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BASIC SCIENCE

Comparison of ultrasound-guided versus blind glenohumeral injections: a cadaveric study

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Background: Intra-articular glenohumeral (GH) injections are important for diagnostic and therapeutic purposes. It has been suggested that ultrasound guided injections are more accurate than blind or freehand injections. This study assessed the accuracy of ultrasound-guided GH injections compared with freehand injections in fresh cadavers.
Methods: The study used 80 shoulder specimens from fresh cadavers. Ultrasound guidance was used to inject radiopaque contrast in 40 shoulders, and freehand technique was used in the remaining 40. All injections were performed by 2 surgeons (A and B) through a posterior approach. After the injections, radiographs were obtained of the specimens to assess the accuracy of the injections.
Results: Sixty-six of 80 (82.5%) injections were accurately administered into the GH joint. Ultrasound-guided injections were accurate in 37 of 40 specimens (92.5%) compared with freehand injections, which were accurate in only 29 of 40 specimens (72.5%; $P = .02$). Both surgeons independently had higher accuracy using ultrasound-guidance compared with the freehand technique (surgeon A: 90% vs 65%, $P = 0.058$; surgeon B: 95% vs 80%, $P = 0.15$). The average time for injections was 52 seconds by the freehand technique and 166 seconds using ultrasound guidance ($P < 0.001$).
Conclusions: The data from this cadaveric study suggest that ultrasound-guided injections are more accurate at reaching the GH joint than freehand injections. The ultrasound-guided injections took substantially longer to administer. Once familiar with the technique, surgeons can expect improved accuracy and efficacy of GH joint injections using ultrasound guidance in the clinical setting.
Level of evidence: Basic Science Study, Anatomic Study.

Keywords: Glenohumeral; injection; shoulder; ultrasound guided; cadaveric; accuracy; time assessment

Intra-articular glenohumeral (GH) injections have an important function in the diagnosis and therapeutic intervention of shoulder pathology.[1,6] Correctly administered GH injections can improve clinical outcomes and provide significant patient satisfaction.[4,11] Conversely, inaccurately placed injected material may cause further damage to the surrounding structures in the shoulder.[7] Therefore, it is essential that the injected material reach its desired location.

Practitioners often take for granted the accuracy of these injections when performed in the clinical setting. Multiple techniques have been described to approach the GH joint, with the anterior and posterior approaches being the most

Investigational Review Board approval was not required for this study.

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common.[6,12] A recent cadaveric study on the accuracy of GH injections reported a 74% success rate.[5] Reports of injections in patients have shown a lower accuracy rate of 11% to 42%,[4,9] Most of these studies were limited by small sample sizes and variable injection techniques. Even less is known about the accuracy of GH injections and the time it takes for administration using various methods. With the increased use of radiology-assisted techniques in orthopedic clinical practice, there is a rising interest in the efficiency of these techniques at providing improved clinical outcomes with no added morbidity to the patient.

The purpose of the study was to compare the accuracy of ultrasound-guided GH injections vs freehand injections in fresh cadavers. The time spent performing each of the techniques was also evaluated.

Materials and methods

This study used 80 cadaveric shoulders (40 male, 40 female) from donors who were an average age of 56.4 years (range, 42-70 years). All shoulders were of medium built. None of the specimens had evidence of prior surgical scars on inspection.

Injections were performed by 2 surgeons who are members of the Department of Orthopedic Surgery at a university-based medical center. Surgeon A is a sports fellowship-trained attending orthopedic surgeon. Surgeon B is a resident in orthopedic surgery. A total of 80 injections were performed on the 80 fresh specimens. Each surgeon performed 20 freehand injections and 20 ultrasound-guided injections through a posterior approach. All injections were performed with the shoulder specimens positioned upright in an arthroscopy holder. One injection attempt was allowed for each specimen.

Before the freehand injection, each shoulder was examined and palpated to determine the borders of the acromion, the GH joint line, and the bony landmark of the coracoid process. An outline of the posterolateral edge of the acromion was marked on the specimen. Next, an 18-gauge spinal needle was guided freehand into the GH joint from a site approximately 2 cm distal and 1 cm medial to the posterolateral point of the acromion and aiming toward the coracoid process (Fig. 1). When the surgeon felt that the joint capsule had been penetrated and the needle was in the GH joint space, 3 mL of iohexol radiopaque contrast (Omnipaque, Novaplus, GE Healthcare Inc, Princeton, NJ) was injected.

The specimen was immediately placed in the minifluoroscopy machine to confirm the accuracy of the injection. The presence of contrast fluid in the GH joint space was considered an accurate injection. The presence of contrast in the surrounding soft tissue or subacromial space was considered an inaccurate injection (Fig. 2).

