

# Efficacy of a non-image-guided diagnostic hip injection in patients with clinical and radiographic evidence of intra-articular hip pathology

Matthew J. Kraeutler<sup>1</sup>, Tigran Garabekyan<sup>2</sup>, Matthew J. Fioravanti<sup>3</sup>,  
David A. Young<sup>4</sup> and Omer Mei-Dan<sup>3\*</sup>

<sup>1</sup>Department of Orthopaedic Surgery, Seton Hall-Hackensack Meridian School of Medicine, South Orange, NJ 07079, USA,

<sup>2</sup>Southern California Hip Institute, North Hollywood, CA 91602, USA,

<sup>3</sup>Department of Orthopedics, University of Colorado School of Medicine, Aurora, CO 80045, USA and

<sup>4</sup>Melbourne Orthopaedic Group, Melbourne, Australia

\*Correspondence to: O. Mei-Dan. E-mail: omer.meidan@ucdenver.edu

Submitted 5 December 2017; revised version accepted 9 April 2018

## ABSTRACT

The purpose of this study was to determine the likelihood of pain relief, as a measure of accurate diagnosis of intra-articular hip pathology and correct needle placement, with a non-image-guided intra-articular hip injection performed bedside in the clinic. A retrospective study of prospectively collected data was performed in a consecutive cohort of patients diagnosed with symptomatic intra-articular hip pathology who underwent a non-image-guided intra-articular injection in the clinic. All patients had clinical and radiographic evidence of hip impingement, hip instability, chondrolabral pathology, or other causes of intra-articular hip pain. A previously described technique for a non-image-guided hip injection was performed using 7–10 ml of 1% lidocaine for diagnostic evaluation with some patients receiving 2 ml of Kenalog<sup>®</sup>-40 if clinically indicated. Ten minutes following each injection, the patient was asked to report the percent improvement in pain (from 0 to 100%) while physical examination and provocative tests were repeated. The final study cohort comprised 142 patients (161 injections). In three cases, patients were either unable to assess or quantify any change in pain level 10 min following the injection. In the remaining 158 hip injections, pain relief was noted in 156 cases (156/158, 98.7%), with at least 70% improvement in pain level noted in 152 cases (152/158, 96.2%). Average pain relief among all 158 injections was  $89 \pm 16\%$ . A non-image-guided diagnostic intra-articular hip injection yields reliable short-term pain relief, simultaneously endorsing accurate diagnosis of hip pathology and intra-articular needle placement.

## INTRODUCTION

Non-image-guided intra-articular injections have been described for the shoulder [1], knee [2] and ankle [3]. By using palpation of anatomic landmarks, these injections can achieve a high level of accuracy, be convenient and be cost-effective, allowing physicians to perform diagnostic and therapeutic injections in the clinic rather than referring the patient to a radiologist [4]. Intra-articular hip injections are typically performed using ultrasound or fluoroscopic guidance [5–8]. Ultrasound-guided hip injections may be performed in the orthopaedic clinic [5], though

these injections are more commonly performed under fluoroscopy guidance by a radiologist, with confirmation provided by the intra-articular positioning of radiopaque contrast material [6]. Recently, however, non-image-guided techniques have been described for the hip using anatomic landmarks and palpation [9–12]. The purpose of this study was to determine the likelihood of pain relief, as a measure of accurate diagnosis of intra-articular hip pathology and correct needle placement, with a non-image-guided intra-articular hip injection performed bedside in the clinic.

