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MR-guided Percutaneous Sclerotherapy of Low-Flow Vascular Malformations: Clinical Experience Using a 1.5-Tesla MR System

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Abstract

Purpose—To demonstrate the feasibility, safety, and effectiveness of image-guided sclerotherapy of low-flow vascular malformations using a 1.5-Tesla magnetic resonance (MR) scanner with real-time imaging capability and in-suite fluoroscopy.

Materials and Methods—33 procedures were performed with real-time 1.5-Tesla MR-guidance on 22 patients with a vascular malformation in the neck ($n = 2$), chest ($n = 6$), abdomen and pelvis ($n = 15$), and extremities ($n = 11$). Quantitative analysis was performed for changes in (a) planning time, (b) targeting time (interval between needle skin puncture and lesion access), (c) intervention time (interval between needle skin puncture and needle removal), and (d) total procedure time. Qualitative analysis was performed for (a) success of therapy and (b) occurrence of complications.

Results—Technical success was achieved in 29 out of 33 procedures. The average planning time did not significantly change between the first seven procedures and the last seven procedures ($P = 0.447$). The average targeting time decreased by 0:24:45 (hours:minutes:seconds) ($P = 0.043$), the average intervention time decreased by 0:26:58 ($P = 0.022$), and the average procedure time decreased by 0:28:41 ($P = 0.046$) when comparing the first seven procedures and the last seven procedures. Overall, there was an improvement in the patients' predominant symptoms following 82% of procedures, including a significant decrease in average pain following therapy ($P < 0.001$). There was a minor complication rate of 3% with no major complications.

Conclusion—MR-guided percutaneous sclerotherapy seems to be a safe, effective, and versatile technique for treating low-flow vascular malformations.

Keywords

Sclerotherapy; Venous malformations; Lymphatic malformations

INTRODUCTION

Venous malformations (VM) and lymphatic malformations (LM) are two types of low-flow vascular malformations (1). VMs and LMs are benign lesions composed of endothelial-lined venous and lymphatic channels, respectively (2). Both types of lesions can arise in any part of the body and range in size from solitary lesions to diffuse masses that extend across multiple tissue planes (2). Common clinical presentations include pain, swelling, bleeding, infection, and cosmetic deformity (2).

Most VMs and LMs can be diagnosed clinically, however, imaging is commonly used to confirm diagnosis, define extent of disease, plan treatment, and follow treatment response (2, 3). Magnetic resonance (MR) imaging is the preferred examination given its wide field of view, excellent soft tissue resolution, and ability to assess contrast enhancement characteristics and hemodynamics (3). In general, VMs and LMs are multilocular masses that demonstrate high signal on T2-weighted sequences (3). VMs will characteristically contain phleboliths and enhance during the venous phase of magnetic resonance angiography (MRA) (3). LMs, typically either demonstrate rim-enhancement or no enhancement but may contain fluid-fluid levels related to prior hemorrhage (3).

Among the various treatment options for vascular malformations, percutaneous sclerotherapy has emerged as a first line therapy (4). This technique involves the placement of a needle into the lesion and injection of an endothelial-damaging agent (sclerosant) to cause thrombosis and fibrosis. A variety of sclerosants are available, including ethanol (ETOH), sodium tetradecyl sulfate (STS), doxycycline (Doxyc), and ethanolamine oleate (EO) (5, 6).

Imaging is an integral component of sclerotherapy and is performed before, during, and after a procedure. Pre-intervention and post-intervention assessments are usually performed using MR. Intra-procedural needle guidance is typically performed using US, given its real-time capabilities, good soft tissue resolution, and ready availability. Once a needle has been placed, fluoroscopy is commonly used to assess lesion hemodynamics and monitor the injection of the sclerosant. Fluoroscopy has the advantages of high spatial and temporal resolution, which are necessary to quickly detect potentially harmful instances of sclerosant extravasation.

