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SCIENTIFIC ARTICLE

A prospective randomized study comparing three different approaches to fluoroscopy-guided shoulder arthrography according to the experience of practitioners

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Abstract
Objective To compare three approaches via the anterior and posterior glenohumeral joints, and the rotator interval in fluoroscopy-guided shoulder arthrography according to the experience of the practitioners.
Materials and methods This prospective randomized study was originally designed to have 34 subjects for each approach, and finally evaluated 98 patients (mean age: 51.5 years; 55 men) from July to December 2014, who had shoulder arthrography via the anterior (n = 41) or posterior glenohumeral joint (n = 27) approaches, or via the rotator interval approach (n = 30) by residents (n=76) or fellows (n=22). The success rate, number of punctures, fluoroscopy time, radiation dose, and complications of the three methods were compared, and according to the practitioners.
Results The success rate was 100% for the anterior glenohumeral joint approach (34 out of 34), 90.0% for the posterior glenohumeral joint approach (23 out of 30), and 88.2% for the rotator interval approach (30 out of 34; p = 0.013). There was no difference in the success rate according to the practitioners' experience. Fluoroscopy time was longest for the posterior glenohumeral joint approach (mean: 95.44 s) and shortest for the rotator interval approach (mean: 31.57 s, p = 0.006). Radiation dose was larger by 1st- or 2nd-year residents (p = 0.014), with no difference among the three approaches. Only one patient who underwent arthrography using the posterior glenohumeral joint approach complained about post-procedural pain.
Conclusion Fluoroscopy-guided shoulder arthrography via the posterior glenohumeral joint or rotator interval approach may be difficult for trainees, and the posterior glenohumeral joint approach may need a long fluoroscopy time.

Keywords Arthrography · Fluoroscopy · Shoulder

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Introduction

Arthrography of the glenohumeral joint is a common preconditioning procedure in computed tomography (CT)- or magnetic resonance imaging (MRI)-based evaluation of rotator cuff tears or shoulder instability [1]. After introduction of the anterior glenohumeral joint approach by Schneider et al. [2], this approach has been the preferred injection approach for shoulder arthrography under fluoroscopic guidance in North America [3]. However, the needle used for injection when using the anterior glenohumeral joint approach may violate the anteroinferior labrocapsular structures, which are critical stabilizers, and anterior contrast medium leakage may induce a diagnostic error, mimicking an anteroinferior capsular tear during arthrography; therefore, this should be avoided in patients with suspected anterior shoulder instability [4, 5].

Additionally, other injection techniques have since been introduced, such as via the posterior glenohumeral joint and the rotator interval [6, 7]. Although some authors have described blind injection techniques, with a wide range of success rates [8–11], imaging-guided injection may be the current gold standard [12]. Several reports have compared the results of injection methods under ultrasound guidance [13, 14], but fluoroscopy-guided injection techniques, via the anterior or posterior glenohumeral joint, or via the rotator interval, have not yet been compared based on the training experiences of the practitioners.

Therefore, this prospective study compared the success rate, number of punctures, fluoroscopy time, radiation dose, and immediate complications of fluoroscopy-guided shoulder arthrography via the anterior and posterior glenohumeral joint and via the rotator interval, according to the experience of the practitioners.

Materials and methods

This prospective study was approved by the institutional review board of our hospital. Written informed consent was obtained from all the participants (IRB number: B-1405-252-004).

Study design

We calculated that to detect a significant difference in the fluoroscopy time of 10 s or more, using an F test ANOVA among the three groups, with a two-sided p value at a 5% significance level and a power of 80%, a sample size of 34 patients per group would be necessary. Therefore, we determined that a total of 102 patients should be enrolled.

A researcher (J.S.K), who was not involved in the study, prepared a computer-generated randomization list with a block size of six, which was used to assign the approach method. Although complete blinding was not possible (as the practitioner would know the approach used), the list was consulted immediately before the shoulder arthrography procedure.

Patients

Candidates for the study were recruited by an orthopedic surgeon specialized in shoulder arthroscopy during an interview in the outpatient clinic of our hospital and were referred to the department of radiology on the scheduled day to obtain CT or MR arthrography for clinical purposes. Inclusion criteria were as follows:

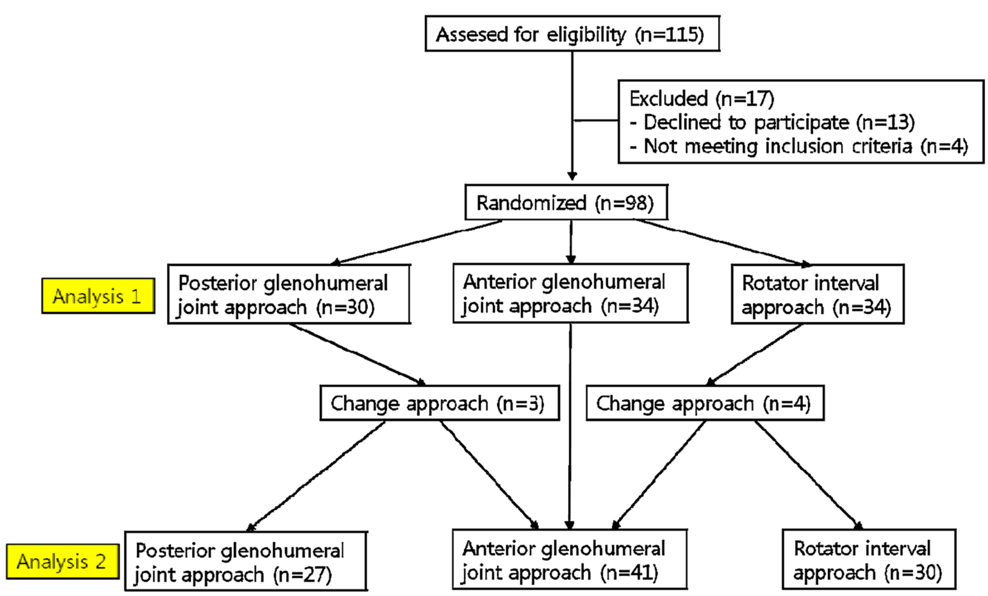
1. Patient's age was 18 years or over
2. No history of operation on the ipsilateral shoulder
3. Patient scheduled to undergo CT or MRI after shoulder arthrography

From July to December 2014, 98 patients (mean age: 51.5 years; range: 18−86 years; 55 men) were evaluated using the anterior (n = 41) or posterior (n = 27) glenohumeral joint, or the rotator interval (n = 30) approaches for scheduled CT (n = 31) or MRI (n = 67) investigations. Three patients underwent arthrography via the anterior glenohumeral joint instead of the allocated posterior glenohumeral joint approach, because they were unable to assume a prone position. Four patients underwent arthrography via the anterior glenohumeral joint, instead of the designated rotator interval approach, because of the human error of allocation during the study. Indication for CT or MRI after shoulder arthrography was as follows: suspected rotator cuff tear (n = 47), shoulder instability (n = 32), and adhesive capsulitis with other suspected causes of shoulder pain (n = 19). A flow chart was shown in Fig. 1.

Shoulder arthrography

Shoulder arthrography was performed as follows: after the patient was placed on the table in an appropriate position for

Fig. 1 Flow chart of the study



the injection technique under fluoroscopy (Integris Allura 15; Philips Medical Systems, Best, The Netherlands), the shoulder was prepared with a solution of povidone–iodine using an aseptic technique, and then draped. The skin and soft tissue at the entry site of the needle were infiltrated with local anesthetic. Intra-articular positioning of the 22-gauge needle was confirmed fluoroscopically after injection of a small amount of contrast medium. Then, 10–12 mL of a solution of 13 mL meglumine ioxithalamate (Telebrix 30 Meglumine; Guerbet, Aulnay-sous-Bois, France) and 7 mL of normal saline was injected for CT arthrography. For MR arthrography, a test injection using 1–2 mL of iodinated contrast medium (Telebrix 30 Meglumine; Guerbet) was performed, first for confirmation of the intra-articular location of the needle, and then 10−12 mL of a solution containing 0.1 mL of gadopentetate dimeglumine (Magnevist, Bayer Schering Pharma, Berlin, Germany) and 20 mL of saline was injected.

For arthrography via the anterior glenohumeral joint and rotator interval, the patient was placed in the supine position with the arm in external rotation and the palm in supination. The middle and lower thirds of the anterior glenohumeral joint space were punctured for the approach via the anterior glenohumeral joint (Fig. 2) [2]. During arthrography via the rotator interval approach, we targeted the superior and medial quadrants of the humeral head and advanced the spinal needle until it contacted the humeral head (Fig. 3) [7]. For arthrography via the posterior glenohumeral joint, the patient was placed in the prone position with a pillow under torso on the examined side and with the ipsilateral arm placed above the patient's head, to gain a tangential view of the posterior glenohumeral joint. Then, the inferior medial quadrant of the humeral head was targeted to avoid a posterior glenoid rim and the needle tip was placed into the lower portion of the posterior glenohumeral joint space, which was modified from a method used in a previous study (Fig. 4) [6]. All arthrography was performed by radiologists, i.e., seven 1st- to 3rd-year residents (three 1st-year residents with the 1st month spent performing arthrography in the training are of the musculoskeletal radiology section, two 2nd-year residents with 3 months, and two 3rd-year residents with 5 months) in 76 patients and three 1st-year fellows with more than 1 year's experience of the musculoskeletal radiology section in 22. A supervisor—a qualified member of staff with 7 years' experiences of musculoskeletal radiology, waited in a room nearby and came to the fluoroscopy room when called for help during the procedure.