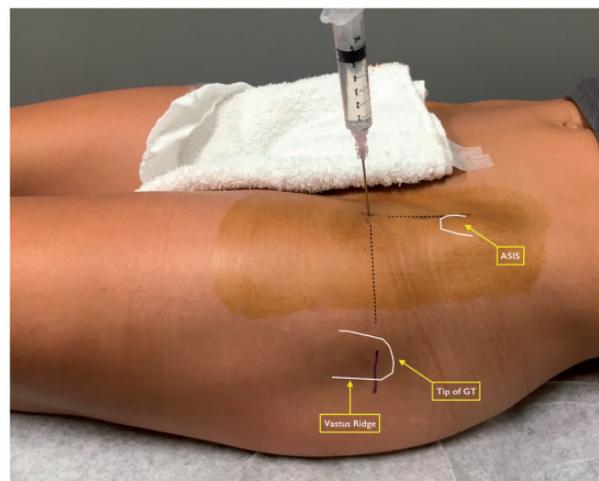
## MATERIALS AND METHODS

After Institutional Review Board approval was obtained, the authors performed a single-center retrospective analysis of prospectively collected data from a consecutive cohort of patients undergoing a non-image-guided intra-articular injection in the clinic. Patients included were injected with lidocaine for diagnostic purposes, or with lidocaine and triamcinolone for diagnostic and/or therapeutic purposes. Inclusion criteria for patients selected for this study were a painful hip joint during comprehensive physical examination whereby several pain sources were established and there was a need to differentiate between them, atypical hip pain (posterior or lateral only), and/or need for temporary treatment of hip pain in the form of steroid injection. Patients who had undergone prior total hip arthroplasty, hip resurfacing, or other open hip or pelvic surgical procedures were excluded. Patients injected with platelet-rich plasma (PRP) or hyaluronic acid (HA), wherein lidocaine was not used, were also excluded. Demographic characteristics including age, sex, height, weight, body mass index (BMI) and lateral center edge angle (LCEA) were recorded for all patients.

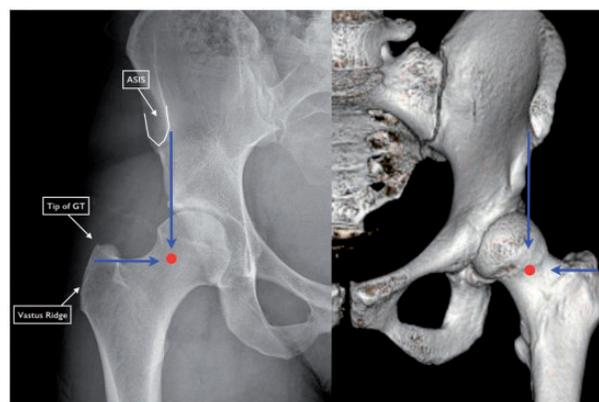
### Injection technique

All injections were performed by the senior author (Meidan, Omer) or by a hip preservation fellow under direct supervision of the senior author. The technique used has previously been described [10]. Briefly, prior to each injection, the patient's anteroposterior (AP) pelvic radiograph was reviewed to determine if any variant anatomy was present (coxa vara/valga, coxa breva, coxa profunda, variant ilium morphology) and, if so, the injection location was adjusted accordingly as described previously [10]. For example, in patients with a lateralized anterior superior iliac spine (ASIS), the needle was angled more medially than normal.

Patients were positioned supine on a standard examination table in the clinic with the hip in a neutral position ( $0^\circ$  of flexion/abduction/adduction) and the foot in a neutral position (toes pointing to the ceiling and feet parallel). Care was taken to ensure that both ASISs were aligned so that the pelvis was not rotated. A point was marked by the respective crossing lines coming longitudinally (proximal to distal) from the medial aspect of the ASIS and transversely (lateral to medial) from 1 cm proximal to the vastus ridge or midway between the tip of the greater trochanter (GT) and the vastus ridge (Figs 1 and 2). The vastus ridge, the most prominent part of the GT, is easily localized by internally and externally rotating the hip with the patient lying supine. Using a sterile technique, a volume of 5 ml of lidocaine was injected subcutaneously. Then, a 19-gauge



**Fig. 1.** Injection technique. A point was marked by the respective crossing lines coming longitudinally (proximal to distal) from the medial aspect of the ASIS (horizontal line) and transversely (lateral to medial) from 1 cm proximal to the vastus ridge or midway between the tip of the trochanter and the vastus ridge (vertical line).