Similar bony landmarks were identified and marked on the cadaveric shoulders before injection under ultrasound guidance. The ultrasound probe was placed over the posterior aspect of the

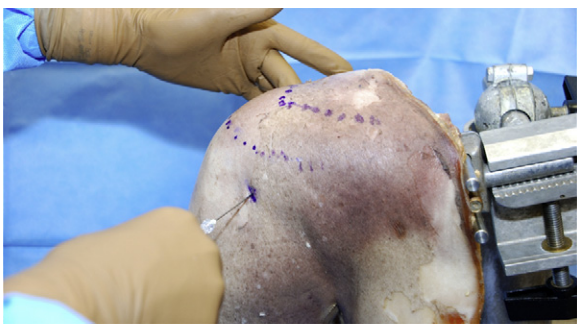

Figure 1 The surgeon performs a glenohumeral joint injection using the freehand technique on a cadaveric left shoulder specimen. The *blue doted line* marks the borders of the acromion. An 18-gauge spinal needle is entering at a point 2 cm inferior and 1 cm medial to the posterolateral corner of the acromion and is being aimed toward the coracoid process.

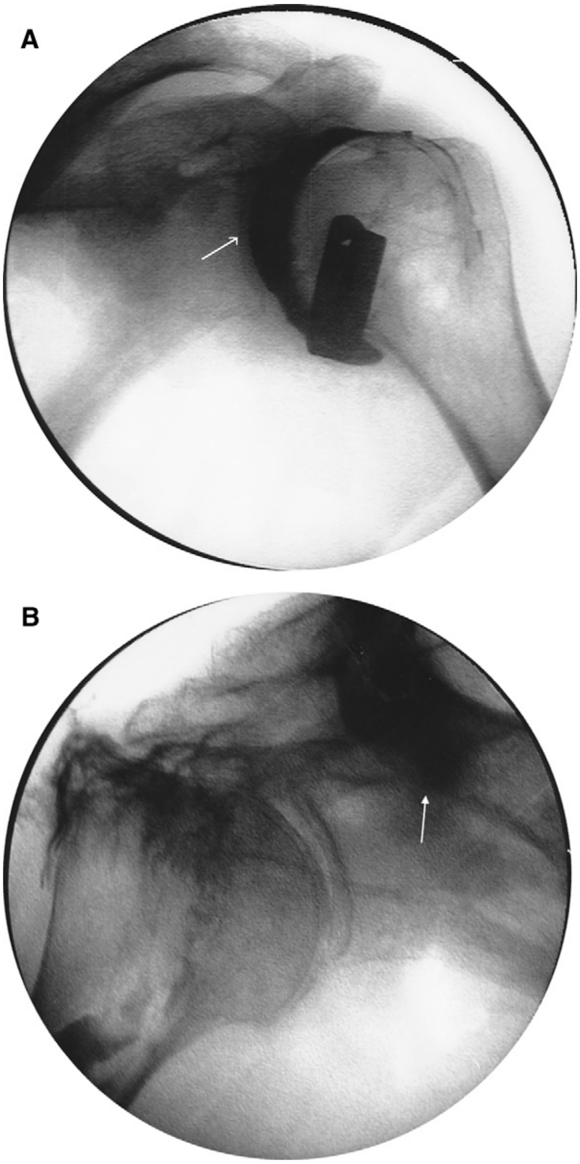

Figure 2 (**A**) A fluoroscopic image shows a cadaveric right shoulder specimen after an ultrasound-guided injection of contrast material. The dark contrast medium within the glenohumeral joint space confirms an accurate injection (*arrow*). (**B**) A fluoroscopic image shows a cadaveric right shoulder specimen after a freehand injection of contrast material. The dark contrast medium within the subacromial space confirms an inaccurate injection (*arrow*).

shoulder and the GH joint space identified under sonographic visualization (Fig. 3) An 18-gauge hyperechoic needle was inserted parallel to the long axis of the probe and advanced under ultrasound visualization, from posterolateral to anteromedial, toward the interval between the boarders of the glenoid and humeral head that outline the GH joint space. Once the surgeon believed the correct position was obtained, 3 mL of radiopaque contrast was injected into the presumed GH joint space. The entry of fluid into the joint space was seen as a dark fluid wave on the ultrasound image (Fig. 4),

Statistical analyses were performed using SAS 9.1.3 software (SAS Institute Inc, Cary, NC, USA). We performed a power analysis with the assumption of a 0.25 difference in success rate. At a power level set at 0.80, we predetermined that at least 36 shoulder specimens were required in each group to ensure adequate power. A χ^2 test was used to compare the differences amongst ultrasound-guided injections compared with freehand injections. Times for administration of the injections were analyzed using a paired *t* test. All significance levels were set at an α level of < 0.05.