Outcome evaluation

Success was defined as when the intra-articular contrast medium was confirmed on a final spot view after injection and on CT or MR images after arthrography, regardless of the number of punctures. Failure was defined as:

1. When the designate practitioner could not complete arthrography and the supervisor had to complete the arthrography
2. When the injection route had to be changed to a method other than the designated method
3. Intra-articular contrast medium could not be confirmed on a final fluoroscopic view or CT or MR images, despite multiple attempts

The data on fluoroscopy time (seconds) and radiation dose (dose area product, DAP, in Gy·cm2^2) were measured automatically and stored in the fluoroscopy machine, and were recorded by a researcher (J.M.C.) who was blinded to the practitioners and any investigators related to this study. The number of punctures, i.e., the number of times that the skin was punctured, during arthrography except for skin anesthesia and any complications from the start of arthrography

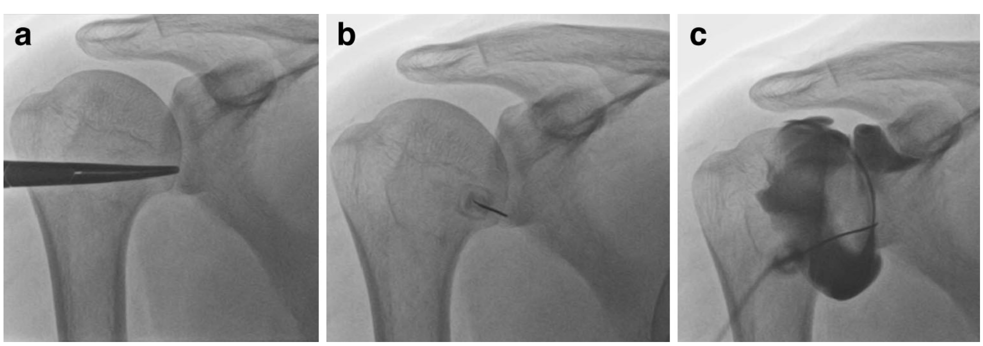


Fig. 2 Shoulder arthrography via the anterior glenohumeral joint approach. **a** With the patient in the supine position, the arm in external rotation, and the palm in supination, the middle and lower thirds of the anterior glenohumeral joint space were marked using a mosquito forceps. **b** A 22-gauge needle was inserted at the entry point on **a**, under fluoroscopic guidance. **c** Intra-articular contrast medium was successfully injected after **b**, showing the linear contrast medium filling along the glenohumeral joint and the bulging contrast medium contour of the glenohumeral joint cavity

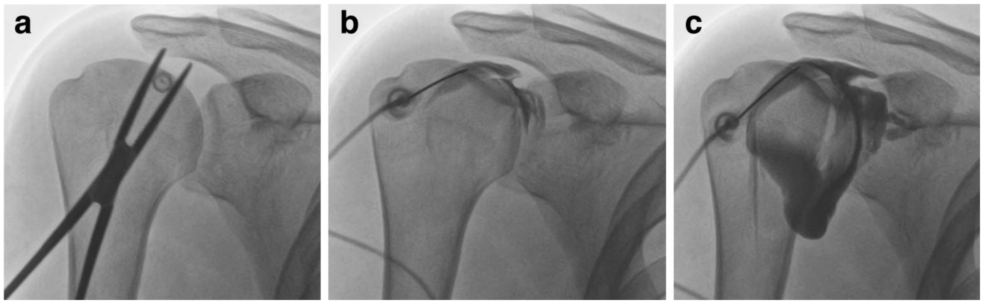


Fig. 3 Shoulder arthrography via the rotator interval approach. **a** With the patient in the supine position, the arm in external rotation, and the palm in supination, the superior and medial quadrants of the humeral head were marked using a mosquito forceps. **b** A 22-gauge needle was inserted at the entry point on **a**, under fluoroscopic guidance. **c** Intra-articular contrast medium was successfully injected after **b**, showing the linear contrast medium filling along the rotator interval and glenohumeral joint and the bulging contrast medium contour of the glenohumeral joint cavity

to before CT or MRI were also recorded by a nurse in the fluoroscopy room.

Statistical analysis

The success rates of the three techniques were compared and according to the state (residents vs fellows) and the experience of the practitioners (the grade of residents and fellows) using the Chi-squared test or Fisher's exact test using both intention-to-treat analysis and as-treated analysis. By as-treated analysis, the number of punctures, fluoroscopy time, and radiation dose of the three approaches were also compared, and according to the practitioners' experience using the independent *t* test (residents vs fellows) and the Kruskal−Wallis test (the grade of residents and fellows), and a subgroup analysis by the approach was carried out according to the practitioner's experiences using one-way ANOVA. Statistical analysis was performed using statistical software (PASW, version 19.0; SPSS, Chicago, IL, USA). A p value of less than 0.05 was considered to indicate a significant difference.

