Verification of palpation-guided intra-articular injections using glucocorticoid-air-saline mixture and ultrasound imaging (GAS-graphy)

J.M. Koski, H.S. Hermunen, V.-M. Kilponen, S.J. Saarakkala, U.K. Hakulinen, J.O. Heikkinen

Mikkeli Central Hospital, Porrassalmenkatu 35-37, Mikkeli, Finland.

Abstract

Objective

To examine a contrast medium method using a glucocorticoid-air-saline mixture and ultrasound imaging (GAS-graphy) for the verification of palpation-guided injections in different joints and to assess the inter-reader reliability of the method.

Methods

A palpation-guided injection of an air-steroid-saline mixture was given into a joint or tendon sheath of 133 consecutive patients. The dynamic ultrasound monitor images of the joints and tendons involved were videotaped before and after the injection. A rheumatologist and two radiologists analyzed separately the video clips of each patient, under blinded conditions. The readers evaluated the accuracy of the injections and the difficulty of the reading process. The inter-reader agreement was assessed by calculating the percentual values and overall kappa coefficient between the readers.

Results

The overall accuracy of the successful injections was 76%, 80% and 82 % evaluated by the three readers. In six out of the ten injection sites the accuracy was higher than 80%. The clarity of the method evaluated by the readers was 8, 8 and 8.5 on a scale from 0 to 10. The inter-reader agreement assessed by percentual values was 84.2%, 85.0% and 88.7%. The kappa coefficient between all readers was 0.595 showing moderate agreement.

Conclusion

The GAS-graphy method for the verification of palpation-guided injections is a simple procedure performable to any joint site and the result can be seen immediately on the monitor after the injection. The reliability of the method is good and it can be used in developing injection techniques as well as in medical or nurse education. The method can be used as an alternative for the radiographic contrast medium method in verifying successful palpation-guided intra-articular injections.

Key words

Ultrasound, contrast medium, injection, joint, accuracy, reliability.

Clinical and Experimental Rheumatology 2006; **24**: 247-252.

Juhani M. Koski, MD, PhD, rheumatologist; Heikki S. Hermunen, MD, radiologist; Vesa-Matti Kilponen, MD, radiologist; Simo J. Saarakkala, BSc, associate physicist; Ullamari K. Hakulinen, BSc, researcher; Jari O. Heikkinen, PhD, medical physicist.

Please address correspondence to: Juhani Koski, Mikkeli Central Hospital, Porrassalmenkatu 35-37, Fin-50100 Mikkeli, Finland. E-mail: f.koski@fimnet.fi

Reprints will not be available from the authors.

Received on August 8, 2005; accepted in revised form on January 25, 2006.

Introduction

Corticosteroids have been used in rheumatology for more than fifty years in the local treatment of arthritis, bursitis and tenosynovitis. Viscosupplementation is another intra-articular therapeutic technique used in osteoarthritis to alleviate symptoms. During the past ten years attention has been paid to the accuracy of needle placement in performing palpation-guided injections. In the first report by Jones *et al.* (1) several joint sites were studied but in other related articles mostly the knee and the shoulder have been the principal targets of interest (2-7). In most studies the method used for the verification of palpation-guided injections has been injecting the mixture of radiographic contrast medium and steroid into a target. Accuracy rates have varied between 29% and 93 % (Table I).

Ultrasound (US) can help in soft tissue injections. A needle guided with US can be inserted accurately into the body's soft tissues, such as joints, bursae and tendon sheaths if an acoustic window is available (8, 9). Fredberg *et al.* (10) and Qvistgaard *et al.* (11) have used air in US guidance for the verification of the needle and delivering the drug. A large amount of air hampers US imaging but, as we have reported earlier, a little amount of air together with steroid and saline forms an excellent contrast medium in grey scale US imaging (12). In this paper we show the potential of the method using **g**lucocorticoid-**a**ir-**s**aline as a contrast medium and US imaging (GAS-graphy) for the verification of palpation-guided injections in different joint and tendon sheath sites and use three readers to assess the reliability of the method.