**Fig. 2.** Plain radiography (left) and computed tomography (right) images of the anatomic landmarks used during injection with location of the injection illustrated by a red dot.

spinal needle was inserted directly from anterior to posterior toward the femoral neck from the previously marked starting point. Upon palpating the anterior femoral neck with the tip of the needle, the contralateral hand is utilized to gently internally and externally rotate the leg to attempt to verify correct placement. The plunger on the syringe is then gently depressed while assessing the degree of resistance, noting that correct intra-articular placement yields mild to minimal resistance. If excessive resistance is encountered, the contralateral hand is placed behind the patient's knee and the hip is gently flexed while maintaining the needle apposed to the anterior femoral neck. This

maneuver relaxes the anterior capsule, enabling it to be elevated from the anterior femoral neck periosteum with the injectate, which consists of 7–10 ml of 1% lidocaine (Xylocaine<sup>®</sup>, lidocaine HCl, Fresenius Kabi USA, LLC, Lake Zurich, IL) with/without 2 ml of Kenalog<sup>®</sup>-40 (triamcinolone acetone, Bristol-Myers Squibb, New York City, NY). It is important to maintain downward pressure with the needle against the femoral neck as the plunger is deployed to prevent retraction of the needle into the extra-capsular space due to backpressure from flow. Additionally, the authors recommend periodically stopping the injection and applying a downward pressure to palpate the femoral neck cortex and ensure the needle has not migrated during the injection. Upon completion of the injection, the needle is withdrawn and a sterile dressing is placed after applying 10 s of gentle downward pressure for hemostasis.

### Clinical diagnosis

Clinical diagnoses of bony impingement and/or acetabular dysplasia were determined according to accepted pathomorphologic signs and measurements [13, 14]. Suggestive physical examination findings included reduction in hip flexion and internal rotation range of motion and/or positive impingement and other commonly utilized provocative tests for the hip and pelvis [15–17]. Confirmative imaging findings of pincer anatomy included acetabular retroversion (crossover sign or ischial spine sign), LCEA exceeding 40° and/or acetabular inclination <0°; features of cam-femoroacetabular impingement (FAI) included an alpha angle exceeding 50° on radial sequences of the head–neck junction and/or a femoral head–neck offset ratio <0.18 [18]. The diagnosis of symptomatic hip instability due to acetabular dysplasia was established by a clinical history of reported instability, pain, positive findings on provocative hip tests indicating labral tear, measurement of LCEA <20° on AP pelvic radiography, increased acetabular version (>25°) or femoral torsion (>35°) and magnetic resonance imaging (MRI) findings of labral hypertrophy, articular cartilage thickening, or partial ligamentum teres tear [19–21].

### Evaluation of pain relief

Ten minutes following each injection, the patient was asked to report the percent improvement in pain (from 0 to 100%). Improvement in pain was assessed in three ways:

1. Repeated physical examination of the same provocative maneuvers that elicited pain and performed by the same examiner as prior to injection.

**Table I. Patient demographics and baseline characteristics**

Patient variables	Value
No. of patients (hips)	142 (161)
Age, mean (SD), years	38.8 (14.2)
Female gender, <i>n</i> hips (%)	120 (74.5)
Height, mean (SD), cm	169.7 (9.1)
Weight, mean (SD), kg	70.9 (14.2)
BMI, mean (SD), kg m <sup>-2</sup>	24.5 (4.2)

2. Patient's reported level of pain in the room with the surgeon, while performing positions and activities which were known to produce pain on a daily basis (squats, knee to chest, etc.).
3. In patients where pain was reported to be present mainly during physical activities, the patient was sent to run, walk up and down stairs, etc. after the injection.

### Statistical analysis

Two-tailed student's *t*-tests were used to compare numerical demographic features as well as the LCEA between patients who experienced at least 70% versus less than 70% pain relief. Chi-square tests were used to compare categorical variables between these two groups.

### RESULTS

During the study period, 809 injections were performed in the clinic by the senior author. After excluding non-intra-articular hip injections and injections of PRP and/or HA without lidocaine, the final study cohort comprised 142 patients (161 hips), of whom 120 hips (74.5%) were female. Mean patient age was 38.8 years (SD, 14.2 years). Additional demographic characteristics are summarized in Table I.