Results

Accuracy

Of the 80 injections, 66 (82.5%) were accurately administered in the GH joint. Ultrasound-guided injections were accurate in 37 of 40 specimens (92.5%) compared with freehand injections, which were accurate in 29 of 40 specimens (72.5%; $P = .02$). Surgeon A successfully administered 18 of 20 injections (90%) in the GH joint using ultrasound guidance compared with 13 of 20 injections (65%) with the freehand technique ($P = .06$). Surgeon B successfully administered 19 of 20 injections (95%) in the GH joint using ultrasound guidance compared with 16 of 20 injections (80%) with the freehand technique ($P = .15$). The difference in accuracy between the 2 techniques (ultrasound guided vs freehand) was statistically significant overall for all 80 specimens but not individually between each surgeon (Table I).

Time assessment

The mean injection time overall was 173 seconds for ultrasound-guided GH injections compared with 53 seconds for freehand injections ($P < 0.01$). Surgeon A performed all ultrasound-guided GH injections at an average time of 166 seconds compared with the freehand technique at an average of 52 seconds ($P < 0.01$). Surgeon B performed all ultrasound-guided GH injections at an average time of 180 seconds compared with the freehand technique at an average time of 58 seconds ($P < 0.01$). The differences between the ultrasound-guided vs freehand techniques were statistically significant overall for all 80 specimens and individually between each surgeon (Table II).

No complications arose during this study.

Discussion

The accurate placement of GH injections in the clinical setting is often taken for granted. In a study by Tobola et al[10] in 2011, the accuracy of injections within the GH joint, regardless of experience, was 64.7% through anterior approach and 45.7% through a posterior approach. A recent cadaveric study on the accuracy of GH injections reported a 74% success rate.[5] Misplaced shoulder injections decrease the diagnostic and therapeutic yield of the injection and may lead to further damage to the surrounding structures in the shoulder, specifically the rotator cuff.[7,8] The main advantage of ultrasound-guided GH joint injections vs freehand technique is that the position of the needle can be more accurately confirmed in the joint space, with direct visualization of the fluid injected.

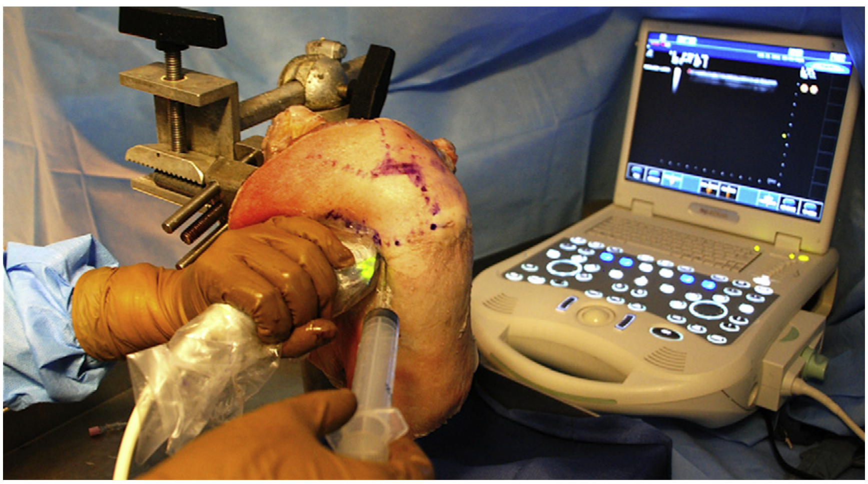

Figure 3 The surgeon uses ultrasound guidance to perform a glenohumeral joint injection in a cadaveric right shoulder specimen. The *blue doted lines* represent the borders of the clavicle (anterior) and acromion (posterior). An 18-gauge spinal needle is guided into the glenohumeral joint under visualization with sonography.

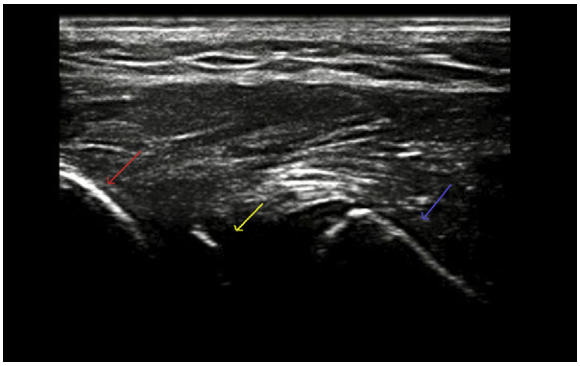

Figure 4 A captured ultrasound image during injection of contrast material into the glenohumeral joint shows dark contrast fluid is occupying the joint space between the humeral head and glenoid. Note the structures visualized: humeral head (*red arrow*), spinal needle in the joint space (*yellow arrow*), and the glenoid (*blue arrow*).