Materials and methods

The ultrasound equipment used in this study was Esaote Technos© (Esaote Biomedica, Via Siffredi 58, 16153 Genova, Italy) equipped with two probes: LA424 (frequency range 7, 5-13 MHz) and LA523 (frequency range 5-10 MHz). Quality assurance measurements were conducted on the ultrasound equipment and both probes. A general purpose CIRS Model 40 -phantom (CIRS Inc., Norfolk, VA, USA) was used and measurements were conducted twice at an interval of 18 months. Near-field resolution, axial resolution, lateral resolution, penetration depth and accuracy of the horizontal and vertical distance measurements were determined. All quality assurance measurements were conducted according to the AIUM recommendations (13).

A palpation-guided injection of a glucocorticoid-air-saline mixture was given into a joint or tendon sheath of 133 consecutive patients. The indication for the injection was arthritis or tenosynovitis diagnosed clinically or with US. The mean age of the patients was 54.6 years (22-85 years). Eighty-five were women and 48 men. The diagnoses were: 86 rheumatoid arthritis, 16 chronic oligoarthritis, 13 psoriatic arthritis, 6 spondyloarthritis, 6 juvenile polyarthritis and gout, osteoarthritis, polymyalgia rheumatica, snapping finger, scleroderma and shoulder pain one of each. GAS-graphy was performed into 27 knee, 23 metatarsophalangeal (MTP), 12 distal interphalangeal (DIP) (hand), 12 proximal interphalangeal (PIP) (hand), 12 elbow, 11 glenohumeral, 11 radiocarpal, 9 metacarpophalangeal (MCP) and 6 tibiotalar joints as well as into 10 flexor tendon sheaths of the hand. The injection technique of each site is shown in Figure 1. The contrast medium used was air + methylprednisolone + saline in 24 and air + triamcinolone-hexacetonide + saline in 109 cases. The amount of the steroid was 0.5 -1 ml and of saline 1-10 ml, depending the size of the synovial space. After adding the steroid and saline into a syringe, non-sterile room air (0.3 - 1ml) was drawn in and the syringe was shaken for a few seconds. The palpation-guided injections were conducted by the rheumatologist (JMK), who has 19 years of experience of joint and soft tissue injections, giving 1200 injections per year.

The dynamic US monitor images of joints and tendons involved were videotaped by the author JMK before and after the palpation-guided injections. The digital video camera connected to the US equipment was Sony DCR-TRV 900E. A dorsal longitudinal

Table I. Accuracy of needle placement in palpation-guided injections found in the literature (1-7).

Author	Method	Target	Accuracy
Jones *et al.* -93	contrast agent and x-ray	1) several joints 2) knee joint	1) 50 % 2) 39 %
Eustace *et al.* -97	contrast agent and x-ray	1) subacromial bursa 2) glenohumeral joint	1) 29 % 2) 42 %
Partington and Broome -98	dye in cadavers	1) subacromial bursa 2) acromioclavicular joint	1) 83 % 2) 67 %
Bliddal -99	air and x-ray	knee joint	91 %
Yamakado -02	contrast agent and x-ray	subacromial bursa	70 %
Jackson *et al*.-02	contrast agent and x-ray	knee joint	71 % lateral approach 75 % medial approach 93 % midpatellar approach
Esenyel *et al*.-03	contrast agent and x-ray	subacromial bursa	87 %

US scan was performed in DIP, PIP, MCP, wrist, tibiotalar and MTP joints in neutral positions. The flexor tendons of the hand were depicted longitudinally and transversely on the volar side. The elbow joint was recorded using a longitudinal dorsal scan elbow in 90 degrees flexion. The glenohumeral joint was depicted transversely in front, obliquely in dorsal and longitudinally in the underarm. The knee joint was scanned placing the probe longitudinally on the lateral compartment. A slight passive movement or compression of the joint or tendon was executed during the recording to get a better vision of the movements of possible intrasynovial material.