More recently, interventional MR has emerged as an imaging alternative for real-time needle guidance (7–9). MR may be particularly beneficial for treatment of vascular malformations that cannot be adequately characterized with US, such as lesions deep within the abdomen, beneath scar or bone, or adjacent to critical structures. Additionally, MR provides the ability to perform multiple treatments to large lesions without exposing patients, many of whom are

children and women of childbearing age, to ionizing radiation. Sclerotherapy of low-flow vascular malformations has previously been performed using a low-field MR system (8, 9). In this paper, we present our experiences in treating low-flow vascular malformations using a modern wide-bore 1.5-Tesla MR system with the goal of demonstrating the feasibility, safety and effectiveness of this technique.

MATERIALS AND METHODS

Between September 2010 to April 2014, a total of 22 patients, 14 females and eight males, with a VM or LM were referred to our division for MR-guided sclerotherapy. Referrals were from clinicians within our institution's multidisciplinary vascular anomaly group based on actual or predicted inability to target a lesion using US. Pregnant patients and those with ferromagnetic prostheses were excluded from the study. The Health Insurance Portability and Accountability Act-compliant protocol and the informed consent process were approved by the institutional review board. The primary operator (C.R.W.) had 11 years of experience in vascular and interventional radiology and six years of experience in MR-guided vascular interventions.

Procedures were conducted in an MRI-angiography "MIYABI" suite with a MAGNETOM Espree 1.5-T MR scanner and an AXIOM Artis dFA (Siemens Healthcare, Erlangen, Germany). Coil selection was determined by the location of the lesion. Initial characterization was performed with a T2-weighted turbo spin echo (TSE) spectral adiabatic inversion recovery (SPAIR) sequence (Figure 1, Table 2). Needle entry points were marked on the skin after localizing a water filled syringe over the lesion while imaging with T2-weighted half Fourier acquired single shot turbo spin echo (HASTE). Trajectory planning for the majority of the procedures was performed using a high-resolution MR dataset within the Siemens Interactive Front End (IFE), an MR navigation and visualization prototype (10).

As is the practice at our institution, all patients undergoing percutaneous sclerotherapy were treated under general anesthesia. Outside of the MR scanner the patient was prepped and draped using sterile technique, the needle entry point was infiltrated subcutaneously with 1% lidocaine, and an MR compatible needle (20–22 gauge; 5–20 cm in length; Cook Medical, Bloomington, IN) was inserted. The needle was advanced into the lesion using HASTE, interactive real-time TrueFISP (BEAT IRTTT), or a custom-made T2-weighted contrast prepared steady state free precession (CP-SSFP) sequence with IFE and a frame rate of 2.5–3.5 frames per second (11, 12). Access was confirmed by the presence of blood or lymphatic fluid with aspiration. If the hemodynamics of a lesion were not fully elucidated on pre-procedure imaging, an injection of 0.002 mmol/cc gadopentetate dimeglumine (Magnevist, Bayer Healthcare Pharmaceuticals, Berlin, Germany) was performed while imaging with a Fast Low Angle Shot (FLASH) sequence to confirm that the lesion demonstrated low (and not fast) flow.

After the needles were placed the workflow diverged depending on the choice of sclerosant (Figure 1). Workflow #1 (MRI for monitoring of sclerosant delivery): "Milder" sclerosants were administered using MR guidance alone. Sclerosants included Doxy (Doxy 100, APP Pharmaceuticals, LLC Schaumburg, IL, USA) for LM and 5% EO (QOL Medical, LLC,

Vero Beach, FL, USA) or 3% STS (Sotradecol, Angiodynamics, Albany, NY, USA) for VM. These sclerosants could be doped with 1.25 to 2.50 micro-molar Magnevist and were therefore considered to be safe to be administered under MR guidance (8). With HASTE or fat-saturated T1-weighted gradient echo (GRE) BEAT IRTTT sequences, these Magnevist doped agents could be seen to fill a lesion or to extravasate, which would be critical for safety. These agents were not foamed because the associated susceptibility artifact would render MR imaging inadequate, and therefore the overall dose with these sclerosants was limited.

