Whole-Brain Black-Blood Imaging with Magnetization-Transfer-Prepared-Spin-Echo-Like Contrast: Application for Contrast-Enhanced Brain Metastasis Screening at 3.0Tesla

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INTRODUCTION:

Contrast-Enhancement magnetic resonance imaging, using a 3D T1-weighted gradient recalled echo sequence, is an established method for screening of brain metastasis **[1-4]**. However, since contrast materials remain in both blood and the tumor parenchyma, and thus increase the signal intensity of both regions, it is often challenging to distinguish brain tumors from blood **[5]**. To overcome this problem, "black-blood" versions of T1-weighted imaging are used since recently **[5-7,10,11]**. These methods are based on 3D variable refocusing flip angle turbo spin echo (3D VRFA-TSE)[**5-7**], or motion sensitized driven equilibrium (MSDE)**[8,9]** prepared 3D VRFA-TSE sequences **[10,11]**. An optimized T1-weighted, 3D-TSE whole-brain imaging sequence (3D LOW Refocusing flip Angle Turbo spin echo: LOWRAT)**[12]**, which employs very low refocusing flip angles with "90°+α/2" pseudosteady-state preparation **[13]**, was recently introduced. In this study, we propose a T1-optimized, "perfect" black-blood imaging method using MSDE prepared LOWRAT ("**MA**gnetization transfer prepared **T**1-weighted spin-echo"-**L**ike contrast **V**olume **E**xamination: MATLVE) for brain metastasis screening at 3.0 Tesla, and compare MATLVE to conventional methods.

METHODS:

SEQUENCE: The MATLVE sequence was based on LOWRAT to acquire contrast-efficient T1-weighted black-blood images. Furthermore, improved MSDE (iMSDE) **[9]** preparation was added for "perfect" suppression of contrast-enhanced (CE) blood signals **[Fig.1]**. The iMSDE preparation consists of a 90°excitation pulse, two 180° MLEV refocusing pulses and a -90° flip-back pulse with motion sensitizing gradients sandwiched in between the RF pulses. Moreover, additional bipolar gradients were inserted in front for eddy currents compensation **[10]**.

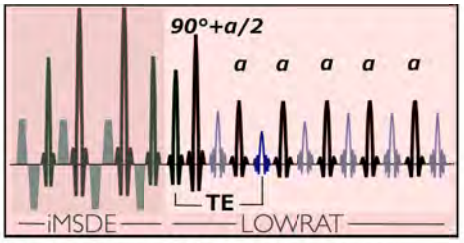

Fig.1 Scheme of MATLVE pulse sequence. iMSDE prepared LOW Refocusing flip Angle Turbo spin echo (LOWRAT). LOWRAT employs very low constant refocusing flip angle trains with short effective TE after "90°+α/2" pseudosteady-state preparation.

EXPERIMENTS: A total of 12 patients with brain metastasis were examined with a 3.0-Tesla whole-body clinical imager (Achieva, Philips Healthcare). The study was approved by the local-IRB, and written informed consent was obtained from all subjects. The effect of MATLVE in the suppression of CE blood-signals and in the depiction of small metastatic brain tumors was compared to conventional T1-weighted gradient-echo (3D-T1TFE) and LOWRAT at high-resolution isotropic whole brain images in the sagittal plane following injection of contrast agent. To minimize bias in estimating the signal intensity of the brain tumors, which may be caused by the different time lag between contrast injection and imaging, three sequences were scanned in a random order in all patients. The imaging parameters common to all methods were FOV=240mm, resolution=1.0mm^2, slices=192, slice thickness=1.0mm, and acquisition time=5min. The imaging parameters specific to 3D-T1TFE were TR / TE / FA = 3.8 / 1.9ms / 15°. Those specific for LOWRAT and MATLVE were TR / TE_{eff} / ETL = 420 / 9.8ms / 16, FA=75°, RFA=30° with "90°+α/2" pseudosteady-state preparation. In addition, iMSDE preparation (duration=17ms, b-value =10.57s/mm^2) was applied in MATLVE. To compare the CE contrast in particular, we used optimized, thick-slice, "1-minute" fast-sequences, in all methods.