In three cases, patients were unable to assess or quantify any change in overall pain level following the injection. In the remaining 158 hip injections, pain relief was noted in 156 cases (156/158, 98.7%), with at least 70% improvement in pain level noted in 152 cases (152/158, 96.2%). Average pain relief among these 158 injections was 89 ± 16%. No post-injection hematomas occurred in the series. One patient complained of a temporary paresthesia of the lateral femoral cutaneous nerve which resolved within a couple of days following injection.

**Table II. Group comparisons based on pain relief**

Variable	Pain relief $\geq$ 70% (n = 152)	Pain relief < 70% (n = 6)	P-value
Sex, N (%) female	114 (75%)	3 (50%)	0.17
Age (years)	38.1 (13.9)	47.0 (12.7)	0.15
Height (cm)	169.7 (9.2)	171.5 (8.8)	0.66
Weight (kg)	70.8 (14.1)	73.9 (19.5)	0.72
BMI (kg m <sup>-2</sup> )	24.5 (4.2)	25.2 (6.9)	0.82
LCEA (°)	30.0 (7.8)	31.7 (7.3)	0.63

Continuous variables are provided as a mean (SD).

In comparing patients who experienced at least 70% pain relief (Group A,  $n = 152$  hips) versus those who experienced less than 70% pain relief (Group B,  $n = 6$  hips), no significant differences were found between groups with regard to gender, age, height, weight, BMI, or LCEA (Table II). In Group A, a diagnosis of one of the pre-arthritis hip pathologies shown in Table III was made in 115 patients (115/152, 76%), compared with 4 patients in Group B (4/6, 67%) ( $P = 0.62$ ).

Among all patients who experienced < 70% pain relief (Group B), one patient was diagnosed with concomitant cam-type FAI and a hamstring tendon tear prior to injection, and experienced 50% pain relief with injection. Both pathologies were addressed surgically with hip arthroscopy and open hamstring tendon repair, with good outcomes noted postoperatively. Similarly, one patient was diagnosed with concomitant mixed-type FAI and gluteus medius tendinopathy and experienced 30% pain relief with injection (though all hip-related pain was relieved). This patient later underwent hip arthroscopy as well as gluteus medius repair, with good outcomes noted postoperatively. One patient was diagnosed with concomitant pincer-type FAI and spine-related pain and experienced 60% pain relief with injection. One patient experienced 20% pain relief and was later diagnosed with piriformis syndrome and underwent successful piriformis release surgery. Two patients, each of whom experienced 0% pain relief, underwent diagnostic injection to differentiate between an intra-articular source of pain and spine and sciatic nerve-related pain, respectively.

## DISCUSSION

Based on the results of this study, non-image-guided intra-articular hip injections can provide substantial pain relief to the majority of patients who had clinical and radiographic

**Table III. Group diagnoses based on pain relief**

Diagnosis	Pain relief $\geq$ 70% (n = 152)	Pain relief < 70% (n = 6)
Cam-type FAI	48 (32%)	1 (17%)
Pincer-type FAI	16 (11%)	1 (17%)
Mixed-type FAI	38 (25%)	1 (17%)
Frank hip dysplasia	10 (6.6%)	0 (0%)
Borderline hip dysplasia	23 (15%)	1 (17%)

Some patients were diagnosed with concomitant FAI and hip dysplasia.

evidence of intra-articular hip pathology. This bedside technique, unencumbered by use of image guidance, may be used to endorse suspected intra-articular pathology or provide short-term treatment with the inclusion of steroid medication.