Workflow #2 (fluoroscopy for monitoring of sclerosant delivery): Workflow #2 applied to the majority of lesions treated with ETOH. Because ETOH cannot not be doped with Magnevist and because of the toxicity of ETOH to normal tissues if extravasation were to occur, ETOH was generally administered with fluoroscopic visualization once the needles had been placed under MR guidance (Workflow #2). During these cases, patients were transferred to the in-suite Artis, where an injection of ioxilan 350 mgI/mL (Guerbet, Villepinte, France) was used to confirm needle location, and ETOH was then administered using fluoroscopy. In both workflows, post-intervention imaging consisted of TSE SPAIR and T1-weighted three-dimensional volumetric interpolated breath-hold examination (VIBE) sequences.

In three procedures, where lesions were in non-critical locations, where the potential risks associated with extravasation were low, and where prior treatments with Doxy, EO, or STS had failed, we administered small volumes of ETOH under MR guidance alone (these lesions were considered under Workflow #1).

Quantitative assessment of MR-guided sclerotherapy focused on the times to complete individual tasks within the procedure as well as the total procedure time. Times (planning, targeting, intervention, and total procedure) were documented for each treatment. Planning time was defined as the interval between the start of pre-intervention imaging and needle skin puncture. During this interval, initial MR images were acquired and interpreted with a focus on best needle approach to the target lesion. Targeting time was defined as the interval between needle skin puncture and lesion access. Intervention time was defined as the interval between needle skin puncture and needle removal. Total procedure time was defined as the interval between the start of pre-intervention imaging and the end of post-intervention imaging. In procedures where multiple lesions were treated in one session, planning, targeting, intervention, and total procedure times were normalized to the number of targets attempted.

Patients were evaluated in our outpatient clinic before and after percutaneous sclerotherapy (post-procedure evaluation occurred on average 75.6 ± 180.3 days following the procedure), at which times interviews and physical examinations were conducted. Patients rated the severity of his or her predominant symptom, such as pain or bleeding, before and after sclerotherapy. Patients who had pain as their predominant symptom rated the severity of pain numerically on a scale of 0 to 10 (0 defined as no pain and 10 defined as worst possible pain). Additionally, any occurrence of complication was evaluated and documented. Major complications were defined as complications that required intervention or prolonged

hospitalization. For patients with large lesions who underwent staged interventions, each sclerotherapy procedure was considered as a separate event for statistical purposes.

The mean value and standard deviation for each of the evaluated quantitative and qualitative parameters were calculated for all procedures, the first seven procedures, and the last seven procedures. The first and last seven patients were chosen for comparison to demonstrate the greatest change in learning. Analysis of differences between the first seven procedures and last seven procedures was performed with unpaired single-tailed Student *t* tests. A *P* value of less than .05 was considered to indicate a statistically significant difference.

RESULTS

The 22 patients referred for MR-guided sclerotherapy ranged in age from 8 to 61 years (mean 37.3 ± 16.0 years). The group yielded a total of 33 procedures, which targeted lesions in the neck ($n = 2$), chest ($n = 6$), abdomen and pelvis ($n = 15$), and extremities ($n = 11$) (Table 1). As many of the 33 procedures involved targeting more than one lesion (or more than one component of a lesion), a total of 69 treatment attempts were ultimately made.

Technical success, defined by intralesional delivery of sclerosant, was achieved in 29 out of 33 procedures (88%) and 59 of 69 treatment attempts. An average of 2.2 ± 1.6 targets per procedure were attempted. An average of 2.3 ± 1.6 needles per procedure were used. An average 2.6 ± 1.8 needle passes per procedure were performed. An average of 2.0 ± 1.5 targets were treated. There were no significant differences in the average number of targets attempted, number of needles used, number of passes performed, or targets treated per procedure when comparing the first seven procedures and last seven procedures (Table 3).

