Morbidity of Direct MR Arthrography

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OBJECTIVE. The purpose of this study was to determine the incidence and severity of arthrographic pain after intraarticular injection of a gadolinium mixture diluted in normal saline for direct MR arthrography.

SUBJECTS AND METHODS. From March 2009 until January 2010, 155 consecutive patients underwent direct MR arthrography; 20 patients were lost to follow-up. Patients were contacted by telephone between 3 and 7 days after joint injection. Using an 11-point numeric pain rating scale, patients were asked to report if they had experienced joint pain that was different or more intense than their preinjection baseline, the severity of pain, the duration of pain, time to onset of pain, and eventual resolution of pain.

RESULTS. The incidence of postarthrographic pain was 66% (89/135), with an average intensity of pain of 4.8 ± 2.4 (range, 1–10). Postarthrographic pain lasted an average of 44.4 ± 30.5 hours (range, 6–168 hours). The time to onset of pain after joint injection was on average 16.6 ± 13.1 hours (range, 4–72 hours). There was no significant difference regarding the severity or incidence of postarthrographic pain between groups on the basis of patient age (p = 0.20 and 0.26), patient sex (p = 0.20 and 0.86), contrast mixture contents (p = 0.83 and 0.49), or joint injected (p = 0.51 and 0.47). No patients experienced any other serious side effects.

CONCLUSION. Sixty-six percent of patients who undergo direct MR arthrography will experience a fairly severe delayed onset of pain that completely resolves over the course of several days.

Keywords: direct MR arthrography, intraarticular injection, pain

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Direct MR arthrography is largely regarded to be a safe and useful procedure [1, 2]. However, the patient morbidity associated with this procedure may be highly underestimated. According to a questionnaire handed out to practicing radiologists, the incidence of postarthrographic pain from MR arthrography has been reported to be approximately 0.02% [1]. In another questionnaire, radiologists reported the incidence of pain and synovitis from conventional arthrography to be 0.1% [3]. A recent study of direct MR arthrography that obtained quantitative data from 1085 patient questionnaires reported a low severity of postarthrographic pain, on the order of an increase from baseline of approximately 1 on a 10-point scale, but did not report incidence of postarthrographic pain [2]. In another series of 202 patients who underwent shoulder direct MR arthrography, the average patient rating of postarthrographic pain was 18.0 on a 100-point scale, but this study also failed to report incidence of postarthrographic pain [4].

Epinephrine has been widely advocated and used in direct MR arthrography. It has been shown with conventional arthrography that the incidence of postarthrographic pain can be reduced from 71% to 42% by withholding epinephrine [5]. However, this data on the effect of epinephrine on the incidence of postarthrographic pain was obtained in the absence of intraarticular gadolinium injection. To our knowledge, there have been no reports in the literature on the influence of intraarticular epinephrine injection on the incidence of postarthrographic pain after direct MR arthrography.

The purpose of our prospective study was to determine the morbidity of direct MR arthrography, specifically the incidence, severity, duration, and time to onset of arthrographic pain after intraarticular injection of a gadolinium and epinephrine mixture diluted in normal saline and of a gadolinium

