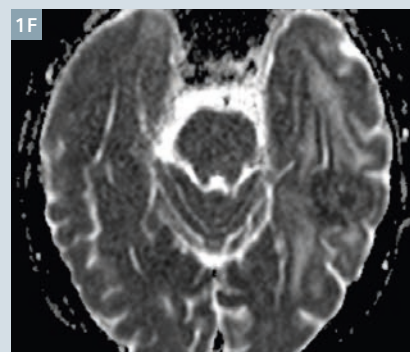
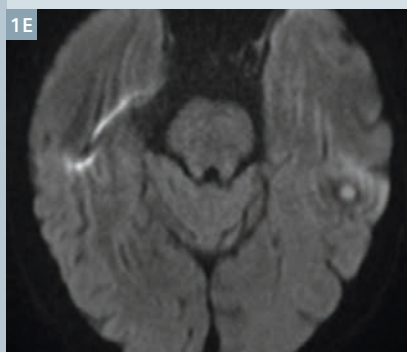
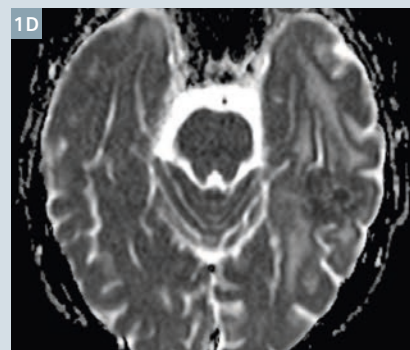
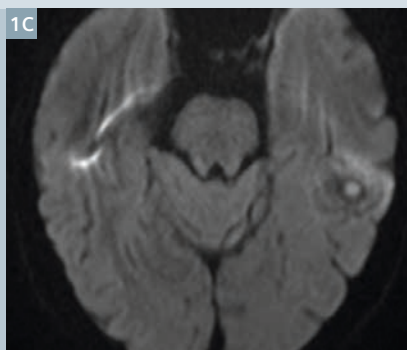
Case 1

60-year-old female patient with multiple lesions at the cortico-medullary junction in the brain.

1A–B T2 FLAIR and T1w post-contrast image show a lesion in the left temporal lobe with surrounding edema and moderate mass effect. The central cavity of the lesion is hyperintense and surrounded by a thin capsule. In postcontrast images the lesion shows a 'target sign' with rim enhancement and central hyperintensity.



1C–F DWI at the same level demonstrates a target lesion, with high signal intensity in b1000 (1C, E) and corresponding lowered ADC (1D, F), reflecting very strong diffusion restriction (mean ADC ~ 400 mm²/s) in the central part of the lesion, consistent with a highly viscous abscess formation. While 1C and D were acquired with standard parameters (see Table 1), images 1E and F were acquired with an SMS factor of 2, which allowed to reduce the TR from 5600 ms to 2700 ms. Accordingly, the overall acquisition time was shortened from 1:54 min to 1:11 min without compromising image quality.



Introduction & Motivation

The service spectrum of our radiology department and medical imaging center at the Hôpital Morvan comprises multidisciplinary diagnostic and interventional activities, with a focus on visceral imaging, neuroradiology, vascular imaging as well as musculo-skeletal imaging. To serve both in- and outpatient referrals of different medical disciplines we are, amongst others,

