Simultaneous Bright- and Black-Blood Imaging Acquisition for Contrast-Enhanced Brain Metastasis Screening

Masami Yoneyama[1], Masanobu Nakamura[1], Tomoyuki Okuaki[1], Takashi Tabuchi[1], Atsushi Takemura[2], Tetsuo Ogino[2], Makoto Obara[2], Thomas Kwee[3], and Taro Takahara[4]

[1]*Yaesu Clinic, Tokyo, Japan,* [2]*Philips Electronics Japan, Tokyo, Japan,* [3]*University Medical Center Utrecht, Utrecht, Netherlands,* [4]*Tokai University School of Engineering, Kanagawa, Japan*

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 images based on turbo spin-echo (TSE) with or without motion sensitized driven equilibrium (MSDE) are used since recently **[5-10]**. However, these methods have difficulties in completely suppressing blood vessel signals, and therefore the differentiation between residual blood vessels and small brain metastases is occasionally difficult. In this study, we propose a new scheme of fast, volumetric, high-resolution, simultaneous bright- and black-blood imaging (**V**olume **I**sotropic **S**imultaneous **I**nterleaved **B**right- and b**L**ack-blood **E**xamination : **VISIBLE**) to improve the differentiation between blood vessels and small brain metastases in brain metastasis screening.

THEORY and SEQUENCE: The VISIBLE sequence was based on improved-MSDE (iMSDE)**[11]** prepared 3D T1-turbo field echo (T1-TFE) readout with centric phase encoding (3D MSDE prepared Rapid Gradient Echo : 3D-MERGE **[12,13]**). We attempted to use the multi-phase (2 phases) version of 3D MERGE, to obtain black-blood images by MSDE preparation at the first phase (with centric phase encoding), and bright-blood images by T1-recovery of blood signals at the second phase (with reverse-centric phase encoding), simultaneously. Therefore, MSDE was employed only once before the initial phase of the individual packages **[Fig.1]**.

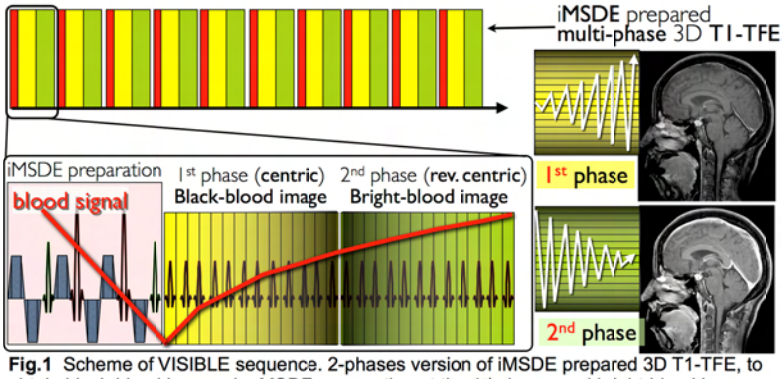

Fig.1 Scheme of VISIBLE sequence. 2-phases version of iMSDE prepared 3D T1-TFE, to obtain black-blood images by MSDE preparation at the 1st phase, and bright-blood images by T1-recovery of blood signals at the 2nd phase, simultaneously.

EXPERIMENTS: A total of 10 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.

EXPERIMENTS1: Contrast optimization of 3D MERGE black-blood imaging for contrast-enhanced studies. 3D-MERGE contrast is T1 weighted with a lesser degree of T2 weighting **[13]**, but the contrast (also black-blood effects) is strongly affected by flip angle (FA) and turbo factor. Therefore, we evaluated the influence of FA and turbo factor for optimal contrast, and attempted parameter optimization for contrast-enhancement studies. To compare the influence of FA and turbo factor quantitatively, signal-to-noise-ratio (SNR) in white-matter (SNR_{WM}) was measured by dividing the WM signal in the region-of-interest (ROI) by the standard deviation of noise outside the brain. Likewise, contrast-ratio (CR) was measured, which is calculated by the signal difference of the two ROIs, was estimated for WM and GM ($CR_{WM\text{-}GM}$) and WM and tumor ($CR_{WM\text{-}Tumor}$), respectively. Furthermore, to compare the blood-suppression effects of FA and turbo factor 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. Qualitative and quantitative analyses were done in a blinded manner. The examined imaging parameters were TR/TE/FA=7.5/3.2ms/**10~20**°. turbo factor=**30~120**, and total acquisition time=40sec.