The injection technique utilized in this study has been described previously [10]. In a case series of 55 patients undergoing hip arthroscopy in the supine position, Mei-Dan *et al.* [10] used the same anatomic landmarks described in this study to place a 19-gauge spinal needle intra-articularly. Accuracy of the needle insertion was assessed by direct visualization with the arthroscope. The authors noted 51 accurate needle placements (93%), with the needle most commonly located near the upper medial femoral head-neck junction. A trend was noted toward a significantly lower accurate needle placement in females ( $P = 0.06$ ). Additional reasons for needle misplacement most commonly revolved around variant anatomy, namely a high-riding greater trochanter, increased femoral version, thick adipose tissue around the anatomic landmarks used, and variant ilium morphology. Finally, in two of the four patients requiring more than two attempts at needle placement, the patients were considered overweight.

In addition to the technique described by Mei-Dan *et al.* [10], Schmidt-Braekling *et al.* [11] recently described a technique for non-image-guided intra-articular hip injections whereby a line is drawn from the ASIS distal and at a 45° angle from the greater trochanter. The point of injection is marked approximately 2 cm lateral to the first line and the needle is angled 45° medial and proximal. Using a 25-gauge needle, a subcutaneous injection of 5 ml of 1% lidocaine is used. This is then replaced with a 22-gauge needle, which is advanced until bony resistance is encountered. Then, the needle is realigned so that the injection (4 ml of 1% lidocaine, 4 ml of 0.5% Marcaine, 1 ml of Kenalog-40) may proceed without resistance. In a retrospective case series of 369 intra-articular hip injections in

331 patients with hip osteoarthritis or rheumatoid arthritis, the authors found that patients experienced more than 50% pain relief in 304 hip injections (82%). Non-responders were found to have a significantly higher BMI than responders ( $P = 0.007$ ).

Finally, Ziv *et al.* [12] performed a case series of intra-articular hip injections in 40 consecutive patients in the operating room prior to undergoing total hip arthroplasty. Patients were positioned in the lateral decubitus position with methylene blue dye injected using an 18-gauge spinal needle inserted 1 cm proximal to the midline of the greater trochanter and directed toward the superolateral aspect of the femoral neck based on preoperative radiographs. Intraoperatively, accuracy of the injection was assessed by the presence of the dye in the joint and surrounding tissues. A successful injection was defined as one in which disseminated dye was found solely in the intracapsular space. Overall, injections were successful in 31 of 40 patients (77.5%). In all nine unsuccessful injections, dye was found distal to the hip joint. This is a lower success rate than that found in the present study, with at least 70% improvement in pain found in 96.2% of patients. Furthermore, most of the patients in our study who did not experience significant pain relief with an intra-articular hip injection were later diagnosed with spinal, hamstring, or gluteal-related pathology as the primary source of their pain, thereby indicating that an inaccurate injection was not the reason for their lack of pain relief, thereby possibly increasing our overall needle placement accuracy rate.

The non-image-guided hip injections performed in this study were well-tolerated by patients after a local anesthetic injection of lidocaine. These injections provide convenience to patients who present with joint or periarticular pain. Patients may undergo a full assessment (with physical examination and radiographic imaging) and get confirmation of the cause of their pain during one visit with the use of diagnostic local anesthetic injections. Furthermore, in patients who do not experience pain relief with a diagnostic hip injection, the provider can immediately prepare for further evaluation or diagnostic tests rather than delaying this process by several days or even weeks. For physicians practicing in rural areas, this can yield significant savings in both time and monetary cost for patients. When these injections are performed by a radiologist, it is much more difficult for the patient to remember the efficacy of the injection by the time the patient follows up with the surgeon. For team physicians, non-image-guided intra-articular injections may provide quick and temporary pain relief to allow immediate return to play for athletes. Finally, the use of this non-image-guided technique could also translate to injection of gadolinium-based contrast material

for magnetic resonance arthrography. Again, this would save healthcare costs and time for patients and radiologists.

Despite the successful results of non-image-guided intra-articular hip injections in several studies described above, previous studies have demonstrated significantly improved accuracy, pain, and/or functional outcomes for image-guided versus palpation-guided injections of the knee joint [2], acromioclavicular joint [22, 23], distal radioulnar joint [24], elbow joint [25], subacromial space [26], and the peroneal tendon sheath [27]. However, as mentioned above, image-guided injections come with an increased cost to patients and time lost between presentation and established diagnosis, two important parameters that the current technique aims to address.