Results

Intention-to-treat analysis showed that the success rate was 100% for the anterior glenohumeral joint approach (34 out of 34), 90.0% for the posterior glenohumeral joint approach (23 out of 30), and 88.2% for the rotator interval approach (30 out of 34), with an overall success rate of 88.8% (87 out of 98). There was a significant difference between the approaches ($p = 0.013$). The success rates by as-treated analysis were as follows: 97.6% for the anterior glenohumeral joint approach (40 out of 41), 85.2% for the posterior glenohumeral joint approach (23 out of 27), and 100.0% for the rotator interval approach (30 out of 30), with an overall success rate of 94.9% (93 out of 98) and a significant difference according to the approaches ($p = 0.024$). There were 5 cases of failure: 4 required a change of practitioner, and the procedure was completed by a qualified member of staff, and 1 required a rotator interval approach instead of a posterior glenohumeral joint approach.

There was no difference in the success rate according to the state of the practitioners according to the intention-to-treat

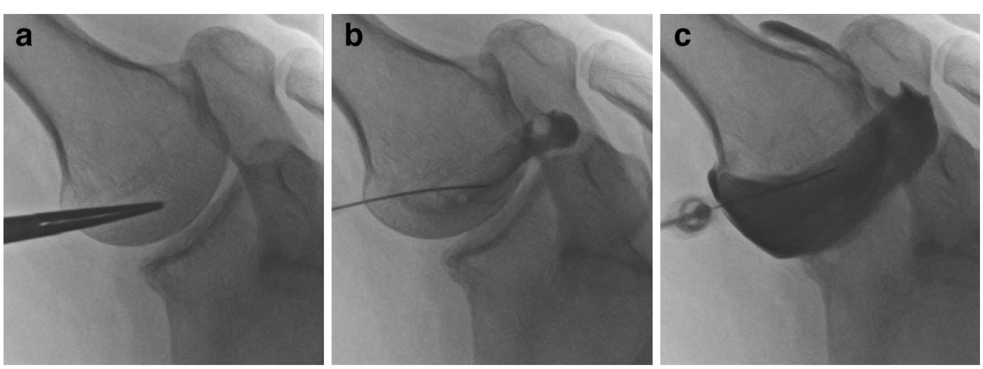


Fig. 4 Shoulder arthrography via the posterior glenohumeral joint approach. **a** With the patient in the prone position, a pillow under the patient's torso on the examined side, and the ipsilateral arm placed above the patient's head, to provide a tangential view of the posterior glenohumeral joint, the inferior medial quadrant of the humeral head was marked using a mosquito forceps to avoid a posterior glenoid rim, and the needle tip was placed into the lower portion of the posterior glenohumeral joint space. **b** A 22-gauge needle was inserted at the entry point on **a** under fluoroscopic guidance. **c** Intra-articular contrast medium was injected successfully after **b**, showing the linear contrast medium filling along the biceps tendon sheath and glenohumeral joint and the bulging contrast medium contour of the glenohumeral joint cavity

analysis (86.8% [66 out of 76] by residents vs 95.5% [21 out of 22] by fellows: $p = 0.260$) and to the as-treated analysis (93.4% [71 out of 76] by residents vs 100.0% [22 out of 22] by fellows: $p = 0.217$). The success rate was not different according to the practitioner's experience according to the intention-to-treat analysis (87.0% [40 out of 46] by 1st-year residents, 88.2% [15 out of 17] by 2nd-year residents, 84.6% [11 out of 13] by 3rd-year residents, and 95.5% [21 out of 22] by 1st-year fellows in the musculoskeletal radiology section: $p = 0.713$) and according to the as-treated analysis (91.3% [42 out of 46] by 1st-year residents, 100.0% [17 out of 17] by 2nd-year residents, 92.3% [12 out of 13] by 3rd-year residents, and 100.0% [22 out of 22] by 1st-year fellows in the musculoskeletal radiology section: $p = 0.320$).

The number of punctures, fluoroscopy time, and radiation dose used are shown in Table 1. The fluoroscopy time was significantly longer in the cases using the posterior glenohumeral joint approach than those using other methods, and shorter when using the rotator interval approach ($p = 0.006$). However, the number of punctures and radiation dose of the three methods did not differ significantly. Between cases by residents and fellows, there was no difference in the number of punctures ($p = 0.548$), fluoroscopy time ($p = 0.931$), or radiation dose ($p = 0.141$). However, in terms of the practitioner's experience, radiation dose was significantly larger in cases performed by 1st- or 2nd-year residents ($p = 0.014$; Table 2). Subgroup analysis by approach revealed that the 1st-year residents needed a significantly longer fluoroscopy time in shoulder arthrography using the anterior glenohumeral joint approach ($p = 0.046$; Table 3).