The rheumatologist (JMK) and two radiologists (V-MK, HSH) analysed the video clips of each patient separate-

Fig. 1. The palpation-guided injection techniques of the joints and tendon sheath used in the study.1 = distal interphalangeal, 2 = proximal interphalangeal, 3 = flexor tendon sheath of the hand, 4 = metacarpophalangeal, 5 = radiocarpal, 6 = elbow, 7 = tibiotalar 8 = glenohumeral, 9 = knee and 10 = metatarsophalangeal.

ly and under blinded conditions. The radiologists knew the identity of the patient, the joint site involved and the orientation of the transducer. They reported in the documentation sheet whether the injections were inside or outside the synovial target. The third option was: I can't say. The given criteria for successful injections were: a clear anechoic widening of the synovial space due to saline and/or finding the characteristic white dots or lines (due to air or steroid) inside the synovial space. After filling out the documentation sheet they evaluated each injection site as to the difficulty level of the reading process on the scale 0 – 10. Zero meant very difficult and unclear, ten very easy and clear decision. The inter-reader agreement was assessed by calculating the percentual agreement and overall kappa coefficient between the readers (14 - 15). The following definitions for the kappa coefficient have been described: kappa < 0.00 means poor, 0.00- 0.20 slight, 0.21- 0.40 fair, 0.41-0.60 moderate, 0.61-0.80 substantial and 0.81-1.00 almost perfect agreement.

The study was approved by the local ethical committee and the patients gave their informed consent.

Table II. The accuracy figures of palpation-guided injections by the three investigators site by site. The figures are % of the 133 injections. JMK, V-MK and HSH are the readers.

Site	Injection is inside the target JMK/V-MK/HSH	Injection is outside the target JMK/V-MK/HSH	I can't say JMK/V-MK/HSH
All sites	80/82 /76	13/14 /19	7/4 /5
Radiocarpal joint	100/91/100		0/9/ 0
Elbow joint	100/92/100	0/8/0	
Metacarpophalangeal joint	100/100/100		
Knee joint	93/96/86	3/4/7	4/ 0/7
Proximal interphalangeal joint	92/92/58	8/8/ 25	0/0/17
Tibiotalar joint	83/83/100	0/17/0	17/0 /0
Glenohumeral joint	82/91/91	9/9/9	9/ 0 /0
Distal interphalangeal joint	68/58/68	16/9/16	16/33/16
Metatarsophalangeal joint	57/65/48	30/30/48	13/5/4
Flexor tendon sheath of the hand	30/50/40	60/50/60	10/0/0

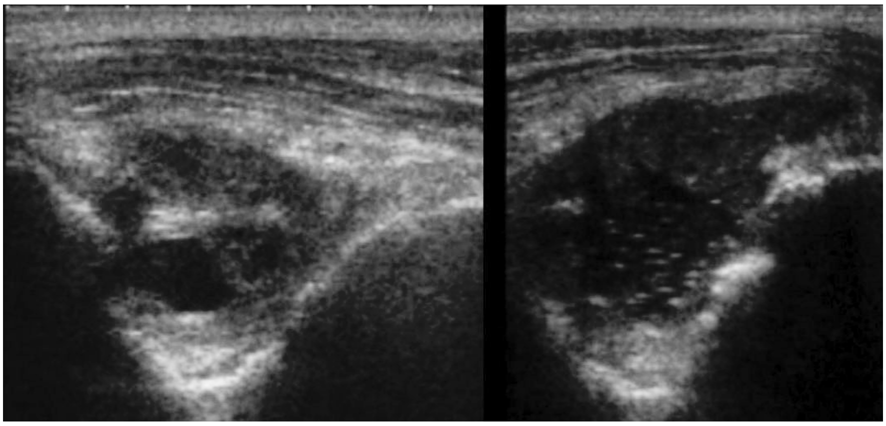

Fig. 2. GAS-graphy of the elbow joint. Elbow is flexed 90 degrees and the transducer is longitudinally dorsal. On the left panel the joint before and on the right panel after injection. In the image on the right the amount of fluid has increased and the typical white dots of air can be seen.