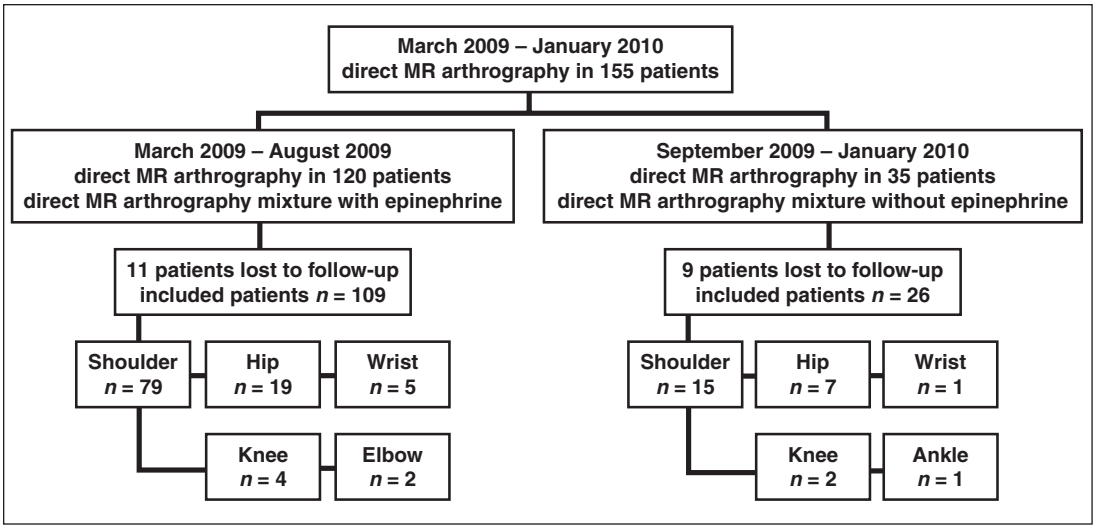

Fig. 1—Flowchart shows data for 155 patients included in this study. Complete follow-up data were available for 136 patients.

mixture without epinephrine diluted in normal saline.

Subjects and Methods

Patients

This prospective, single-center nonrandomized study was approved by the institutional review board of our institution. From March until August 2009, 120 consecutive patients underwent direct MR arthrography for standard clinical indications (Fig. 1). Eleven patients were lost to follow-up. Seventy-nine shoulders, 19 hips, five wrists, four knees, and two elbows were injected with 41% iopamidol (Isovue-M 200, Bracco), 2 mmol/L gadopentetate dimeglumine (Magnevist, Bayer HealthCare), 1% ropivacaine HCl (Naropin, APP Pharmaceuticals), and 1:1000 epinephrine diluted in bacteriostatic normal saline and followed by MRI.

We also investigated whether epinephrine had an influence on the incidence of postarthrographic pain after direct MR arthrography. From September 2009 through January 2010, 35 patients underwent direct MR arthrography for standard clinical indications at our institution (Fig. 1). Nine patients were lost to follow-up. Fifteen shoulders, seven hips, one wrist, two knees, and one ankle were injected with 41% iopamidol, 2 mmol/L gadopentetate dimeglumine, and 1% ropivacaine HCl diluted in bacteriostatic normal saline and followed by MRI.

Patient demographic data were recorded. Seventy-eight males and 58 females were included. The average age of males and females in the study was 34.8 ± 12.5 years and 36.6 ± 13.2 years, p = 0.42. Patient age ranged from 15 to 72 years.

Injection Technique

All injections were performed with fluoroscopic guidance in accordance with institutional standard operating procedures. Technical parameters are described in Table 1 [6]. All arthrography was performed by musculoskeletal radiology fellows. Local anesthesia was obtained by injecting a small volume of ~2–5 mL of 1% lidocaine HCL (Xylocaine-MPF, AstraZeneca) mixed with 8.4% sodium bicarbonate (84 mg/ mL) subcutaneously and deeper to the bone. The local anesthesia mixture consisted of 4 mL of 1% lidocaine HCl and 1 mL of 8.4% sodium bicarbonate (84 mg/ mL). Approximately the same total volume of the direct MR arthrography mixture was injected into each of the respective joints. Fluid was never injected into a joint past patient discomfort. Generally, each joint was injected until the patient reported a sense of fullness to insure joint distention, which accounted for some variability in the total volume injected into each joint.