Only one patient suffered immediate complications; this patient underwent arthrography via the posterior glenohumeral joint and then complained of local shoulder pain, which was relieved without any treatment within an hour.

Discussion

Arthrography has become essential for CT or MRI evaluations of the intra-articular structures of the shoulder [1]. Some authors have proposed blind injection techniques; however, imaging-guided arthrography has typically been performed using fluoroscopy or ultrasound [12, 15]. According to a current review article, there was no significant difference in the accuracy of arthrography between fluoroscopy and ultrasound guidance [15]. Plus, several previous studies have shown the utility of ultrasound as an imaging-guided technique [13, 14, 16–19]. However, fluoroscopy-guided arthrography is a very common procedure in daily practice, especially for CT or MRI, in spite of the concerns about radiation exposure. Most are performed by trainees, such as residents or fellows, especially in tertiary medical training centers. Moreover, there have been no reports comparing these three approaches for shoulder arthrography according to the experience of the practitioners. Therefore, this study was aimed at evaluating the

Table 1 The number of punctures, fluoroscopy time, and radiation dose in the shoulder arthrography via anterior, posterior glenohumeral joints, and rotator interval

	Method	Mean±SD	95% CI	*p* value
Number of punctures	Anterior glenohumeral joint (*n*=41)	1.24±0.58	1.06, 1.43	
	Posterior glenohumeral joint (*n*=27)	1.44±0.89	1.09, 1.80	
	Rotator interval (*n*=30)	1.10±0.31	0.99, 1.21	
	Total (*n*=98)	1.26±0.63	1.13, 1.38	0.154
Fluoroscopy time (s)	Anterior glenohumeral joint (*n*=41)	49.22±47.26	34.30, 64.14	
	Posterior glenohumeral joint (*n*=27)	95.44±87.26	60.92, 129.96	
	Rotator interval (*n*=30)	31.57±22.99	22.98, 40.15	
	Total (*n*=98)	56.55±61.29	44.26, 68.84	0.006*
Radiation dose ($Gy{\cdot}cm^2$)	Anterior glenohumeral joint (*n*=41)	742.83±1,713.56	201.96, 1,283.70	
	Posterior glenohumeral joint (*n*=27)	1,300.74 ±2,034.78	495.81, 2,105.67	
	Rotator interval (*n*=30)	940.27±1,807.34	265.40, 1,615.14	
	Total (*n*=98)	956.98±1,830.18	590.05, 1,323.91	0.052

SD standard deviation, *CI* confidence interval

*Statistically significant

Table 2 The number of punctures, fluoroscopy time, and radiation dose in shoulder arthrography according to the practitioners

	Practitioner	Mean ± SD	95% CI	*p* value
Number of punctures	1st-year residents (*n* = 46)	1.24 ± 0.48	1.10, 1.38	
	2nd-year residents (*n* = 17)	1.24 ± 0.44	1.01, 1.46	
	3rd-year residents (*n* = 13)	1.15 ± 0.38	0.93, 1.38	
	Fellows (*n* = 22)	1.36 ± 1.05	1.00, 1.86	
	Total (*n* = 98)	1.26 ± 0.63	1.13, 1.38	0.880
Fluoroscopy time (s)	1st-year residents (*n* = 46)	60.80 ± 66.68	41.00, 80.60	
	2nd-year residents (*n* = 17)	51.41 ± 57.46	21.87, 80.95	
	3rd-year residents (*n* = 13)	50.00 ± 42.12	24.55, 75.45	
	Fellows (*n* = 22)	55.50 ± 64.87	35.20, 90.05	
	Total (*n* = 98)	56.55 ± 61.29	44.26, 68.84	0.839
Radiation dose (Gy·cm^2)	1st-year residents (*n* = 46)	1,281.37 ± 2,415.48	564.06, 1,998.68	
	2nd-year residents (*n* = 17)	1,026.53 ± 1,591.04	208.49, 1,844.57	
	3rd-year residents (*n* = 13)	239.38 ± 219.13	106.97, 371.80	
	Fellows (*n* = 22)	649.00 ± 600.36	410.46, 736.10	
	Total (*n* = 98)	956.98 ± 1,830.18	590.05, 1,323.91	0.014*

SD standard deviation, *CI* confidence interval

*Statistically significant

three techniques of fluoroscopic-guided arthrography that are more familiar to trainees.