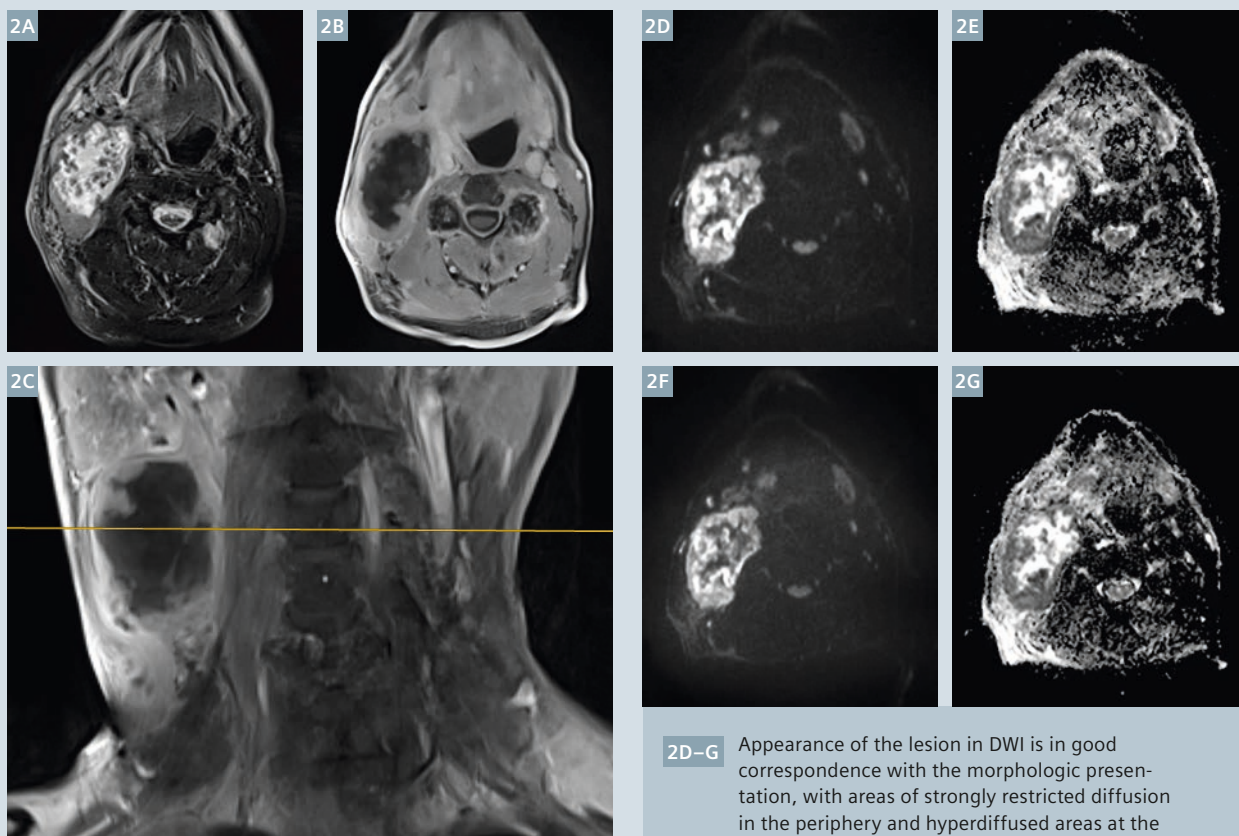
equipped with two Magnetic Resonance Imaging (MRI) systems of which one is a MAGNETOM Avanto^{fit}, 1.5T scanner.

Running on *syngo* MR E11C software, this system facilitates a new method for advanced and accelerated diffusion-weighted imaging (DWI), namely Simultaneous Multi-Slice (SMS) imaging, which is of tremendous value for our daily clinical work.

DWI has become an integral part not only of neuro imaging studies but also imaging of the head & neck region, breast, liver, prostate, rectum and so forth. Especially in body oncology, DWI can be used as a sensitive tool to identify potential areas of impeded diffusion on high b-value images and to improve lesion characterization in terms of cellular properties with the Apparent Diffusion Coefficient (ADC).

Case 2

72-year-old male patient with mass tumor in the right submandibular space.

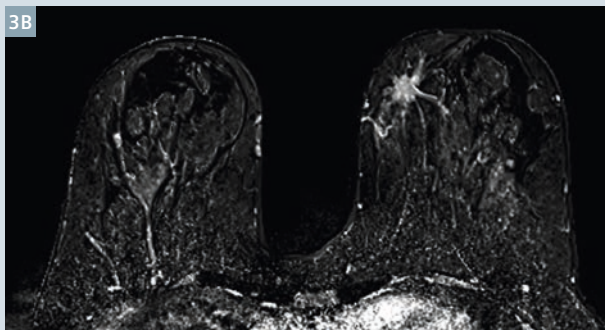
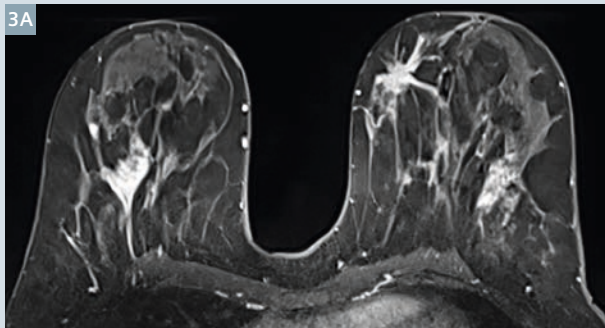


2A–C T2w and T1w postcontrast images show an extended, oval-shaped, inhomogeneous imposing mass in the right submandibular space, displacing the trachea and major cervical vessels towards medial. The tumor presents with solid, nodular appearing areas in the parietal part and shows T2w hyperintensity in the more centrally located aspects, consistent with fluid accumulation due to necrosis. T1w postcontrast images show rim like enhancement of the tumor and advanced infiltration of the musculus sternocleidomastoideus, lingual area, platysma and tongue are present.