The average planning time for all procedures was $0:45:42 \pm 0:24:35$ (hours:minutes:seconds). There was a non-significant decrease in planning time of $0:01:44$ ($P = 0.447$) from an average of $0:41:59 \pm 0:27:08$ for the first seven procedures to an average of $0:40:16 \pm 0:20:09$ for the last seven procedures. The average targeting time for all procedures was $0:14:18 \pm 0:19:49$. The targeting time decreased by $0:24:45$ ($P = 0.043$) from an average of $0:33:33 \pm 0:31:07$ for the first seven procedures to an average of $0:08:48 \pm 0:11:44$ for the last seven procedures. The average intervention time for all procedures was $0:39:24 \pm 0:23:07$. The intervention time decreased by $0:26:58$ ($P = 0.022$) from an average of $0:56:42 \pm 0:27:57$ for the first seven procedures to an average of $0:29:45 \pm 0:09:16$ for the last seven procedures. The average total procedure time for all procedures was $1:25:05 \pm 0:37:59$. The total procedure time decreased by $0:28:41$ ($P = 0.046$) from an average of $1:38:42 \pm 0:31:07$ for the first seven procedures to an average of $1:10:00 \pm 0:27:19$ for the last seven procedures.

While technical success was achieved in the majority of cases, four of the 33 procedures were technically unsuccessful. Patient 1 (Table 1) had a small VM in the chest wall that was accessed and completely aspirated such that sclerotherapy could not be performed. A VM in the thigh of patient 3 was too small to be accessed using a 22-gauge needle. Patient 7 had an intraosseous VM in the pelvis, which could not be adequately accessed using the MR compatible tools available at the time of the procedure. The foot VM in patient 10 was

successfully accessed, however, further characterization of this lesion with intralesional contrast injection and FLASH imaging demonstrated the malformation to be a type IV lesion with a rapidly draining ectatic plantar vein, which was deemed too complicated to treat under MR guidance.

Therapeutic success, defined by improvement in predominant symptom, was achieved following 27 out of 33 procedures (82%). Twenty-two patients endorsed pain as their predominant symptom and yielded a total of twenty-seven procedures. These patients reported an average pre-procedure pain rating of 5.1 ± 2.7 and an average post-procedure pain rating of 2.6 ± 2.4 for an average decrease in pain of 2.5 ($P < 0.001$) (Table 3). Eight patients (24%) reported complete resolution of their pain following a single procedure. Six patients (18%) reported no change in their pain, although four of these patients had lesions that were not ultimately treated with sclerotherapy, as described above. Patient 5, who had a VM involving the urinary bladder and hematuria as his predominant symptom, reported complete resolution of symptoms following sclerotherapy. Patient 17, who underwent five procedures for a VM involving the rectum and hematochezia as his predominant symptom, subjectively reported gradual improvement in his symptoms following every procedure. Several patients reported improvement in secondary symptoms, including dysuria, hand dysfunction, and gait abnormality.

There were no major complications. The minor complication rate was 3% ($n = 1$) with one patient experiencing urinary retention for 24 hours following treatment of a perirectal VM. There was no evidence of adjacent organ damage on follow up imaging for patients with intra-abdominal lesions. The two patients with a VM in the neck did not exhibit signs or symptoms of airway compromise during or after the procedure and were uneventfully extubated following sclerotherapy.

The majority of procedures utilized MR-guidance alone to place the needle and administer sclerosant (Workflow #1). One example is the case of a 41-year-old woman with Klippel-Trenaunay syndrome (patient 12 in Table 1) causing multifocal VMs throughout the abdomen and lower extremity. She had previously undergone a series of US-guided interventions on her thigh and leg. In the abdomen, her predominant symptom was pain secondary to mass effect. She was referred for MR-guided sclerotherapy of her intra-abdominal lesion because of its proximity to deep critical structures, such as the abdominal aorta and inferior vena cava. One of her MR-guided interventions is outlined in Figure 2.

In four procedures, after MR-guided needle placement, the patient was transferred to the fluoroscopy table for sclerosant delivery (Workflow #2). One example is the case of a 20-year-old woman with Blue Rubber Bleb Nevus Syndrome (patient 2 in Table 1) and a VM that was not adequately visualized with US but was clearly visible with MR imaging. Her paraspinal lesion was successfully accessed with MR-guidance and subsequently treated with ETOH under fluoroscopy (Figure 3). Follow-up imaging performed at 6 weeks post-sclerotherapy shows complete thrombosis of the lesion (Figure 3f).