In our study, the success rate was lower and the fluoroscopy time was longer in patients who underwent arthrography using a posterior glenohumeral joint approach than in that using other approach methods. This implies that trainees might have some difficulty in performing shoulder arthrography via the posterior glenohumeral joint and require more experience to learn how to do so successfully. However, there was no difference in the success rate according to the experience of the practitioner. Given that most practitioners in this study were 1st-year residents, with the 1st training month spent performing arthrography in the musculoskeletal radiology section (*n* = 3), all three approaches may be considered relatively easy methods, even for beginners such as the 1st-year residents.

The posterior glenohumeral joint approach needed a longer fluoroscopy time than the other methods, which was not different according to the practitioner's experience (Table 1). Generally, the anterior glenohumeral joint approach may be the method that is learnt first by radiology residents and may be used as the gold standard approach to shoulder arthrography, whereas the posterior glenohumeral joint approach may not, and this holds true in our institute. Furthermore, the posterior glenohumeral joint approach may be more difficult to perform, especially for 1st-year residents who may not be familiar with shoulder anatomy and to avoid a posterior glenoid rim. Subgroup analysis according to the approach demonstrated that there was a significant difference in fluoroscopy time between the practitioners using the anterior glenohumeral joint approach (Table 2). Radiology residents tend to be aware of the anterior glenohumeral joint approach first before other methods of shoulder arthrography in our institute, and likely in other medical institutes; therefore, 1st-year residents may need a longer time than the senior residents or fellows, who may already be skilled in using the anterior glenohumeral joint approach. On the other hand, overall fluoroscopy time was longer using the posterior glenohumeral joint approach, and that in arthrography using the rotator interval approach was similar to or shorter regardless of the practitioners (Table 3). This may mean that the posterior glenohumeral joint approach may be difficult for trainees to perform; on the contrary, the rotator interval approach may be easy, especially for the 1st-year residents. In addition, the fluoroscopy time was shortest when using the rotator interval approach in our results, which revealed similar values to a previous study [7]. One potential explanation for why the rotator interval approach may be easy for the trainees to perform within the shortest fluoroscopy time compared with the other two approaches, may be that the target area is larger, although the other two approaches need a needle tip to be located in the more smaller joint spaces by the practitioners.

Contrary to general expectation, our results revealed that all three outcomes—number of punctures, fluoroscopy time, and radiation dose—were more better in cases by 3rd-year residents than those by the fellows (Table 2). This study was performed during the first half of the academic year, and all fellows who worked for the first time in our institute during that year had some experience of only the anterior glenohumeral joint approaches when they had been residents at other institutes. On the other hand, our institute had a curriculum for radiology residents to perform interventions using

Table 3 The number of punctures, fluoroscopy time, and radiation dose in shoulder arthrography via the anterior and posterior glenohumeral joints, and via the rotator interval, according to the practitioners

Method	Number of punctures			Fluoroscopy time (s)			Radiation dose (Gy·cm^2)		
Practitioner	Mean ± SD	95% CI	*p* value	Mean ± SD	95% CI	*p* value	Mean ± SD	95% CI	*p* value
Anterior glenohumeral joint									
1st-year residents (*n* = 13)	1.31 ± 0.48	1.02, 1.60		77.31 ± 73.21	33.07, 121.55		1,586.38 ± 2,896.84	−164.16, 3,336.93	
2nd-year residents (*n* = 12)	1.25 ± 0.45	0.96, 1.54		28.83 ± 15.39	19.05, 38.61		440.17 ± 352.84	215.98, 664.35	
3rd-year residents (*n* = 7)	1.00 ± 0.00	1.00, 1.00		32.57 ± 8.04	25.14, 40.01		104.86 ± 34.55	72.90, 136.81	
Fellows (*n* = 9)	1.33 ± 1.00	0.56, 2.10		48.78 ± 24.61	29.86, 67.69		424.11 ± 397.12	118.86, 729.36	
Total (*n* = 41)	1.24 ± 0.58	1.06, 1.43	0.676	49.22 ± 47.26	34.30, 64.14	0.046*	742.83 ± 1,713.56	201.96, 1,283.70	0.187
Posterior glenohumeral joint									
1st-year residents (*n* = 13)	1.38 ± 0.65	0.99, 1.78		94.00 ± 83.91	43.29, 144.71		1,348.54 ± 2,372.33	−85.05, 2,782.12	
2nd-year residents (*n* = 3)	1.33 ± 0.58	−0.10, 2.77		142.00 ± 98.65	−103.06, 387.06		3,440.67 ± 2,958.14	−3,907.77, 10,789.10	
3rd-year residents (*n* = 4)	1.50 ± 0.58	0.58, 2.42		91.75 ± 59.94	−3.63, 187.13		391.50 ± 229.52	26.28, 756.72	
Fellows (*n* = 7)	1.57 ± 1.51	0.17, 2.97		80.29 ± 111.85	−23.15, 183.73		814.43 ± 787.78	85.86, 1,543.00	
Total (*n* = 27)	1.44 ± 0.89	1.09, 1.80	0.971	95.44 ± 87.26	60.92, 129.96	0.803	1,300.74 ± 2,034.78	495.81, 2,105.67	0.213
Rotator interval									
1st-year residents (*n* = 20)	1.10 ± 0.31	0.96, 1.24		28.50 ± 25.67	16.49, 40.51		1,039.45 ± 2,199.05	10.26, 2,068.64	
2nd-year residents (*n* = 2)	1.00 ± 0.00	1.00, 1.00		51.00 ± 4.24	12.88, 89.12		923.50 ± 23.34	713.85, 1,133.15	
3rd-year residents (*n* = 2)	1.00 ± 0.00	1.00, 1.00		27.50 ± 3.54	−4.27, 59.27		406.00 ± 369.11	−2,910.32, 3,722.32	
Fellows (*n* = 6)	1.17 ± 0.41	0.74, 1.60		36.67 ± 18.14	17.63, 55.70		793.33 ± 602.01	161.56, 1,425.11	
Total (*n* = 30)	1.10 ± 0.61	0.99, 1.21	0.882	31.57 ± 22.99	22.98, 40.15	0.566	940.27 ± 1,807.34	265.40, 1,615.14	0.969