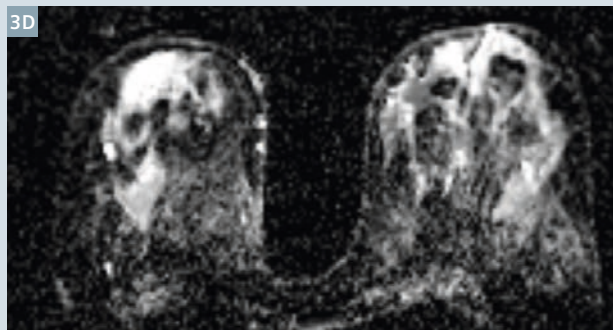
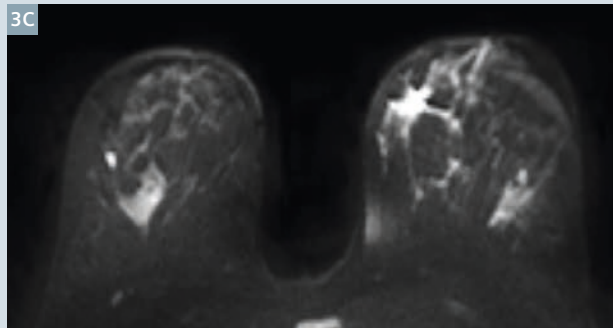
2D–G Appearance of the lesion in DWI is in good correspondence with the morphologic presentation, with areas of strongly restricted diffusion in the periphery and hyperdiffused areas at the center. By applying an SMS factor of 2, it was possible to reduce the TR from 4300 to 2200 ms and the overall acquisition time from 4:18 min to 2:12 min (further parameters in Table1).

Case 3

33-year-old woman with invasive breast cancer of the left breast.



3A–B First postcontrast T1w image of the dynamic contrast-enhanced series and respective subtraction view clearly show a lesion in the left breast, demonstrating fast enhancement and subsequent washout. The mass is irregular shaped, spiculated and homogeneously enhancing. In the right breast, wedge-shaped, moderate enhancement of the glandular tissue and a small lenticular lesion can be found.



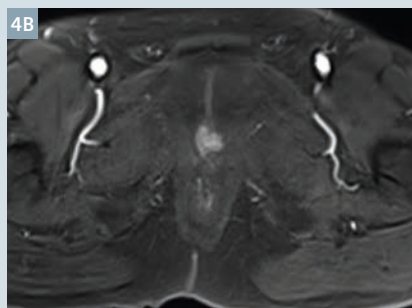
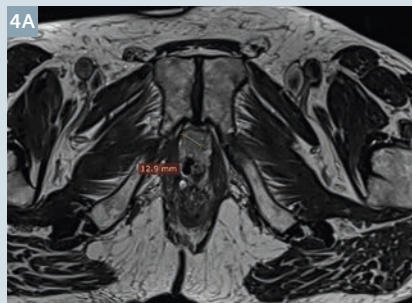
3C–D SMS accelerated DWI at the same level shows a hyperintense area in the left breast in b1000 with corresponding ADC restriction and a mean ADC value of $865 \times 10^{-3} \text{ mm}^2$. The small, round, well circumscribed lesion in the right breast manifests as a T2 shine-through effect in the high b-value image with corresponding high ADC value, most likely corresponding to a fibroadenoma. Acquisition parameters can be found in Table 1.

Region		Field-of-View [mm]	Matrix	Slice thickness [mm]	#slices	TR / TE [ms]	b-values [s/mm ²]	PAT factor	SMS factor	Acquisition time [min]
Brain	Conv	230x230	384x384i	4	26	5600 / 84	0, 1000	2	0	1:54
	SMS					2700 / 84		2	2	1:11
Head & Neck	Conv	230x230	384x384	4	24	4300 / 106	50, 800	2	0	4:18
	SMS					2200 / 106		2	2	2:12
Breast	SMS	203x339	108x180	4	26	2600 / 84	50, 800	2	2	3:08
Prostate	Conv	200x200	128x128	3.5	18	3400 / 72	50, 800	2	0	4:58
	SMS					2000 / 72		2	2	2:55
Rectum	SMS (axial)	200x200	128x128	4	24	2400 / 72	50, 400, 800	2	2	2:24
	SMS (sag)	200x200	128x128	4	20	2100 / 79	50, 800, 1600	2	2	3:30