ETOH, the most potent of the four sclerosants used, was injected into 18 lesions. An average of 7.9 mL ETOH was injected into 15 lesions in four patients while observing with

fluoroscopy. These lesions were intra-abdominal except for one that was located within a thigh. An average of 3.8 mL ETOH was injected into three lesions in three patients while observing with real-time MR imaging. These lesions were located within the shoulder, knee, and abdomen. All other sclerosants (Doxyl, EO, STS) were injected while observing with real-time MR alone.

DISCUSSION

In the present study we evaluated the feasibility, safety, and effectiveness of percutaneous sclerotherapy of low-flow vascular malformations using a 1.5-Tesla MR with real-time imaging capability and in-suite fluoroscopy. Over the course of 33 procedures a technical success rate of 88% was achieved despite difficult lesion location and morphology. Given that ultrasound guided sclerotherapy had either previously failed or was predicted to fail in all of the lesions targeted in this study, this 88% can also be considered as a salvage therapy rate. MR therefore demonstrated its utility in this study as a problem-solving tool for lesions that could not be treated by traditional methods.

The procedure proved to be safe without any incidence of major complication and a minor complication rate of 3%. The most commonly reported complication of sclerotherapy is skin damage (blistering, necrosis, and ulceration), which has been reported as occurring in 13% to 50% of cases by Berenguer *et al.* and in 14% of cases by O'Donovan *et al.* (13, 14). There were no instances of skin damage in our procedures reported here. The discrepancy between the reported complication rate and our experiences is likely related in part to the overall deeper location of the lesions we targeted.

Efficacy was demonstrated by symptomatic improvement after 82% of procedures, which is similar to previously reported symptomatic improvement rates of 75% to 86% (13, 14). Eight patients reported complete pain resolution after a single treatment. While we realize that complete symptomatic relief after a single sclerotherapy treatment is quite rare, the targets in these particular cases were either focal lesions or associated with low pre-procedure pain levels.

As more procedures were performed, familiarity with the procedure increased and technical efficiency improved, as demonstrated by significant decreases in the targeting, intervention, and total procedure times when comparing the first and last seven procedures. Use of image-assisted needle targeting software likely improved our practice by allowing us to define optimal needle entry points and needle path to target before skin puncture. The software clearly outlines the planned needle path compared to the actual needle position, and those images can be displayed on a projection screen alongside the scanner (10).

Interestingly, planning time did not significantly change when comparing the first and last seven procedures. This is likely related to the fact that the majority of the planning time was devoted to the acquisition of a standard set of MR sequences for all patients, which resulted in little opportunity to increase efficiency. Overall, the total procedure time, procedure learning curve, and treatment response with MR guidance are on par with our institutional experience with US and fluoroscopy guided procedures. We look forward to further

optimizations in computer-aided needle path planning, which we believe will further increase procedural efficiency, and increases in real-time pulse sequence refresh frequency, which may allow for improved monitoring of delivery of potent sclerosants such as ETOH.

There are several limitations of this study. Firstly, there are constraints on the generalizability of the described technique. While the presence of a fluoroscopy table within the same room as an interventional MR system allows for efficient transfer of patients between the two modalities, interventionalists within the medical community at large may be limited by the lack of availability of such a combined MR-radiographic fluoroscopy suite. However, this will likely only be a disadvantage in the setting where large volume ETOH is the preferred sclerosant. As demonstrated here, Doxy, EO, STS, and small volumes of ETOH were safely and effectively administered without the need for fluoroscopy.

An additional weakness is the small sample size, which limits the strength of some of the conclusions presented here. Comparison of the first and last seven procedures, which was done to demonstrate a learning curve, is confounded by differences in lesion location and complexity. While there were not enough procedures to control for these differences, no significant differences were demonstrated between the first and last seven procedures when considering several objective measures, such as average number of targets attempted, number of needles used, number of passes performed, and targets treated per procedure. In the future, we look forward to strengthening the conclusions presented here by comparing data on the treatment of lesions in similar locations and of similar size.

In conclusion, our results demonstrate that MR-guided sclerotherapy of low-flow vascular malformations is feasible, safe, and effective. This technique can be considered as a salvage therapy for lesions that cannot be safely accessed with US. The procedure is readily adaptable to advanced interventional practices with an interest in treating vascular malformations.

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Figure 1.