Contrast Media Injection

Our standard protocol for the shoulder, hip, elbow, and ankle involved first injecting a small volume of dilute iodinated contrast material into the joint. The iodinated contrast mixture was composed of 10 mL of bacteriostatic normal saline (9 mg/mL sodium chloride and 9 mg/mL benzyl alcohol) or nonbacteriostatic saline (9 mg/mL sodium chloride, 0.308 mOsmol/mL) and 10 mL of 41% iopamidol in a 30-mL syringe. A small volume of ~2 mL of this dilute iopamidol was first injected into the joint to ensure appropriate intraarticular needle tip localization. Subsequently, a standard volume of a 2 mmol/L dilution of gadopentetate dimeglumine (469.01 mg gadopentetate dimeglumine/mL) was injected into the joint but never past the patient's subjective perception of joint fullness. The gadolinium mixture consisted of 15 mL of bacteriostatic normal saline (9 mg/mL sodium chloride and 9 mg/mL benzyl alcohol), 5 mL of 1% ropivacaine HCl (10 mg/mL), 0.3 mL of 1:1000 epinephrine (1 mg/mL), and 0.1 mL of gadopentetate dimeglumine. Standard total injection volumes

TABLE 1: Technical Issues and Injected Volumes of Local Anesthetics, Iodinated Contrast Media, and Gadolinium Chelates

Joint	Injection Point	Needle Size (cm, gauge)	50% Dilute Iopamidol[a] (mL)	0.5% Dilute Gadopentetate Dimeglumine[b] (mL)
Shoulder	Anterior rotator interval	2.5, 22	2	10
Elbow	Transtriceps tendon	2.5, 22	2	4
Hip	Superolateral femoral neck	3.5, 20	2	8
Knee	Superolateral patellofemoral	2.5, 20	4	21
Ankle	Anterior tibiotalar	2.5, 22	2	2
Wrist	Radioscaphoid	2.5, 25	4[c]	4[c]

Note—Data are best approximations of volume injected. Slight variability between patients did occur.
[a]Isovue-M 200 manufactured by Bracco.
[b]Magnevist manufactured by Bayer HealthCare.
[c]MR arthrography of the wrist was performed with iopamidol and gadopentetate dimeglumine diluted in the same mixture. The total of ~4 mL of a mixture was composed of 10 mL of iopamidol, 5 mL of bacteriostatic normal saline, 5 mL of 1% ropivacaine, 0.1 mL of gadopentetate dimeglumine, and 0.3 mL of 1:1000 epinephrine.

TABLE 2: Postarthrographic Pain After Direct MR Arthrography in Different Joints

Joint	No. of Patients	Incidence of Pain (%)	Pain Score	Duration (h)	Time to Onset (h)
Shoulder	94	68 (64/94)	4.7 ± 2.3	45.5 ± 33.1 (56)	16.3 ± 13.5 (25)
Hip	26	77 (20/26)	5.2 ± 2.8	37.8 ± 15.3 (17)	19.0 ± 14.9 (6)
Wrist	6	33 (2/6)	7.0 ± 2.8	48.0 ± 0 (2)	NP
Knee	6	50 (3/6)	4.0 ± 2.0	58.7 ± 56.8 (3)	14.0 ± 7.2 (3)
Elbow	2	(0/2)	NA	NA	NA
Ankle	1	(0/1)	NA	NA	NA
Total	135	66 (89/135)	4.8 ± 2.4	44.4 ± 30.5	16.6 ± 13.1

Note—Unless otherwise indicated, data are means and SDs. Pain score used the numeric pain rating scale. Data in parentheses are number of patients providing information. NP = information not provided. NA = not applicable.

were 12 mL for the shoulder, 6 mL for the elbow, 4 mL for the radiocarpal joint, 10 mL for the hip, 25 mL for the knee, and 4 mL for the ankle (Table 1).

Our injection technique for the wrist was slightly different from the other joints. For the wrist, we used only one mixture, which contained both iopamidol and gadopentetate dimeglumine, to visualize and document under fluoroscopy contrast extravasation from the radiocarpal joint into the distal radioulnar joint or intercarpal row in cases of ligamentous injury. Our wrist mixture consisted of 10 mL of Isovue-M 200, 5 mL of bacteriostatic or nonbacteriostatic normal saline (9 mg/mL sodium chloride and 9 mg/mL benzyl alcohol), 5 mL of 1% ropivacaine HCl, 0.3 mL of 1:100 epinephrine (1 mg/mL), and 0.1 mL of gadopentetate dimeglumine (469.01 mg gadopentetate dimeglumine/mL). Approximately 4 mL of this wrist mixture was injected between the radius and scaphoid into the radiocarpal joint (Table 1).

