MR-GUIDED SCLEROTHERAPY OF LOW-FLOW VASCULAR MALFORMATIONS USING T_2-WEIGHTED INTERRUPTED BSSFP (T_2W-ISSFP): COMPARISON OF PULSE SEQUENCES FOR VISUALIZATION AND NEEDLE GUIDANCE

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BACKGROUND Venous malformations (VMs) and lymphatic malformations (LMs) are congenital lesions that affect both children and adults.[1] T_2-weighted fat suppressed turbo spin echo imaging (T_2W -TSE) is the gold standard for diagnostic imaging of VMs and LMs, and these lesions are typically treated percutaneously using ultrasound (US) for needle insertion and fluoroscopy for assessment of flow and draining veins. However, certain lesions cannot be accessed using US. Typically these include lesions that are deep within the body, that lie beneath scar, or are located in or behind bone. Real-time MR-guided intervention serves as an alternative. However, conventional real-time sequences are limited; they are either slow, with blurry, distorted edges (HASTE)[2] or demonstrate ambiguous malformation delineation because of poor T_2-weighting (bSSFP)[3].

PURPOSE To clinically deploy a new technique specifically designed for the visualization of VMs and LMs during real-time image guidance during intervention: T_2-weighted interrupted bSSFP (T_2W-iSSFP).

METHODS ***Sequence design:*** T_2W-iSSFP is a variable flip angle interrupted bSSFP sequence. T_2 contrast and fat suppression are based on T_2-TIDE[4] and FS-TIDE[5]. A prolonged TR combines T_2-TIDE and FS-TIDE, hence achieves simultaneous T_2 contrast and fat suppression.[6] T_2 weighting and fat suppression are customizable with higher/lower flip angles (HFA/LFA) in the bSSFP train, respectively. ***Patient testing:*** To compare the malformation visualization, patients (N=8) were scanned by HASTE, bSSFP and T_2W-iSSFP; TSE was used as the reference of lesion detection. Evaluation imaging was performed as pre-procedural imaging, with IRB approval. To evaluate the sequence's performance in patients, CNR efficiency (CNR of VMs vs. muscle divided by the square root of acquisition time) and image sharpness (the reciprocal of mean edge width of needles in the images of swine),[7] were used. Further, MR-guided percutaneous needle placement procedures were carried out using T_2W-iSSFP on swine (N=3) and on VM patients (N=8). All patients had undergone prior percutaneous sclerotherapy procedures with an actual or predicted inability to access their malformations using US.

RESULTS Using TSE as the reference sequence, 14 VMs were detected. The lesion detection rates are 14/14 (HASTE), 7/14 (bSSFP) and 14/14 (T_2W-iSSFP). The evaluation of the three real-time sequences are shown in Table 1. All MR guided sclerotherapy procedures using T_2W-iSSFP were successful. Specifically, all needles (14 punctures) were placed in the targeted lesions, which was confirmed by post-insertion T_2W-TSE and post-contrast FLASH. A successful MR guided VM embolization is presented in Fig 1.

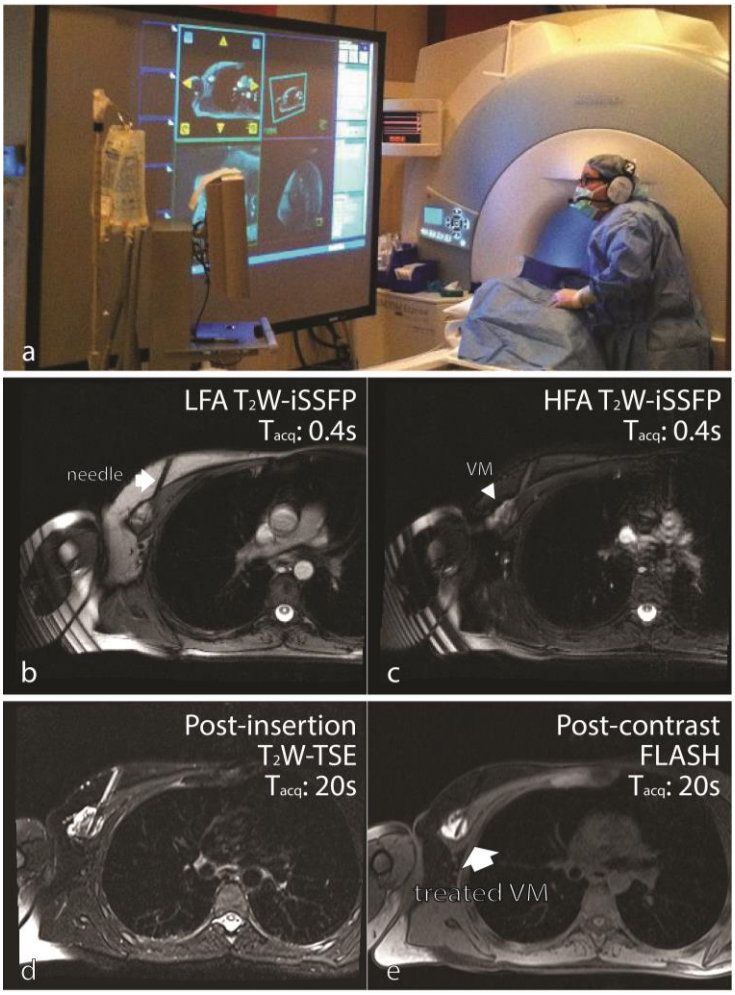

Fig 1. (a) Image depicting scanner suite layout as used during a VM embolization procedure. This 33 y.o. woman had a lesion in the right lateral chest wall adjacent to axilla and was referred for MR guidance due to a failure to locate the lesion using US. (b) LFA and (c) HFA T_2W-iSSFP images of real-time needle guidance are shown. Specifically, LFA T_2W-iSSFP permits superior needle and soft tissue delineation (arrow) while HFA T_2W-iSSFP depicts the VM (arrowhead). (d) Post-insertion T_2W-TSE and post-contrast 3D Fast Low Angle SHot (FLASH) demonstrate that the treated lesion was filled with gadolinium doped sclerosant successfully (3% sodium tetradecyl sulfate).

Table 1. Evaluation of image contrast, sharpness, speed, and SAR.

Metrics	HASTE	bSSFP	T_2W-iSSFP
CNR efficiency (a.u.)	797±66	281±44	860±29
Image sharpness (mm^{-1})	0.21±0.06	0.48±0.02	0.49±0.03
Time per slice (second)	1-2	0.3-0.6	0.3-0.7
SAR (W/kg)	1.6±0.1	1.1±0.3	1.3±0.1

CONCLUSION T_2W-iSSFP provides effective lesion identification and needle visualization. Using this sequence in MR-guided sclerotherapy, we successfully treated eight patients, which are all difficult cases. This sequence has potential use in other MR-guided procedures where heavily T_2-weighted real-time images are needed, such as liver biopsy, nephrostomy, and biliary drainage.

REFERENCES 1. Legiehn et al, Sem. Inter. Rad. 2010; 2. Ali et al, IMRI 2012; 3. Lewin et al, Radiology 1999; 4. Paul et al, MRM 2006; 5. Paul et al, MRM 2006; 6. Xu et al, ISMRM 2012; 7. Lai et al, MRM 2008.