Methods Flowchart. **a:** Workflow #1 was completed with MR imaging alone; “Milder” sclerosants including Doxy, EO, and STS, as well as smaller volumes of ETOH are delivered with real-time MR guidance. **b:** Workflow #2 utilized the in-suite fluoroscopy, which allowed for the safe delivery of larger volumes of ETOH.

Figure 2.

Treatment of 41-year-old woman with Klippel–Trénaunay Syndrome. **a:** Pre-treatment axial T2 TSE with fat saturation demonstrating a massive intraabdominal VM. **b:** Scanner setup showing interventional radiologist placing needles under direct MR-guidance using the IFE projected onto a screen in the scanner room. **c:** Axial RT TrueFISP image showing multiple needles (yellow arrows) placed in deep lesions, avoiding critical structures such as the Aorta and Vena Cava (red arrows). **d:** Post-treatment axial 3D VIBE confirming delivery of gadolinium-doped sotradecol within multiple portions of the VM. Two of the treatment needles can also be seen (yellow oval).

Figure 3.

20-year-old woman with Blue Rubber Bleb Nevus Syndrome. **a:** Pre-treatment axial T2 SPAIR with fat saturation demonstrating septated VM (arrow) within the right psoas muscle. **b:** Needle targeting VM (arrow) with sagittal RT TrueFISP. **c:** Flow assessment within the lesion (arrow) with axial subtracted FLASH. **d:** AP planar projection during administration of sclerosant (100% ETOH, arrow) using fluoroscopy. A 19 cm loop coil used for MR-guided needle placement can be seen. **e:** Axial T1 VIBE of VM (arrow) 10 minutes after treatment showing thrombus within the lesion. **f:** Axial T2 TSE with fat saturation of healed VM site (arrow) 6 weeks post-treatment.

Summary of 33 MR-guided percutaneous sclerotherapy procedures. Some patients were treated by more than one procedure as indicated by the repeats in patient number. Abbreviations: Doxy (Doxy 100), EO (ethanolamine oleate), STS (Sotradecol), ETOH (ethanol), VM (venous malformation), LM (lymphatic malformation)

Table 1

Procedure number	Patient number	Age (years)	Gender	Lesion type	Lesion location	Predominant symptom	Targets attempted	Targets treated	Sclerosant	Workflow Number	Technical Success	Therapeutic Success
1	1	54	F	VM	Left chest wall	Pain	1	0	None	1	No	No
2	2	20	F	VM	Right lower back	Pain	2	2	ETOH	2	Yes	Yes
3	3	18	F	VM	Left shoulder	Pain	1	0	None	1	No	No
4	4	56	M	LM	Right acetabulum	Pain	2	2	Doxy	1	Yes	Yes
5	5	8	M	LM	Urinary bladder	Hematuria	2	1	Doxy	1	Yes	Yes
6	6	22	F	VM	Left thigh	Pain	6	5	ETOH	2	Yes	Yes
7	7	27	M	VM	Right pelvis	Pain	1	0	None	1	No	No
8	8	48	F	VM	Left shoulder	Pain	1	1	ETOH	1	Yes	Yes
9	9	21	M	VM	Left knee	Pain	1	1	ETOH	1	Yes	Yes
10	10	37	F	VM	Left foot	Pain	1	0	None	1	No	No
11	11	52	F	VM	Left triceps	Pain	1	1	EO	1	Yes	Yes
12	8	48	F	VM	Left shoulder	Pain	2	1	EO	1	Yes	Yes
13	12	40	F	VM	Abdomen	Pain	4	4	STS	1	Yes	Yes
14	13	23	F	VM	Left thigh	Pain	1	1	STS	1	Yes	Yes
15	12	40	F	VM	Abdomen	Pain	7	7	STS, ETOH	1	Yes	Yes
16	12	40	F	VM	Abdomen	Pain	4	4	ETOH	2	Yes	Yes
17	14	33	F	VM	Right chest wall	Pain	1	1	STS	1	Yes	Yes
18	12	40	F	VM	Abdomen	Pain	4	4	ETOH	2	Yes	Yes
19	12	40	F	VM	Abdomen	Pain	1	1	STS	1	Yes	Yes
20	15	54	M	VM	Shoulder	Pain	2	2	STS	1	Yes	Yes
21	12	40	F	VM	Abdomen	Pain	2	2	STS	1	Yes	Yes
22	14	33	F	VM	Right chest wall	Pain	1	1	STS	1	Yes	Yes
23	16	27	F	VM	Left hand	Pain	1	1	STS	1	Yes	No
24	17	48	M	VM	Perirectal	Hematochezia	1	1	STS	1	Yes	Yes