In the present study, the average pain relief experienced by all patients was 89%, with the majority of patients experiencing 90–100% pain relief. Lack of complete pain relief after an intra-articular injection of lidocaine may be related to extracapsular and surrounding musculature inflammation resulting directly or indirectly from the intra-articular pathology. All six patients who reported less than 70% improvement in their pain following a non-image-guided hip injection were later confirmed to have an extra-articular pain source, thereby explaining the incomplete pain relief experienced by these patients. Among these patients, the negative or incomplete result of the non-image-guided intra-articular injection enabled prompt referral to appropriate specialists and/or additional imaging tests and extra-articular diagnostic injections to arrive at the correct diagnosis.

The strengths of this study include a large sample size of patients undergoing a previously described technique of non-image-guided hip injections performed or supervised by the same physician in all cases. The limitations of this study should also be noted. In particular, this study did not assess the efficacy of these hip injections based on experience level, and therefore the results speak only to the clinical experience of the senior author. On a related note, the surgeon was present in each patient's clinic room and assessed each patient's pain level following lidocaine injection, which could result in a bias in pain reporting. This study was not controlled by a placebo group, and therefore it is possible that some patients could have experienced pain relief without the needle being within the hip joint. However, this is unlikely given that patients treated had a positive hip impingement test prior to injection and a negative impingement test following injection. The small sample size of patients in Group B (< 70% pain relief post-injection) made it difficult to identify significant patient factors associated with lack of pain relief. This was an inherent limitation given the relatively infrequent

occurrence of a negative injection response. Finally, some patients underwent injection with lidocaine only, while others underwent injection with lidocaine and triamcinolone. However, because the primary outcome of this study was immediate pain relief, the addition of triamcinolone in some patients would likely have no effect on this parameter.

A non-image-guided diagnostic intra-articular hip injection yields reliable short-term pain relief, simultaneously endorsing accurate diagnosis of hip pathology and intra-articular needle placement.

#### FUNDING

No funding was obtained for the purposes of this study.

#### CONFLICT OF INTEREST STATEMENT

None declared.