The accuracy of GH joint injections varies considerably.[2,3,5,8-10] Sethi et al[9] reported a 50% accuracy rate and 0.67 positive-predictive value for posterior injections in fresh cadavers. A recent prospective study by Tobola et al[10] in patients undergoing freehand injections demonstrated that regardless of experience, the accuracy of posterior injections was 45.7%.

We compared ultrasound-guided GH joint injections vs freehand injections through the posterior approach because this is the most common approach used for GH joint injections in our institution. The results of this study demonstrated that ultrasound-guided injections are more accurate than freehand injections. An in-depth analysis of the data showed that the accuracy improved over time for each surgeon using ultrasound guidance, whereas the error rate remained relatively stable for the freehand injections. This suggests that with increasing experience, as the learning curve passes, surgeons can reliably expect to achieve better results over time. Although the anterior approach was not performed in this investigation, prior studies have suggested that the anterior approach may give higher rate of success compared with posterior injections. Sethi et al,[8] in 2006, reported an 80% accuracy rate with the anterior approach in GH joint injections in 40 cadavers vs a 50% accuracy rate with the the posterior approach.

Table I Glenohumeral joint injection accuracy analysis

Variable	No.	Success (No.)	Miss (No.)	Success rate (%)	*P*
Surgeon A					
US guided	20	18	2	90.0	...
Freehand	20	13	7	70.0	.15
Surgeon B					
US guided	20	19	1	95.0	...
Freehand	20	16	4	80.0	.06
Combined					
US guided	40	37	3	92.5	...
Freehand	40	29	11	72.5	.02
Totals	80	66	14	82.5	

US, ultrasound.

Table II Glenohumeral joint injection time analysis

Variable	No	Mean (SE) (sec)	Min-max (sec)	*P*
Surgeon A				
US guided	20	166 (8.81)	120-300	...
Freehand	20	52 (4.53)	25-96	<.001
Surgeon B				
US guided	20	180 (4.57)	138-214	...
Freehand	20	58 (3.09)	37-81	<.001
Combined				
US guided	40	173 (5.02)	120-300	...
Freehand	40	53 (2.75)	25-96	<.001

SE, standard error; *US,* ultrasound.

Analysis of the time for injection data demonstrated that the ultrasound-guided injections were more time consuming than freehand injections. This may be due to a variety of factors: First, it takes longer for the injector to initially locate the GH joint space using the ultrasound machine compared with palpating the bony landmarks of the shoulder for a freehand injection. Second, once the joint space is visualized on the ultrasound machine, additional time is needed to guide the spinal needle into the joint space under direct visualization. Finally, surgeon familiarity with the more commonly used freehand technique led to quicker injection rates. We noted that the injection times by ultrasound guidance decreased for both surgeons as the study progressed and we became more comfortable with the technique. Specifically, the average time for the last 10 injections for each surgeon using ultrasound guidance was quicker compared with the first 10 injections (surgeon A: 146 vs 186 seconds; surgeon B: 165 vs 195 seconds).

Ultrasound-guided injections may potentially reduce unnecessary attempts at GH placement.[2] In addition, ultrasound is readily available, portable, and can be used quickly at a lower cost compared with other imaging modalities such as fluoroscopy and magnetic resonance imaging. Most important, it can be performed with relatively no additional side effects to the patient.

To simulate application in the clinical setting, the surgeons were allowed one pass into the shoulder specimen; however, our results may not accurately reflect a similar outcome in actual patients given certain limitations. The use of cadaveric specimens limits the ability to appreciate muscle tension during insertion of the needle. Our specimens also lacked significant GH joint disease, which makes accurate placement of the spinal needle more difficult secondary to narrowing of the joint space. Finally, we only compared accuracy with posterior injections and not other approaches that are used by other surgeons and may be more or less accurate. Further studies comparing different injections techniques vs ultrasound guidance are needed.

Conclusion

We achieved a significantly higher accuracy rate using ultrasound guidance compared with freehand posterior GH injections, despite the longer time to injection. We encourage the use of ultrasound guidance in clinical practice because it obviates the need for radiation or contrast medium, or both. As such, we plan to obtain Investigational Review Board approval to perform a similar study in clinical patients.

Disclaimer

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Laith Jazrawi, or an immediate family member, serves as a paid consultant to or is an employee of ConMed Linvatec, Ferring Pharmaceuticals, Knee Creations, Core Essence, and Depuy Mitek, but did not receive any financial payments or other benefits related to the subject of this article. None of the other authors, their immediate families, or any research foundations with which they are affiliated received any financial payments or other benefits from any commercial entity related to the subject of this article.

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