EXPERIMENTS2: Experiments of VISIBLE in contrast-enhanced studies. The 2-Phase version of 3D-MERGE as VISIBLE sequence based on the results of EXPERIMENTS1 was performed in contrast-enhanced studies. In addition, we attempted a quantitative comparison with black- (1st phase) and bright-blood (2nd phase) images, which were acquired by the optimized VISIBLE sequence. The imaging parameters for VISIBLE were FOV=240mm, resolution=1.0mm^2, slices=180, slice thickness=1.0mm (no slice ZIP), TR/TE/FA=7.5 / 3.2ms / 15°. turbo factor=30, iMSDE preparation (duration=15ms, b-value=8.22s/mm^2), and total acquisition time = **4 min (2min/phase)**.

RESULTS: **Fig.2** demonstrates the quantitative comparison of SNR_{WM}, numbers of blood vessels, $CR_{WM\text{-}GM}$, and $CR_{WM\text{-}Tumor}$. SNR_{WM} decreased as FA increased, whereas No. of blood vessels, $CR_{WM\text{-}GM}$, and $CR_{WM\text{-}Tumor}$ increased as FA increased. The optimal FA was chosen as 15° because it provides both high CR and black-blood effect, and prevents SNR decrease. Meanwhile, $CR_{WM\text{-}Tumor}$ decreased as turbo factor increased, whereas SNR_{WM}, No. of blood vessels, and $CR_{WM\text{-}GM}$ increased as turbo factor increased. The optimal turbo factor was chosen as 30 because of high $CR_{WM\text{-}Tumor}$ and black-blood effect. **Fig.3** demonstrates the quantitative comparison with black- (1st phase) and bright-blood (2nd phase) images, which were acquired with the optimized VISIBLE sequence. **Fig.4** shows the contrast-enhanced black- and bright-blood images acquired with the optimized VISIBLE sequences (total acquisition time=4 min) of a patient with brain metastasis.

CONCLUSION: This study showed a new scheme of fast, volumetric, high-resolution, simultaneous bright- and black-blood imaging. This sequence can be used for 3D volumetric T1 weighted bright- and black-blood imaging, and is promising for detecting small brain metastases, because it yields improved differentiation between blood vessel and small brain metastases. Further clinical investigations are needed.

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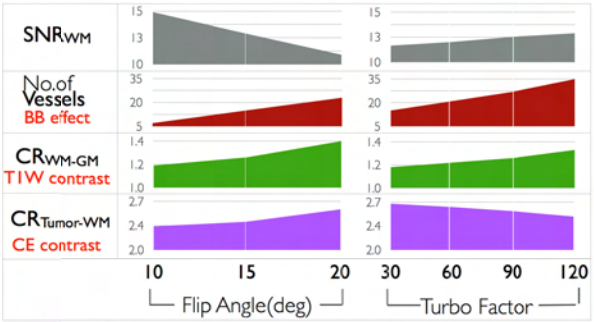

Fig.2 Quantitative comparison of SNR_{WM}, Numbers of blood vessels (as black-blood effect), $CR_{WM\text{-}GM}$(as T1 weighted contrast), and $CR_{WM\text{-}Tumor}$(as CE contrast).

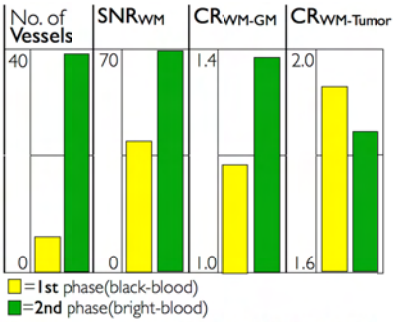

Fig.3 Comparison with black- (1st phase) and bright-blood (2nd phase) images, which acquired by optimized VISIBLE sequence.

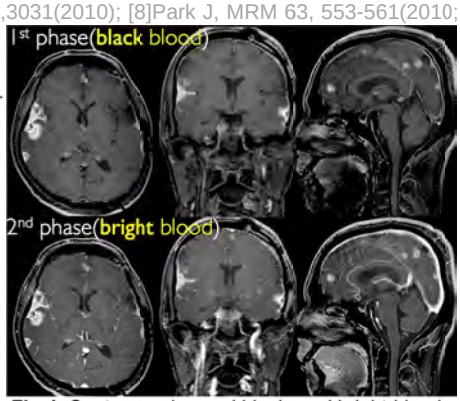

Fig.4 Contrast-enhanced black- and bright-blood images by optimized VISIBLE sequences of a patient with brain metastasis.