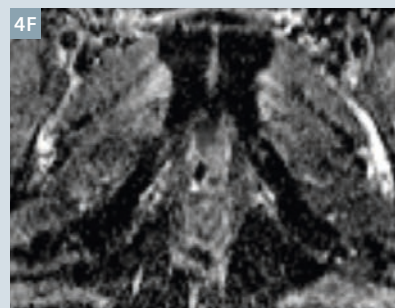
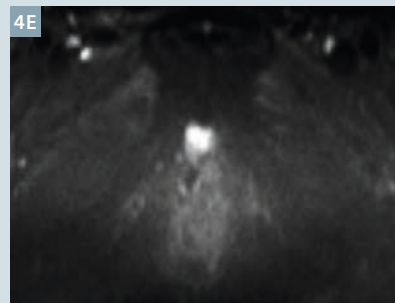
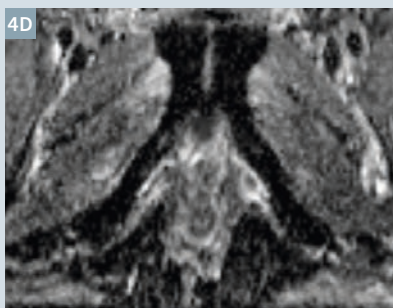
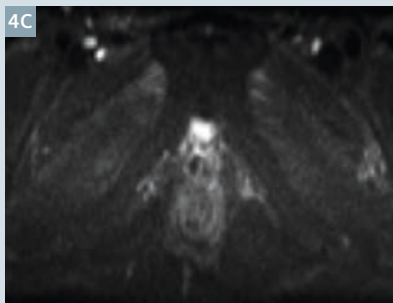
Table 1: Acquisition parameters

Case 4

68-year-old man with prostate cancer.

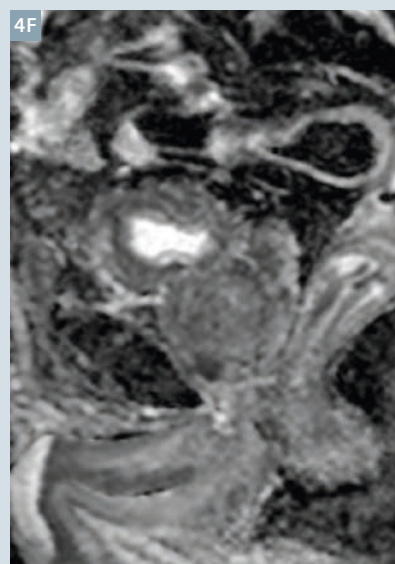


4A–B T2w images show a benign hyperplasia of the transition zone of the prostate in accordance with the patient's age. In the apex of the gland, however, a lenticular shaped, T2 hypointense lesion with irregular margins and a maximum diameter of ~13 mm is visible. Early phase T1w images after contrast application show a distinct, well circumscribed enhancement of contrast medium in the respective area.



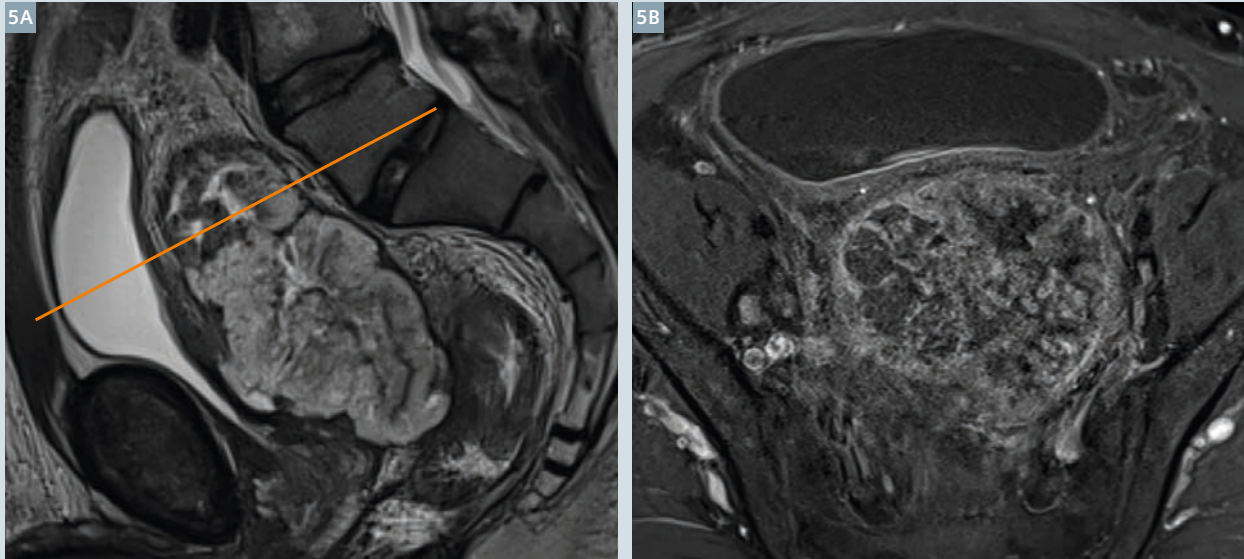
4C–F Conventional (**4C, D**) and SMS accelerated (**4E, F**) high b-value image and ADC map show an apical lesion with strongly restricted diffusion. Measured ADC values show a high inter-method reproducibility with values of 758 and 744 $\times 10^{-3}$ mm²/s, respectively. With Simultaneous Multi-Slice acceleration, acquisition time could be reduced from 4:58 min to 2:55 min (further parameters in Table 1).