Results

The performance of the B-mode of the US equipment, used was excellent. In the quality assurance measurements the near-field resolution, axial resolution and lateral resolution of the system were < 1.0 mm, < 0.5 mm and < 1.0 mm, respectively. The maximum penetration depth was 60 mm when working with the LA424 probe and 100 mm with the LA523 probe. The accuracy of the horizontal distance measurements was 1.0 % at the depth of 2 cm from the surface (both probes) and 1.0 % at the depth of 9 cm from the surface (probe LA523). The accuracy of the vertical distance measurements was between 1% and 5 % depending of the probe, measured distance or depth. All the parameters measured were the same after 18 months.

The overall success figures of accuracy in all injection sites were 76% (HSH), 80% (JMK) and 82 % (V-MK). The accuracy percents varied between 30-100 in different joint sites. However, in six out of the ten injection sites the accuracy was more than 80% among all readers (Table II) (Figs. 2, 3). The procedure caused neither complications nor side effects in the 6 months follow-up period. The outcome of the sites treated was not the objective of this study.

The GAS-graphy method was a new technique for the two radiologists. After a short theoretical initiation to the technique they did not find it difficult to evaluate the cases on the videotape. The inter-reader agreement, as assessed by percentual values, was 84.2%, 85.0% and 88.7%. The kappa coefficient between all readers was 0.595 showing moderate agreement. The average grade of clarity in evaluating the reading process was 8,17 on the scale from zero to ten (Table III).

Discussion

The palpation-guided injection of joints and soft tissues is an important clinical skill used in everyday work by doctors in several specialty fields. There are studies to show the outcome as better when corticosteroid is injected into the target planned (2, 16-17), but also reports to the effect that a total accuracy of needle placement may not be essential to a satisfactory outcome (18-19). However, it is obvious that discomfort experienced by the patient and tissue atrophy within the extra-articular soft tissues can be diminished if the needle is placed accurately. Viscosupplementation should also be injected into the joint cavity. It is not an easy task to perform when the joint (commonly the knee) is dry or the patient is obese. It is said that soft tissue injection techniques are easily

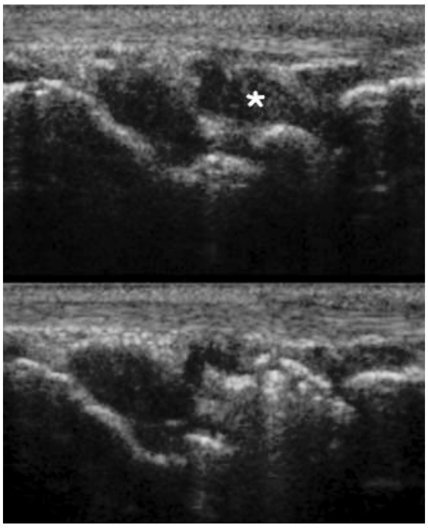

Fig. 3. GAS-graphy of the radiocarpal joint. Upper panel: US image of the wrist joint showing fluid and proliferation in the radiocarpal (asterisk) and midcarpal joints. The transducer is longitudinally dorsal, the radius is on the right. Lower panel: the same joint after an injection of the contrast medium with air-steroid-saline showing white lines and dots in the radiocarpal joint as a verification of a successful injection into the target.

Table III. Grade of the clarity in the GAS-graphy technique evaluated by the readers, injection site by site. The scale is zero to 10, zero meaning very difficult and unclear, 10 very easy and clear decision. JMK, V-MK and HSH are the readers.