MRI

MR images were obtained with a 1.5- or 3-T MR unit. Images were obtained within 45 minutes of joint injection. Standard protocols obtained included multiple planes of T1-weighted fat saturation and one plane of T2-weighted fat saturation images. A dedicated eight-channel coil was used for the shoulder and knee. An eight-channel torso coil was used for the hip. Dedicated eight-channel coils were used for the wrist and ankle. A single-channel research coil was used for the elbow. The type of MR unit used was based on availability.

TABLE 3: Significance of Variables on Postarthrographic Pain After Direct MR Arthrography

Variable	Pain Score	p^a	Incidence of Pain (%)	p^b
Contrast mixture		0.83		0.49
With epinephrine	4.8 ± 2.4		64 (70/109)	
Without epinephrine	4.9 ± 2.5		73 (19/26)	
Sex		0.20		0.86
Male	4.6 ± 2.4		65 (51/78)	
Female	5.2 ± 2.4		67 (39/58)	
Age (y)		0.20		0.26
≥ 30	4.6 ± 2.4		62 (53/85)	
< 30	5.3 ± 2.4		72 (37/51)	
Sex and age (y)		0.11		0.43
Males ≥ 30	4.4 ± 2.4		63 (32/51)	
Females < 30	5.6 ± 2.5		75 (18/24)	
Joint		0.51		0.47
Shoulder	4.7 ± 2.3		68 (64/94)	
Hip	5.2 ± 2.8		77 (20/26)	

Note—Pain rated according to the numeric pain rating scale. Pain scores are reported as averages and SDs. Data in parentheses are number of patients.
[a]Pain score *p* values were calculated using the Mann-Whitney *U* test.
[b]Incidence of pain *p* values were calculated using two-tailed Fisher's exact test.

Pain Evaluation

Patients were contacted by telephone between 3 and 7 days after joint injection as part of routine clinical follow-up. Patients were asked to report if they had experienced joint pain that was different from or more intense than their preinjection baseline, the severity of pain, the duration of pain, time to onset of pain, and pain resolution. The 11-point numeric pain rating scale was used [7, 8].

We decided it was good clinical practice to talk to our arthrography patients after we injected their joint. Most radiologists do not follow-up their own patients and therefore often are unaware of any complications that may ensue after the procedure. We decided to make this telephone follow-up a part of our routine clinical practice after we had heard second-hand about the delayed onset of severe pain after arthrography from our referring orthopedic surgery colleagues.

On the basis of our background clinical experience, we found that patients were developing pain the day after injection and that it would resolve over 2–3 days. By calling patients 3–7 days after the injection, we could get all the information that we needed for our study in one telephone call. Specifically, this time frame allowed the delayed onset of pain not only to develop but also to resolve and for any other complications to occur. Moreover, the previously published data on postarthrographic pain detailed a similar time frame of onset and resolution of postarthrographic pain [2, 4, 9].

To report incidence of postarthrographic pain, patients who experienced pain were separated from patients who did not experience pain after direct MR arthrography in data analysis. Therefore, the pain score averages were composed of data only from patients who experienced pain (i.e., no values of zero were included in the pain score data averages).

Patients also provided comments describing the quality of the pain that they experienced after direct MR arthrography. Patients were also asked if they experienced any other side effects or complications, such as signs or symptoms of infection. Although patients were not specifically asked, some patients offered what they took or did to relieve the postarthrographic pain. Patient comments were recorded.

Radiologists

A total of five musculoskeletal radiology fellows each with less than 1 year of musculoskeletal radiology experience performed the joint injections under the supervision of two senior staff musculoskeletal radiologists each with more than 10 years of experience.

Statistical Analysis

Mean values and SDs were calculated for continuous variables. The unpaired, two-tailed Student *t* test was used for the comparison of age data. The two-tailed Fisher's exact test was used for the comparison of incidence of postarthrographic pain data. The Mann-Whitney *U* test was used for the comparison of the pain score data. GraphPad InStat (GraphPad Software) software was used for statistical calculations.