4G–F Due to the unusual position of the lesion an additional DWI scan with a very high b-value of 1600 s/mm² was performed in the sagittal plane, which confirmed the suspicion and was rated PI-RADS 4.



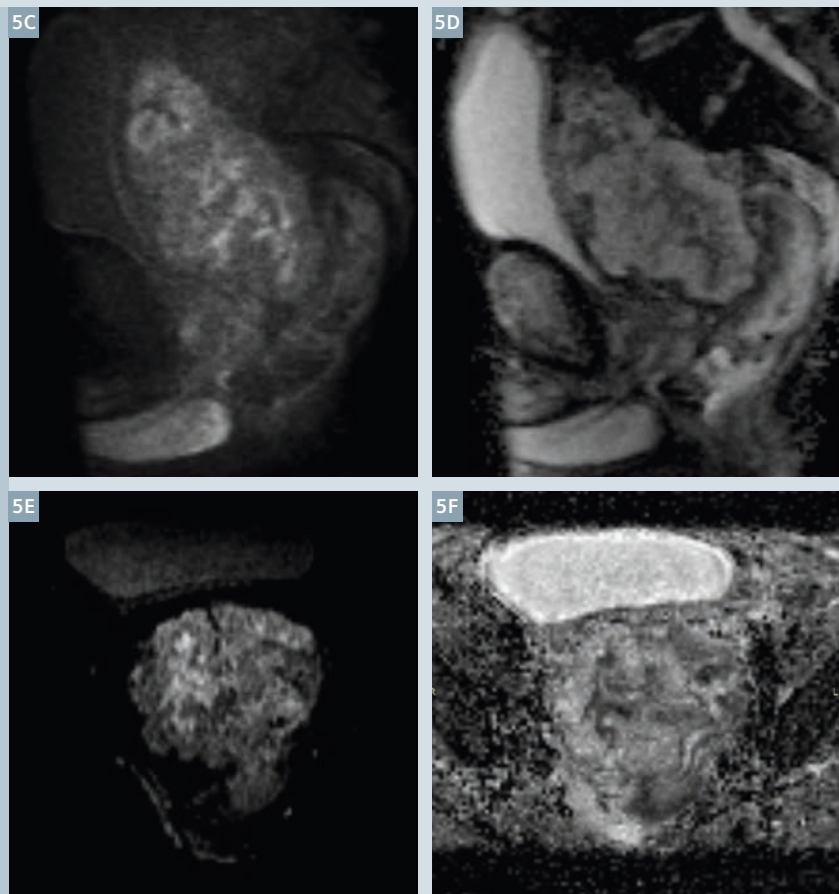
Case 5

65-year-old male patient with sigmoid carcinoma.



5A–B T2w images show a hyperintense, regularly structured mass in the pelvis, most probably originating from the sigma. Towards caudal, the tumor touches the seminal vesicles or potentially infiltrates these. Metastasis of lumbar vertebra 4 and iliac lymph nodes are likely to be present. In postcontrast T1 images, the tumor shows irregular, enhancement from parietal aspects towards the center.

5C–F Corresponding sagittal (5C, D) and axial (5E, F) diffusion-weighted images (b800) and ADC maps show a very inhomogeneous pattern in the tumor corresponding to the anatomical appearance and with aspects, especially towards cranial and in the center, showing strongly restricted diffusion.