Site	Grade by JMK	Grade by V-MK	Grade by HSH
Overall evaluation	8.5	8	8
Radiocarpal joint	10	7	9
Elbow joint	10	8	10
Metacarpophalangeal joint	8	7	7
Knee joint	10	9	10
Proximal interphalangeal joint	8	7	7
Tibiotalar joint	8.5	8	10
Glenohumeral joint	8.5	9	10
Distal interphalangeal joint	8	7	7
Metatarsophalangeal joint	7	7	7
Flexor tendon sheath of the hand	6	7	8

learned (20). However, the studies show various success rates in needle placement (Table I). Thus it is still important to evaluate and develop palpation-guided injection techniques as shown by Jackson *et al.* A fluoroscopy study showed that the midpatellar portal with the knee extended was the most accurate approach for intra-articular needle placement into a knee with no effusion.

This paper introduces a method for the verification of intra-articular or intra-tendon sheath injections using a contrast medium of mixture with glucocorticoid, air and saline imaged with US (GAS-graphy). As we have shown in earlier work, air is the principal producer of contrast in US imaging but in experimental conditions the best contrast was achieved using all the three components (12). A small amount of air injected together with the steroid and saline can be seen in the target as minor dots, a white line or in patches. Saline is needed to increase the volume of the mixture, which is important when the post-injection images are compared with the images taken before the procedure. Saline is also needed as a carrier of the steroid and air bubbles. The steroid suspension contains crystals and is less echogenic by itself but combined with saline and air they produce the best contrast. The crystals probably diminish the size of the air bubbles and make the mixture more homogenous. Passive or active extension and flexion movements of the site injected are essential in searching for the contrast medium in the target space.

In this study more synovial sites were examined than in previous papers. The GAS-graphy worked also when injections into the tendon sheaths were evaluated. Only Jones *et al.* examined several joint sites. They found out that the overall accuracy of injections in different joints was only about 50%. In that paper the injections were predominantly performed by trainee rheumatologists. We report here higher success rates emphasizing variability among doctors performing blind injections. However, it should be noticed that the accuracy figures in these two papers are not fully comparable, because in the present paper the same person performed the preceding sonography and injections. Thus, the injection procedure can not perfectly be regarded as blind.

In the knee joint the success rate was 92% (mean of the three readers) being interestingly almost the same as reported by Jackson *et al.* (93%). Both studies used the midpatellar portal for delivering the contrast medium into the joint cavity. There were low success rates in some synovial sites like MTP joints and tendon sheaths. Especially here the US could be used to guide the needle more accurately. The author (JMK) always uses US guidance in the hip joint, subacromial bursa and midtarsal joint injections and therefore these sites were not included in this palpation-guided injection study.

The GAS-graphy method introduced in this study was found to be accurate and inter-reader agreement was moderate (the kappa coefficient was 0.595). However, calculated percentually the inter-reader agreement was excellent (84%-89%). The clarity of the method evaluated by the readers was acceptable. In only a few cases the readers could not say whether the injection was inside or outside of the target evaluated. The percentage of reportable US images in this study is higher than that of reportable x-rays in the Jones's study. However, in the reporting on the videos on some joints there were marked discrepancies. This can be due to different interpretations of the US criteria by the assessors. For a further validation and establishing of the technique some amount of training exercise to agree on reporting techniques with subsequent re-scoring of the blinded videos should be considered.

The GAS-graphy method described for the verification of palpation-guided injections is a simple procedure. The method does not use radiation, it can be performed to any joint site and the result can be seen immediately on the monitor after the injection. The method can be used in developing injection techniques and in medical or nurse education. In the author's opinion the method could be an alternative for the radiographic contrast medium method in the verifying success of palpation-guided intra-articular injections.