Results

Pain Scores

When all the patients were pooled together—those who underwent direct MR arthrography with epinephrine and those without—the total incidence of postarthrographic pain was 66% (89/135) (Table 2). The average severity of postarthrographic pain was 4.8 ± 2.4 (range, 1–10). The average duration of postarthrographic pain was 44.4 ± 30.5 hours (range, 6–168 hours). The average time to onset of postarthrographic pain was 16.6 ± 13.1 hours (range, 4–72 hours).

Of the 109 patients who underwent direct MR arthrography with intraarticular injection with iopamidol, gadopentetate dimeglumine, 1% ropivacaine, and 1:1000 epinephrine diluted in normal saline, 70 patients experienced pain after direct MR arthrography; the incidence of postarthrographic pain was 64% (Table 3). Of the 70 patients who experienced pain after joint injection with epinephrine, the average severity of pain was 4.8 ± 2.5 (range, 1–10). Sixty-three of the 70 patients with postarthrographic pain reported the pain to have lasted an average of 43.7 ± 28.2 hours (range, 8–168 hours), and 26 of the 70 patients who experienced postarthrographic pain reported an average of 18.1 ± 14.4 hours (range, 4–48 hours) between joint injection and onset of postarthrographic pain.

Of the 26 patients who underwent direct MR arthrography with intraarticular injection with iopamidol, gadopentetate dimeglumine, and 1% ropivacaine without epinephrine diluted in normal saline, 19 patients experienced pain after direct MR arthrography; the incidence of pain was 73% (Table 3). Of the 19 patients who experienced pain after joint injection without epinephrine, the average severity of pain was 4.9 ± 2.5 (range, 1–10). Sixteen of the 19 patients with postarthrographic pain reported the pain to have lasted an average of 44.3 ± 39.4 hours (range, 6–168 hours), and seven of the 19 patients who experienced postarthrographic pain reported an average of 10.9 ± 5.0 hours (range, 6–16 hours) between joint injection and onset of postarthrographic pain.

TABLE 4: Sex and Age Distribution and Pain Scores

Parameter	Male < 30 y	Male ≥ 30 y	Female < 30 y	Female ≥ 30 y
With epinephrine				
Pain score	5 ± 2.1	4.32 ± 2.5	5.5 ± 2.8	4.9 ± 2.2
Incidence of pain (%)	63 (15/23)	64 (25/39)	74 (14/19)	57 (16/28)
Without epinephrine				
Pain score	5 ± 3.9	4.6 ± 2.2	5.8 ± 1.3	4.8 ± 2.9
Incidence of pain (%)	100 (4/4)	58 (7/12)	80 (4/5)	83 (5/6)
Total				
Pain score	5 ± 2.5	4.4 ± 2.4	5.6 ± 2.5	4.9 ± 2.3
Incidence of pain (%)	70 (19/27)	63 (32/51)	75 (18/24)	62 (21/34)

Note—Pain rated according to the numeric pain rating scale. Pain scores are reported as averages and SDs. Data in parentheses are numbers of patients.

Postarthrographic pain was reported to occur in all joints except the ankle and elbow (Table 2). However, there were only two elbows and one ankle injected in this study. Furthermore, the incidence of postarthrographic pain in the shoulder compared with the hip was not significantly different, 68% versus 77%, respectively, $p = 0.47$ (Table 3). The severity of postarthrographic pain in the shoulder and the hip was also similar, 4.7 ± 2.3 versus 5.2 ± 2.8, $p = 0.51$ (Table 3).

Sex and age of the patient had no significant effect on the severity or incidence of postarthrographic pain (Tables 3 and 4). Males and females and all patients younger than 30 years old versus all patients 30 years or older reported similar pain scores and pain incidence. However, men 30 years of age or older reported the lowest severity of pain, 4.4 ± 2.4, whereas females younger than 30 years of age reported the highest severity of pain, 5.6 ± 2.5, but this was not significantly different, $p = 0.11$ (Table 3). In fact, pain scores and incidence were strikingly similar across all groups, regardless of age, sex, contrast mixture, or joint injected, with the pain score hovering around 5 and the incidence hovering around 66% (Table 3).