SD standard deviation, *CI* confidence interval

*Statistically significant

fluoroscopy as often as possible, especially in the abdomen and genitourinary sections in addition to the musculoskeletal section. This may be a possible reason for that result.

There was no difference in radiation dose among three approaches, although fluoroscopy time was longer during arthrography using the posterior glenohumeral joint approach: however, a larger radiation dose was generated in cases by 1st- or 2nd-year residents. Therefore, radiation dose may be related to the familiarity with handling a fluoroscopy machine according to the experience of the practitioners, rather than fluoroscopy time itself. In our results, average fluoroscopy time was similar between the 2nd- and 3rd-year residents, whereas the mean radiation dose was markedly lower in cases dealt with by 3rd-year residents than those dealt with by 2nd-year residents. This may mean that other contributing factors regarding radiation dose, such as collimation, intermittent fluoroscopy, or last-image-hold, may play an important role in the decreased radiation dose of 3rd-year residents, in addition to fluoroscopy time.

Previous studies evaluated the procedure time, three of which mentioned the fluoroscopy or exposure time and the rest described the procedure time [7, 20–22]. All arthrography was conducted by qualified members of staff or trainees under strict supervision by a skilled radiologist throughout the procedure, and the procedure time and the fluoroscopy time were very short. In this study, the fluoroscopy time was relatively long, because most of the practitioners were 1st-year residents beginning an arthrography procedure using fluoroscopy and performing arthrography without a supervisor in the fluoroscopy room, but one who waited and came when called for help.

Our study showed the radiation dose according to the approach and the training experiences of the practitioners;

however, it could not be compared with previous literature, because there were no previous reports on that. Considering the relatively long fluoroscopy time of our study, the radiation hazard may be an important issue during arthrography carried out only by unskilled trainees. In this respect, ultrasound-guided arthrography may be more suitable for inexperienced trainees.

In terms of complications, previous studies have reported that the post-procedural pain was tolerable and that complications after arthrography were very rare, without a life-threatening event [23, 24]. There was only one patient who experienced an immediate complication (sustained pain) in our study.

Also in this study, the difficulty in interpretation related to contrast medium leakage of the three approaches was not compared. Several studies have reported that contrast medium leakage may cause interpretation errors and that a tailored approach is superior [4, 13, 14]. On the other hand, a recent study has demonstrated that there was no association of the location or pattern of contrast medium leakage with the injection pathway [25]. Based on our results, there were no differences regarding any measures among the three approaches, except for fluoroscopy time; thus, the tailored method should be used particularly in patients with suspected anterior shoulder instability.

This study had some limitations. First, some patients underwent arthrography using an injection approach other than the allocated method, because of practical problems, which caused an uneven number of cases for the different approaches. Second, none of the practitioners was a qualified member of staff; thus, a comparison could not be made between trainees and trained radiologists. However, the present study focused on trainees. Third, the radiation dose to the practitioners could not be measured. Furthermore, many factors that contribute to radiation dose besides fluoroscopy time such as collimation, magnification, or distance between the detector and the patient could not be standardized; therefore, there may be an interpretation bias of our results on radiation dose. Fourth, the scale of pain during or after arthrography could not be examined.

In conclusion, of the three approaches, fluoroscopy-guided shoulder arthrography via the rotator interval approach may be easy, and the posterior glenohumeral joint approach may be difficult for trainees, requiring further learning experience.