#### REFERENCES

- Kraeutler MJ, Cohen SB, Ciccotti MG *et al.* Accuracy of intra-articular injections of the glenohumeral joint through an anterior approach: arthroscopic correlation. *J Shoulder Elbow Surg* 2012; **21**: 380–3
- Curtiss HM, Finnoff JT, Peck E *et al.* Accuracy of ultrasound-guided and palpation-guided knee injections by an experienced and less-experienced injector using a superolateral approach: a cadaveric study. *PM R* 2011; **3**: 507–15.
- Wisniewski SJ, Smith J, Patterson DG *et al.* Ultrasound-guided versus nonguided tibiotalar joint and sinus tarsi injections: a cadaveric study. *PM R* 2010; **2**: 277–81.
- Hall MM. The accuracy and efficacy of palpation versus image-guided peripheral injections in sports medicine. *Curr Sports Med Rep* 2013; **12**: 296–303.
- Balog TP, Rhodehouse BB, Turner EK *et al.* Accuracy of ultrasound-guided intra-articular hip injections performed in the orthopedic clinic. *Orthopedics* 2017; **40**: 96–100.
- Byrd JW, Potts EA, Allison RK *et al.* Ultrasound-guided hip injections: a comparative study with fluoroscopy-guided injections. *Arthroscopy* 2014; **30**: 42–6.
- Levi DS. Intra-articular hip injections using ultrasound guidance: accuracy using a linear array transducer. *PM R* 2013; **5**: 129–34.
- Robinson P, Keenan AM, Conaghan PG. Clinical effectiveness and dose response of image-guided intra-articular corticosteroid injection for hip osteoarthritis. *Rheumatology (Oxford)* 2006; **46**: 285–91.
- Masoud MA, Said HG. Intra-articular hip injection using anatomic surface landmarks. *Arthrosc Tech* 2013; **2**: e147–9.
- Mei-Dan O, McConkey MO, Petersen B *et al.* The anterior approach for a non-image-guided intra-articular hip injection. *Arthroscopy* 2013; **29**: 1025–33.
- Schmidt-Braekling T, Waldstein W, Renner L *et al.* Ultrasound and fluoroscopy are unnecessary for injections into the arthritic hip. *Int Orthop* 2015; **39**: 1495–7.
- Ziv YB, Kardosh R, Debi R *et al.* An inexpensive and accurate method for hip injections without the use of imaging. *J Clin Rheumatol* 2009; **15**: 103–5.
- Jesse MK, Petersen B, Strickland C *et al.* Normal anatomy and imaging of the hip: emphasis on impingement assessment. *Semin Musculoskelet Radiol* 2013; **17**: 229–47.
- Tannast M, Siebenrock KA, Anderson SE. Femoroacetabular impingement: radiographic diagnosis—what the radiologist should know. *AJR Am J Roentgenol* 2007; **188**: 1540–52.
- Clohisy JC, Knaus ER, Hunt DM *et al.* Clinical presentation of patients with symptomatic anterior hip impingement. *Clin Orthop Relat Res* 2009; **467**: 638–44.
- Martin HD, Kivlan BR, Palmer IJ *et al.* Diagnostic accuracy of clinical tests for sciatic nerve entrapment in the gluteal region. *Knee Surg Sports Traumatol Arthrosc* 2014; **22**: 882–8.
- Skendzel JG, Weber AE, Ross JR *et al.* The approach to the evaluation and surgical treatment of mechanical hip pain in the young patient: AAOS exhibit selection. *J Bone Joint Surg Am* 2013; **95**: e133.
- Welton KL, Jesse MK, Kraeutler MJ *et al.* The anteroposterior pelvic radiograph: acetabular and femoral measurements and relation to hip pathologies. *J Bone Joint Surg Am* 2018; **100**: 76–85.
- Garabekyan T, Ashwell Z, Chadayammuri V *et al.* Lateral acetabular coverage predicts the size of the hip labrum. *Am J Sports Med* 2016; **44**: 1582–9.
- Kraeutler MJ, Garabekyan T, Pascual-Garrido C *et al.* Hip instability: a review of hip dysplasia and other contributing factors. *Muscles Ligaments Tendons J* 2016; **6**: 343–53.
- Petersen BD, Wolf B, Lambert JR *et al.* Lateral acetabular labral length is inversely related to acetabular coverage as measured by lateral center edge angle of Wiberg. *J Hip Preserv Surg* 2016; **3**: 190–6.
- Park KD, Kim TK, Lee J *et al.* Palpation versus ultrasound-guided acromioclavicular joint intra-articular corticosteroid injections: a retrospective comparative clinical study. *Pain Physician* 2015; **18**: 333–41.
- Sabeti-Aschraf M, Lemmerhofer B, Lang S *et al.* Ultrasound guidance improves the accuracy of the acromioclavicular joint infiltration: a prospective randomized study. *Knee Surg Sports Traumatol Arthrosc* 2011; **19**: 292–5.
- Nam SH, Kim J, Lee JH *et al.* Palpation versus ultrasound-guided corticosteroid injections and short-term effect in the distal radioulnar joint disorder: a randomized, prospective single-blinded study. *Clin Rheumatol* 2014; **33**: 1807–14.
- Kim TK, Lee JH, Park KD *et al.* Ultrasound versus palpation guidance for intra-articular injections in patients with degenerative osteoarthritis of the elbow. *J Clin Ultrasound* 2013; **41**: 479–85.
- Hsieh LF, Hsu WC, Lin YJ *et al.* Is ultrasound-guided injection more effective in chronic subacromial bursitis? *Med Sci Sports Exerc* 2013; **45**: 2205–13.
- Muir JJ, Curtiss HM, Hollman J *et al.* The accuracy of ultrasound-guided and palpation-guided peroneal tendon sheath injections. *Am J Phys Med Rehabil* 2011; **90**: S64–71.