Side Effects

Other than pain, there were no other reported complications. Each patient's joint pain eventually resolved. Specifically, we had no cases of septic arthritis after direct MR arthrography (0/135). No other major side effects were reported, including anaphylactic reactions, infections, or vascular complications.

A total of 24 patients described the quality of the postarthrographic pain. Postarthrographic pain was most commonly described as "soreness," by 12 patients. "Aching" and "throbbing" were the second most common descriptions of postarthrographic pain by three patients each. Two patients described postarthrographic pain as "dull." One patient each described postarthrographic pain as "sharp," "shooting," or "pain with motion."

Some patients reported taking nonsteroidal antiinflammatory drugs to relieve their postarthrographic pain. Others mentioned placing ice on the affected joint. Both remedies offered some relief. However, what patients took for their pain relief was not specifically included in the telephone follow-up and therefore was not rigorously evaluated.

Discussion

Direct MR arthrography is a well-established technique, and its diagnostic superiority to conventional MRI in the evaluation of many internal derangements is well documented [10–18]. However, direct MR arthrography is an invasive procedure and can result in pain and anxiety [4, 19]. In rare circumstances, it can result in septic arthritis [3].

Previously, the amount of postarthrographic pain that patients experienced after direct MR arthrography has been reported in a large series of patients by Saupe et al. [2]. In this series of 1085 patients, the largest increase in pain score was 4 hours after injection and was between a 0.5–1.2 increase from baseline, shoulder and hip respectively. Saupe et al. did not report the number of patients who were completely pain free after direct MR arthrography, and therefore no data on the incidence of postarthrographic pain are available. Our study is the first to report the incidence of postarthrographic pain attributable to direct MR arthrography, which was 66%.

The incidence of postarthrographic pain after direct MR arthrography in our study population of 66% is similar to the incidence of pain after conventional shoulder arthrography of 74% reported by Hall et al. [9]. The fact that different compounds injected into a joint result in a similar incidence of postarthrographic pain suggests that joint distention may be a causative factor. However, iodinated contrast material was injected in both of these studies.

Previous reports have suggested that postarthrographic pain may be due to joint distention or direct irritation of the synovium resulting in a chemical synovitis [2, 5, 9, 20]. If postarthrographic pain is due to joint distention, then it would follow that everyone who undergoes direct MR arthrography should develop postarthrographic pain. However, our data show that only 66% of patients develop postarthrographic pain. Therefore, an inflammatory response developed by the patient in response to a direct chemical irritation by the injected contrast material may be a more likely explanation [2, 4, 9]. The development of an inflammatory response could explain why not everyone develops postarthrographic pain, in that in the minority of patients, the synovium either may not get irritated by the injected contrast material or the patient may not form an inflammatory response, just as some people are allergic and some are not. Moreover, the time it takes to develop an inflammatory response may be responsible for the delay in onset of postarthrographic pain.

It is accepted that therapeutic intraarticular injections can result in a steroid crystal-induced synovitis [21]. Our data do not elucidate the cause of the postarthrographic pain; our data simply document the common occurrence and severity of postarthrographic pain and show that direct MR arthrography is safe in the short term. Whether direct MR arthrography results in long-term damaging effects to the joint synovium is also uncertain, but some animal data suggest that it may [22]. Histologic rabbit data suggest that iodinated contrast material is responsible for irritant effects on the joint synovium, whereas gadolinium does not induce changes in the synovium [20, 22]. Further research in this area is warranted.

The peak amount of postarthrographic pain from injection of the shoulder for direct MR arthrography has been reported previously by Binkert et al. [4] to occur at 12 hours after arthrography and to be of an intensity of 18.0 ± 22.7 on a 100-point scale. Hall et al. [9] also reported a moderate to severe increase in shoulder discomfort 24–48 hours after shoulder injection. We had similar results in that the onset of postarthrographic pain was on average 16.6 ± 13.1 hours. However, Saupe et al. [2] reported the peak amount of postarthrographic pain occurred 4 hours after injection, which is less than what our data and that reported by Binkert et al. and Hall et al. show. The delayed onset of postarthrographic pain may be due to the intraarticular local anesthetic that is initially injected [4, 9]. Differences in the type of intraarticular local anesthetic may be responsible for the differences in the delay of onset of postarthrographic pain.