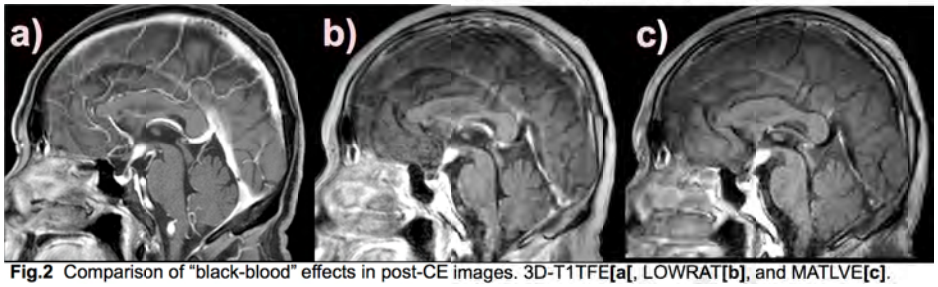

Fig.2 Comparison of "black-blood" effects in post-CE images. 3D-T1TFE[**a**[, LOWRAT[**b**], and MATLVE[**c**].

To evaluate the blood-suppression effects of the three methods quantitatively, the number of visualized blood vessels (including both arteries and veins) around the brain surface in a single slice at the level of the semioval center was assessed. To evaluate the CE contrast of the three methods quantitatively, contrast-ratio (CR) was calculated by the signal difference of the two regions of interest between WM and GM ($CR_{WM\text{-}GM}$) and WM and tumor ($CR_{WM\text{-}Tumor}$), respectively. Qualitative and quantitative analyses were done in a blinded manner. The $CR_{WM\text{-}GM}$ and $CR_{WM\text{-}Tumor}$ ot the different sequences were compared using a paired t-test.

RESULTS and DISCUSSION:

Fig.2 demonstrates the CE images acquired in patients using conventional 3D-T1TFE **[Fig.2a]**, LOWRAT **[Fig.2b]**, and MATLVE **[Fig.2c]**. The signal intensity of CE blood substantially decreases in MATLVE. The numbers of blood vessels on the brain surface for 3D-T1TFE, LOWRAT, and MATLVE were 42.7±7.1, 9.1±4.5 and 3.0±2.1, respectively **[Fig.3a]**. Significant differences were found in all three comparisons. Quantitative comparison of $CR_{WM\text{-}GM}$ for LOWRAT versus MATLVE is shown in **Fig.3b**; that of $CR_{WM\text{-}Tumor}$ for conventional 3D-T1TFE, LOWRAT, and MATLVE is shown in **Fig.3c**. $CR_{WM\text{-}GM}$ of MATLVE was slightly lower than that of LOWRAT, but this difference was not significant. On the other hand, $CR_{WM\text{-}Tumor}$ of MATLVE was significantly higher than those of conventional 3D-T1TFE and LOWRAT. One possible reason for this observation is that iMSDE preparation worked like "on-resonance magnetization transfer" preparation in T1-weighted spin-echo (MTSE) imaging and thus MATLVE increased in "white matter to tumor" contrast **[14]**.

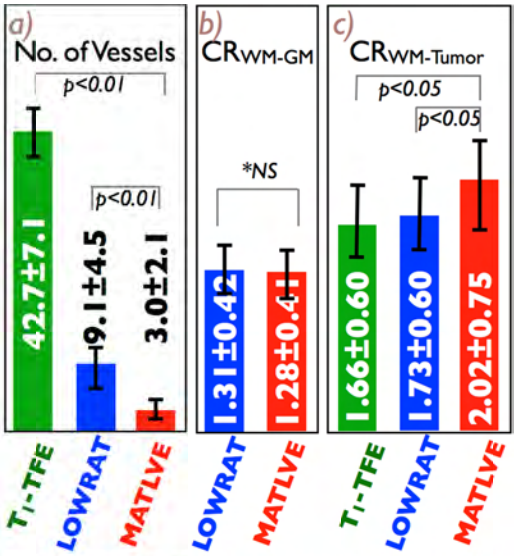

Fig.3 Comparison of "Numbers of visualized vessels" **[a]**, $CR_{WM\text{-}GM}$ **[b]**, and $CR_{WM\text{-}Tumor}$ **[c]** in post-CE images (n=12).

CONCLUSION:

This study showed the new scheme of the T1-optimized, "perfect" black-blood 3D TSE pulse sequence with MTSE-like contrast. This sequence can be used for 3D volumetric T1-weighted black-blood imaging, and is effective in detecting small brain metastases by selectively enhancing tumor signals while suppressing blood signals. Further clinical investigations are needed.

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