MRI-guided Sclerotherapy of Low-flow Vascular Malformations at 1.5T using Tri-Plane Gradient-echo Pulse Sequences with Variable Frame Rates: Our Experience and Imaging Times

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Introduction

Magnetic resonance imaging (MRI)-guided sclerotherapy of low-flow vascular malformations has previously been described (1-3). MR-guided sclerotherapy with visualization of needle placement and injection requires high spatial and temporal resolution. Tri-plane gradient-echo (GRE) pulse sequences using continuous imaging in 3 different planes provides excellent spatial resolution however at relatively slow frame rates (3). We have developed slow, medium and fast frame rate versions of the tri-plane GRE sequences by adjusting imaging parameters. This study describes our experience and investigates the duration of various sclerotherapy steps in all sessions conducted over a 2 year period using these sequences.

Methods

This study is IRB-approved. One radiologist conducted 72 sclerotherapy sessions between August 2009 and July 2011 on lesions located in the head, neck or extremity of 27 subjects (age 13 days to 67 years). All procedures were performed on a 1.5T imaging system (Magnetom Espree, Siemens). During each session, diagnostic images (T_1W, T_2W and fat-saturated T_2W) were first obtained to plan the needle trajectory. Subsequently, the entry site for the needle was localized by moving a syringe filled with water along the skin surface over the lesion while monitoring by imaging with a tri-plane true fast imaging with steady state precession (True-FISP) pulse sequence. Three planes of True-FISP were chosen to visualize the entry site, target lesion and adjacent vital structures. The syringe was moved until it was visible at the desired entry site. A 20- or 22-gauge MRI-compatible needle was inserted into the lesion from the entry site also while monitoring using the same True-FISP sequence. Location of the needle tip can be estimated from the susceptibility artifact made by the metallic shaft. A gadolinium-mixed sclerosing agent (ethanolamine or doxycycline; 0.3cc of gadopentate dimeglumine was mixed in 5cc of normal saline and 0.3cc of the resultant solution was mixed in every 2cc of the sclerosing agent) was injected into the lesion while imaging with a tri-plane fast low-angle shot (FLASH) pulse sequence. Alignment of the three planes of FLASH was kept similar to the True-FISP used to place the needle. The extent of lesion filling by the sclerosing agent was estimated from the size of signal hyperintensity in FLASH images. Diagnostic imaging (post-contrast T_1W) was repeated to verify success of injection and exclude complications.

Two sets of pulse sequences were used in this study. Our first generation True-FISP and FLASH (averages = 3) yielded images with time/frame of 4 and 8s, respectively. We have recently developed slow, medium and fast versions of second generation sequences based on the first generation by removing averaging and varying spatial resolution and data acquisition bandwidth (Table 1). Any version can be chosen for a procedure depending upon the desired spatial and temporal resolution. Of 70 successful sessions, 59 were performed with first generation and 11 with second generation sequences. Total needle and scanner times were noted for each session. Mean values of both needle and total scan times were determined for all sessions and separately for the two sequence generations. Unpaired t-test (one-tailed, $\alpha = 0.05$) was used to study the significance of difference between times for the two generations of sequences.

Pulse sequence		TR/TE/α (ms/ms/°)	Voxel size (mm)	Aver-ages	BW (Hz)	Time/ frame
True-FISP	1st GEN	5.5/2.6/60	1.3×1.3×5	3	555	4s
	Slow	3.7/1.9/55	1.3×1.3×5	1	1015	1s
	Medium	3.5/1.7/50	1.6×1.6×5	1	1184	500ms
	Fast	3.8/1.9/50	2.3×2.3×5	1	558	250ms
FLA-SH	1st GEN	11.5/5.3/25	1.3×1.3×5	3	130	8s
	Slow	9.0/4.8/15	1.3×1.3×5	1	250	2s
	Medium	8.4/4.4/15	1.6×1.6×5	1	250	1s
	Fast	7.8/4.2/15	2.3×2.3×5	1	250	500ms

Table 1: Imaging parameters of the pulse sequences (field of view was taken as 30×30 cm). GEN: Generation.

Results and Discussion

The mean value of total needle and scanner time for all sessions was 8 min 53 s and 92 min 37 s, respectively. Average total needle time with the second generation pulse sequences was 41% shorter than that with first generation sequences (5 min 30 s vs. 9 min 21 s; $p = 0.05$). The mean scanner time was also reduced by 24% upon applying second generation pulse sequences (73 min 20 s vs. 96 min 13 s; $p = 0.001$). Complications were limited to two subjects who developed skin breakdown over the lesion, which healed without any further intervention. The injection was not possible in two sessions (both with first generation sequences) despite successful needle placement; in one case the lesion was thrombosed and in the other the lesion was too small.

Either of the two sequences can be used to localize the entry site, place the needle and inject the sclerosing agent. In our experience, due to contrast differences (T_1W from FLASH, T_2*/T_1W from True-FISP), True-FISP is more suitable for entry site localization and needle placement as it delineates the anatomy better and the sclerosing agent is more readily identified from FLASH. The flexibility of these sequences in choosing alignments of three imaging planes helps reduce the risk of injury to vital structures in vicinity to the needle path. The major fraction of total scanner time was spent on diagnostic imaging and operational planning, while the actual intervention lasted only 10% of total scanner time. We have achieved 4-16 times higher frame rate with second generation sequences compared to first generation sequences by sacrificing only a small extent of image quality (Figure 1). Our application of these new pulse sequences has further reduced the mean needle time to only 17% of the average value of intervention time previously reported at 0.2T (1).

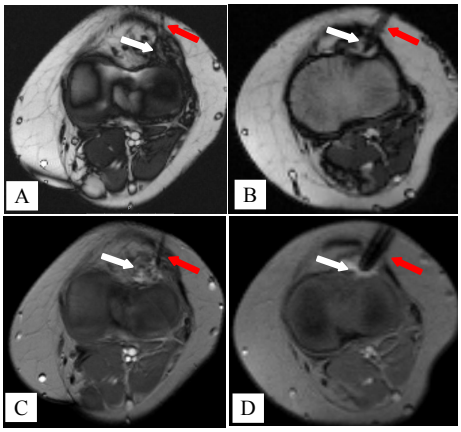

Figure 1: True-FISP (A, B) and FLASH (C, D) images of a lesion obtained using first and second generation sequences, respectively, in two separate sessions. White arrows denote the lesion and red arrows the needle. Visibility of fine structures is mildly lower in the images from new sequences. Signal hyper-intensity from the sclerosing agent is visible in both FLASH images and a True-FISP image (A). The needle appears thinner in A and C as its not fully aligned along the imaging slice.

Conclusion

Sclerotherapy can be performed at 1.5T with a needle time less than 10 min. Our application of new GRE sequences with faster frame rates have further reduced the needle time to ≈ 5 min.

References

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