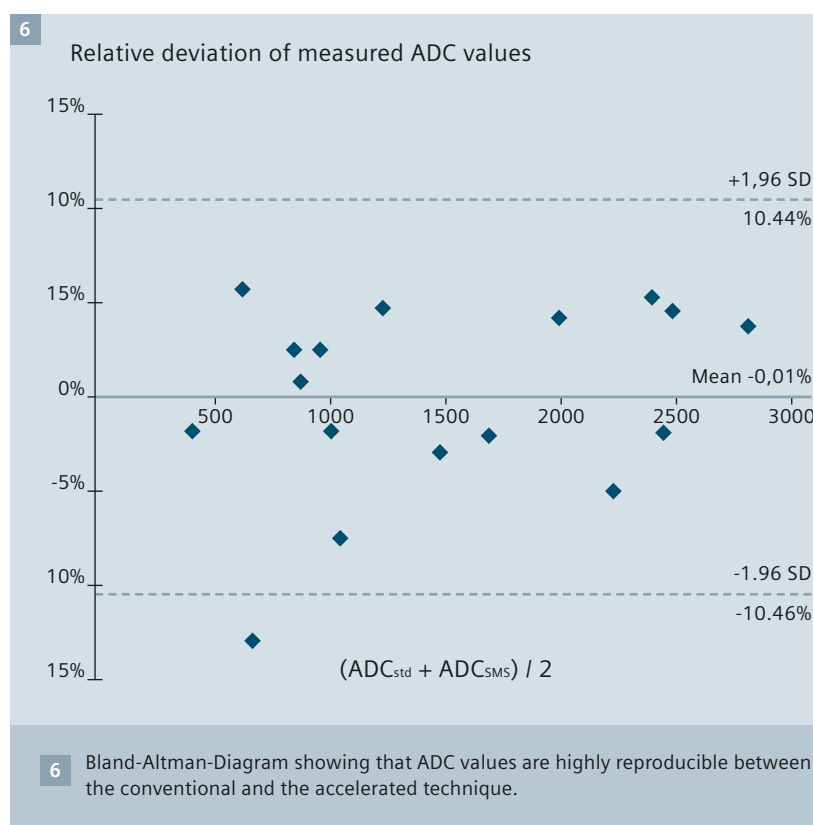


Technically, however, DWI is commonly based on a single-shot, 2D EPI sequence, which is a highly inefficient approach of image acquisition. Every imaging slice has to be excited individually, then the diffusion encoding gradients are played out and finally the image information is acquired with EPI encoding [1]. This process is repeated multiple times, once for each imaging slice, until the entire volume of interest is covered. This inefficient approach can be overcome with Simultaneous Multi-Slice. Instead of a successive excitation of slices, slices are excited simultaneously with a multiband pulse and blipped-CAIPIRINHA SMS-EPI ensures preservation of high SNR and low artifact levels [2].

Motivated by the promising results with Simultaneous Multi-Slice accelerated abdominal imaging presented by the NYU group [3], we decided to evaluate the benefits of Simultaneous Multi-Slice beyond neuro imaging and started to set up own protocols for imaging of various body regions with the support of our local application specialist.

Summary and Conclusion

As demonstrated with the cases presented here, Simultaneous Multi-Slice acceleration is a valuable technique for the acceleration of diffusion-weighted imaging in almost all clinical applications where DWI is commonly applied. Robust results and good image quality can be achieved with an SMS factor of 2, which allows to achieve near two-fold acceleration in DWI



acquisitions. As shown in the Bland-Altman-Diagram (Fig. 6), ADC values are highly reproducible between the conventional and the accelerated technique.

In the meantime we have incorporated Simultaneous Multi-Slice Diffusion-weighted Imaging (SMS DWI) with 2-fold acceleration in our clinical protocol for various body regions, allowing shorter overall scan time, better slice coverage or improved resolution.

References

- 1 Setsompop K, et al. Advancing Diffusion MRI Using SMS EPI. *MAGNETOM Flash* 3(63): 2015; 16-22.
- 2 Breuer F, et al. CAIPIRINHA – Revisited. *MAGNETOM Flash* 3(63): 2015; 8-15.
- 3 Chandarana H, et al. Simultaneous Multi-Slice Accelerated Free-Breathing Diffusion-Weighted Imaging in Abdomen and Pelvis. *MAGNETOM Flash* 3(63): 2015; 32-35.



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