Procedure number	Patient number	Age (years)	Gender	Lesion type	Lesion location	Predominant symptom	Targets attempted	Targets treated	Sclerosant	Workflow Number	Technical Success	Therapeutic Success
25	18	61	M	VM	Left neck	Pain	1	1	STS	1	Yes	Yes
26	17	48	M	VM	Perirectal	Hematochezia	2	2	STS	1	Yes	Yes
27	17	48	M	VM	Perirectal	Hematochezia	2	2	STS	1	Yes	Yes
28	19	50	F	VM	Back	Pain	5	3	STS	1	Yes	No
29	20	51	M	VM	Left upper back	Pain	2	1	STS	1	Yes	Yes
30	17	48	M	VM	Perirectal	Hematochezia	3	3	STS	1	Yes	Yes
31	21	53	M	VM	Left posterior neck	Pain	1	1	STS	1	Yes	Yes
32	17	48	M	VM	Perirectal	Hematochezia	2	2	STS	1	Yes	Yes
33	22	18	F	VM	Right thigh	Pain	1	1	STS	1	Yes	Yes

Table 2

Parameters for each of the pulse sequences used during pre-intervention planning, needle guidance, sclerosant delivery, and post-intervention assessment.

	T2 TSE SPAIR	HASTE	BEAT IRTTT (SSFP)	BEAT IRTTT (GRE)	CP-SSFP	VIBE
Field of view	300	300	300	300	300	300
Slice thickness (mm)	5	5	5	5	5	3
Acquisition time (s)	20	2	0.7	1	0.7	
TE/TR (ms)	90/5000	91/2000	1.87/376	2.29/496	2.25/4.5	2.38/4.75
Echo spacing (ms)	15.8	7.5			4.5	
Flip angles (degrees)	90/180	90/180	60	30	90/180/60	9.5
Pixel bandwidth (Hz/px)	100	195	810	330	868	416

Table 3

Summary of quantitative and qualitative results calculated for all procedures, the first seven procedures, and the last seven procedures. Abbreviations: SD (standard deviation).

	Mean	SD	Difference	P-value
Targets attempted	2.2	1.6		
Targets attempted (first 7)	2.1	1.8		
Targets attempted (last 7)	2.3	1.4	+0.2	0.435
Number of needles	2.3	1.6		
Number of needles (first 7)	2.4	1.7		
Number of needles (last 7)	2.4	1.3	0	0.500
Numbers of passes	2.6	1.8		
Numbers of passes (first 7)	3.1	2.1		
Numbers of passes (last 7)	2.6	1.3	-0.6	0.277
Targets treated	2.0	1.5		
Targets treated (first 7)	1.9	1.5		
Targets treated (last 7)	1.9	0.9	0	0.500
Planning time	0:45:42	0:24:35		
Planning time (first 7)	0:41:59	0:27:08		
Planning time (last 7)	0:40:16	0:20:09	-0:01:44	0.447
Targeting time	0:14:18	0:19:49		
Targeting time (first 7)	0:33:33	0:31:07		
Targeting time (last 7)	0:08:48	0:11:44	-0:24:45	0.043
Intervention time	0:39:24	0:23:07		
Intervention time (first 7)	0:56:42	0:27:57		
Intervention time (last 7)	0:29:45	0:09:16	-0:26:58	0.022
Total procedure time	1:25:05	0:37:59		
Total procedure time (first 7)	1:38:42	0:31:07		
Total procedure time (last 7)	1:10:00	0:27:19	-0:28:41	0.046
Pre-procedure pain	5.1	2.7		
Post-procedure pain	2.2	2.1	-2.9	<0.001