In our institution, 1% ropivacaine was used for intraarticular analgesia injection for direct MR arthrography. Ropivacaine was used instead of bupivacaine because ropivacaine has been shown in vitro to be significantly less toxic to chondrocytes than bupivacaine [23]. Ropivacaine has also been shown in vitro to be less chondrocyte toxic than lidocaine [24]. Ropivacaine has also been shown to be as effective as or more effective than bupivacaine in providing intraarticular analgesia [25–27].

Our results differed from Binkert et al. [4] regarding the severity of pain. In our study, the average severity of postarthrographic pain in patients who underwent shoulder direct MR arthrography was 4.70 ± 2.31, which is considerably higher than in the study by Binkert et al. Those investigators used the 100-point visual analog scale (VAS), whereas we used the 11-point numeric pain rating scale. These two scales have shown similar sensitivities when assessing pain, and therefore comparison between the two scales is valid [28]. Binkert et al. injected the shoulder with iopamidol (Iopamiro 200, Bracco) and gadoteridol (ProHance, Bracco), whereas we injected the shoulder with Isovue-M 200 and Magnevist. Differences in the components of the injection media for direct MR arthrography between the study by Binkert et al. and our study may be responsible for our higher severity of postarthrographic pain. The effect of the volume of injected fluid into the shoulder joint cannot be compared because Binkert et al. did not report the volume of fluid injected into the joint.

Duc et al. [19] previously reported the intensity of postarthrographic pain after direct MR arthrography of the hip to be 13–17 ± 19, 12 hours after injection using the VAS. Our patient population reported an average intensity of postarthrographic pain after direct MR arthrography of the hip of 5.2 ± 2.8 using the numeric pain rating scale. Again, our patients experienced a higher severity of postarthrographic pain in the hip than previously reported. In both protocols, the hip was injected with ~10 mL of total fluid volume. However, the components of our cocktail for direct MR arthrography differed from that reported by Duc et al.

Another reason that we may be reporting a higher total severity of pain than by Duc et al. [19] and Binkert et al. [4] is that we have separated those patients who experienced postarthrographic pain from those who did not experience postarthrographic pain to report incidence. If we include all the patients who did not experience pain from shoulder or hip direct MR arthrography in calculating the average, then our severity of postarthrographic pain drops to 3.17 ± 2.92 for the shoulder and 4.0 ± 3.31 for the hip. These values are still higher but are closer to previous reports.

Our data show no significant difference in the severity of postarthrographic pain from direct MR arthrography in the hip compared with the shoulder: 5.2 ± 2.8 versus 4.7 ± 2.3, $p = 0.47$ (Table 3). But the trend is in agreement with the trend reported by Saupe et al. [2], who found that the increase from baseline was slightly greater in the hip compared with the shoulder: 1.2 versus 0.5. However, Binkert et al. [4] reported an intensity of pain in the shoulder to be 18 ± 22.7, 12 hours after injection, whereas Duc et al. reported an intensity of pain in the hip to be 13–17 ± 19, 12 hours after injection. Given all the conflicting data, there is probably no difference in postarthrographic pain between the shoulder and the hip.

No postarthrographic pain was reported in our study population in the ankle and the elbow. However, this was almost certainly due to the low number of ankle ($n = 1$) and elbow ($n = 2$) joints injected in our study population. Saupe et al. [2] reported an increase in baseline pain after injection of the ankle and elbow. Based on the similarity of pain scores for the hip and the shoulder reported by several authors previously and on the fact that postarthrographic pain was reported in the knee and wrist in our study as well as previously, postarthrographic pain is probably similar in all joints [2, 4, 19].