References

1. JONES A, REGAN M, LEDINGHAM J, PATTRICK M, MANHIRE A, DOHERTY M: Importance of placement of intra-articular steroid injections. *BMJ* 1993; 307: 1329-30.
2. EUSTACE JA, BROPHY DP, GIBNEY RP, BRESNIHAN B, FITZGERALD O: Comparison of the accuracy of steroid placement with clinical outcome in patients with shoulder symptoms. *Ann Rheum Dis* 1997; 56: 59-63.
3. PARTINGTON PF, BROOME GH: Diagnostic injection around the shoulder: hit and miss? A cadaveric study of injection accuracy. *J Shoulder Elbow Surg* 1998; 7: 147-50.
4. BLIDDAL H: Placement of intra-articular injections verified by mini air-arthrography. *Ann Rheum Dis* 1999; 58: 641-3.
5. YAMAKADO K: The targeting accuracy of subacromial injection to the shoulder: an arthrographic evaluation. *Arthroscopy* 2002; 18: 887-91.
6. JACKSON DW, EVANS NA, THOMAS BM: Accuracy of needle placement into the intra-articular space of the knee. *J Bone Joint Surg Am* 2002; 84-A: 1522-7.
7. ESENYEL CZ, ESENYEL M, YESILTEPE R, AYANOGLU S, BULBUL MM, KARA AN: The correlation between the accuracy of steroid injections and subsequent shoulder pain and function in subacromial impingement syndrome. *Acta Orthop Traumatol Turc* 2003; 37: 41-5.
8. KOSKI JM: Ultrasound guided injections in rheumatology. *J Rheumatol* 2000; 27: 2131-38.
9. FESSELL DP, JACOBSON JA, CRAIG J *et al.*: Using Sonography to Reveal and Aspirate Joint Effusions. *AJR* 2000; 174: 1353-62.
10. FREDBERG U, VAN OVEREEM HANSEN G, BOLVIG L: Placement of intra-articular injections verified by ultrasonography and injected air as contrast medium. *Ann Rheum Dis* 2001; 60: 542.
11. QVISTGAARD E, KRISTOFFERSEN H, TERSLEV L, DANNESKIOLD-SAMSOE B, TORP-PEDERSEN S, BLIDDAL H: Guidance by ultrasound of intra-articular injections in the knee and hip joints. *Osteoarthritis Cartilage* 2001; 9: 512-7.
12. KOSKI JM, SAARAKKALA S, HEIKKINEN J, HERMUNEN H: Use of air-steroid-saline mixture as contrast medium in greyscale ultrasound imaging: experimental study and practical applications in rheumatology. *Clin Exp Rheumatol* 2005; 23: 373-8.
13. AIUM (AMERICAN INSTITUTE OF ULTRASOUND IN MEDICINE): Standard methods for measuring performance of pulse-echo ultrasound imaging equipment, Rockville, MD: AIUM, 1990.
14. FLEISS JL: Measuring nominal scale agreement among many raters. *Psychological Bulletin* 1971; 76: 378-82.
15. LANDIS JR, KOCH GG: The measurement of observer agreement for categorical data. *Biometrics* 1977; 33: 159-74.
16. NAREDO E, CABERO F, BENEYTO P *et al.*: A randomized comparative study of short term response to blind injection versus sonographic-guided injection of local corticosteroids in patients with painful shoulder. *J Rheumatol* 2004; 31: 308-14.
17. ZINGAS C, FAILLA JM, VAN HOLSBEECK M: Injection accuracy and clinical relief of de Quervain's tendinitis. *J Hand Surg* (*Am*) 1998; 23: 89-96.
18. TARAS JS, RAPHAEL JS, PAN WT, MOVAGHARNIA F, SOTEREANOS DG: Corticosteroid injections for trigger digits: is intrasheath injection necessary? *J Hand Surg* (*Am*) 1998; 3: 717-22.
19. KANE D, GREANEY T, SHANAHAN M *et al.*: The role of ultrasonography in the diagnosis and management of idiopathic plantar fasciitis. *Rheumatology* (*Oxford*) 2001; 40: 1002-8.
20. DOHERTY M, HAZLEMAN BL, HUTTON CW, MADDISON PJ, PERRY JD: Rheumatology examination and injection techniques. London, WB Saunders, 1992.