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Compliance with ethical standards

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Conflicts of interest The authors declare that they have no conflicts of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

References

1. Rhee RB, Chan KK, Lieu JG, Kim BS, Steinbach LS. MR and CT arthrography of the shoulder. Semin Musculoskelet Radiol. 2012;16:3–14.
2. Schneider R, Ghelman B, Kaye JJ. A simplified injection technique for shoulder arthrography. Radiology. 1975;114:738–9.
3. Shortt CP, Morrison WB, Roberts CC, Deely DM, Gopez AG, Zoga AC. Shoulder, hip, and knee arthrography needle placement using fluoroscopic guidance: practice patterns of musculoskeletal radiologists in North America. Skeletal Radiol. 2009;38:377–85.
4. Chung CB, Dwek JR, Feng S, Resnick D. MR arthrography of the glenohumeral joint: a tailored approach. Am J Roentgenol. 2001;177:217–9.
5. Hodler J. Technical errors in MR arthrography. Skeletal Radiol. 2008;37:9–18.
6. Farmer K, Hughes P. MR arthrography of the shoulder: fluoroscopically guided technique using a posterior approach. Am J Roentgenol. 2002;178:433–4.
7. Dépelteau H, Bureau NJ, Cardinal E, Aubin B, Brassard P. Arthrography of the shoulder: a simple fluoroscopically guided approach for targeting the rotator cuff interval. Am J Roentgenol. 2004;182:329–32.
8. Sethi PM, Kingston S, Elattrache N. Accuracy of anterior intra-articular injection of the glenohumeral joint. Arthroscopy. 2005;21:77–80.
9. DeMouy E, Menendez Jr C, Bodin C. Palpation-directed (non-fluoroscopically guided) saline-enhanced MR arthrography of the shoulder. Am J Roentgenol. 1997;169:229–31.
10. Catalano OA, Manfredi R, Vanzulli A, et al. MR arthrography of the glenohumeral joint: modified posterior approach without imaging guidance. Radiology. 2007;242:550–4.
11. Powell SE, Davis SM, Lee EH, et al. Accuracy of palpation-directed intra-articular glenohumeral injection confirmed by magnetic resonance arthrography. Arthroscopy. 2015;31:205–8.
12. Daley EL, Bajaj S, Bisson LJ, Cole BJ. Improving injection accuracy of the elbow, knee, and shoulder does injection site and imaging make a difference? A systematic review. Am J Sports Med. 2011;39:656–62.
13. Koivikko M, Mustonen A. Shoulder magnetic resonance arthrography: a prospective randomized study of anterior and posterior ultrasonography-guided contrast injections. Acta Radiol. 2008;49:912–7.
14. Ogul H, Bayraktutan U, Ozgokce M, et al. Ultrasound-guided shoulder MR arthrography: comparison of rotator interval and posterior approach. Clin Imaging. 2014;38:11–7.
15. Amber KT, Landy DC, Amber I, Knopf D, Guerra J. Comparing the accuracy of ultrasound versus fluoroscopy in glenohumeral injections: a systematic review and meta-analysis. J Clin Ultrasound. 2014;42:411–6.
16. Souza PM, de Aguiar ROC, Marchiori E, Bardoe SAW. Arthrography of the shoulder: a modified ultrasound guided technique of joint injection at the rotator interval. Eur J Radiol. 2010;74:e29–32.

17. Gokalp G, Dusak A, Yazici Z. Efficacy of ultrasonography-guided shoulder MR arthrography using a posterior approach. Skeletal Radiol. 2010;39:575–9.
18. Choudur HN, Ellins ML. Ultrasound-guided gadolinium joint injections for magnetic resonance arthrography. J Clin Ultrasound. 2011;39:6–11.
19. Perdikakis E, Drakonaki E, Maris T, Karantanas A. MR arthrography of the shoulder: tolerance evaluation of four different injection techniques. Skeletal Radiol. 2013;42:99–105.
20. Berná-Serna J, Redondo M, Martínez F, et al. A simple technique for shoulder arthrography. Acta Radiol. 2006;47:725–9.
21. Rutten MJ, Collins JM, Maresch BJ, et al. Glenohumeral joint injection: a comparative study of ultrasound and fluoroscopically guided techniques before MR arthrography. Eur Radiol. 2009;19:722–30.
22. Redondo MV, Berná-Serna JD, Campos PA, et al. MR arthrography of the shoulder using an anterior approach: optimal injection site. Am J Roentgenol. 2008;191:1397–400.
23. Newberg A, Munn C, Robbins A. Complications of arthrography. Radiology. 1985;155:605–6.
24. Saupe N, Zanetti M, Pfirrmann CW, Wels T, Schwenke C, Hodler J. Pain and other side effects after MR arthrography: prospective evaluation in 1085 patients. Radiology. 2009;250:830–8.
25. Ogul H, Kantarci M, Topal M, et al. Extra-articular contrast material leaks into locations unrelated to the injection path in shoulder MR arthrography. Eur Radiol. 2014;24:2606–13.