Our data show that epinephrine results in no significant difference on the incidence or severity of postarthrographic pain after direct MR arthrography (Table 3). In our study, the incidence of postarthrographic pain in patients who were injected without

epinephrine versus those who were injected with epinephrine was 64% versus 73% (p = 0.49). This lack of impact on incidence of pain is in direct disagreement with conventional arthrographic data reported by Hall et al. [5]. Hall et al. reported that intraarticular injection of epinephrine and conventional ionic contrast material resulted in a 71% incidence of postarthrographic pain, whereas intraarticular injection of conventional ionic contrast material without epinephrine resulted in a 42% incidence of postarthrographic pain (p = 0.0004). In fact, our data suggest that intraarticular injection of epinephrine may result in a lower incidence of postarthrographic pain. However, our data are not directly comparable to the study by Hall et al. because those authors did not inject gadopentetate into the joint.

Epinephrine has been shown to potentiate the chondrocyte toxicity of bupivacaine in vitro [24]. However, 3-month follow-up data in an in vivo rabbit model showed no permanent impairment of cartilage function after bupivacaine or bupivacaine and epinephrine infusion into the glenohumeral joint [29]. These rabbit data suggest that analgesic injection along with epinephrine may not impart any permanent damage to articular cartilage in humans.

We found no association between severity and intensity of postarthrographic pain and patient sex or age (Tables 3 and 4). Saupe et al. [2] previously reported that patients younger than 30 years experienced significantly more postarthrographic pain than patients 30 years or older (p = 0.044). In our study, patients younger than 30 years had an average pain score of 5.3 ± 2.4 and incidence of pain of 72%, whereas patients 30 years or older had an average pain score of 4.6 ± 2.4 and incidence of pain of 62% (p = 0.20 and 0.26, respectively). The trend in our data of more postarthrographic pain in younger patients mirrors that of Saupe et al. Perhaps we could not confirm more postarthrographic pain in younger patients because of our smaller population size (136 vs 1085).

Most patients who provided spontaneous comments regarding the quality of postarthrographic pain described it as "soreness." Some patients offered that they took nonsteroidal antiinflammatory drugs and placed ice on the affected joint to relieve their pain.

Relief of postarthrographic pain by nonsteroidal antiinflammatory drugs and ice lends further credence to the theory of inflammation being responsible for the development of postarthrographic pain. This information is useful in that radiologists can counsel patients on what they can expect to feel after direct MR arthrography to alleviate patient anxiety. Moreover, the absence of any serious side effects other than pain in our study validates the short-term safety of our method of direct MR arthrography.

Our study had several limitations. We did not record the baseline pain of the patients who underwent direct MR arthrography. However, Saupe et al. [2] previously showed the increase in pain from baseline from direct MR arthrography in a large series of patients. Our goal was to report new information regarding the incidence of pain from direct MR arthrography which has not yet been reported, and to validate the severity of pain from direct MR arthrography, which, in addition to Saupe et al., has only been previously reported by Binkert et al. [4] in the shoulder and Duc et al. [19] in the hip.

Other limitations of our study included the fact that we did not record the degree of difficulty of the injection or contrast leakage. Moreover, by directly asking patients if they experienced pain, we could have caused a recall bias or an overestimation of pain. Another limitation was the small number of joints in our study other than the shoulder and hip. Furthermore, although we did not notice any difference in image quality between those groups of patients who received intraarticular epinephrine and those who did not, we did not rigorously record or evaluate image quality.

In conclusion, we have shown prospectively that the incidence of postarthrographic pain after direct MR arthrography is 66%. We have documented that the severity and duration of postarthrographic pain are significant. We found that postarthrographic pain was similar across all groups, regardless of age, sex, joint injected, or contrast mixture. We have also shown that direct MR arthrography is safe in the short term, with no complications other than pain that eventually completely resolves. The significance of these findings is that patients and referring physicians can be well informed of the morbidity of direct MR arthrography so that they can make an informed decision about undergoing this diagnostic test and to alleviate anxiety if and when postarthrographic pain predictably does occur.

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