Best Practice & Research Clinical Rheumatology xxx (2016) 1–15

Contents lists available at ScienceDirect

Best Practice & Research Clinical Rheumatology

journal homepage: www.elsevierhealth.com/berh

10

Musculoskeletal interventional procedures: With or without imaging guidance?

David Kane [a, *], Juhani Koski [b]

[a] Department of Rheumatology, Trinity College Dublin, Ireland
[b] Mikkeli Central Hospital, Porrassalmenkatu 35-37, 50100 Mikkeli, Finland

Keywords:
Intra-articular injection
Ultrasound guided
Musculoskeletal
Procedural
Efficacy

A B S T R A C T

Aspiration and injection of joints and soft tissues is an indispensable skill used in everyday practice by the clinical rheumatologist. Most rheumatologists recognise that performing these procedures using anatomical landmarks is not always successful, particularly in the case of small or infrequently injected joints, bursae or tendon sheaths. Musculoskeletal ultrasound confirms the local pathological-anatomical diagnosis and is the most applicable and feasible imaging method that can be applied in clinical practice in guiding musculoskeletal interventional procedures. From 1993, there has been substantial examination of the accuracy of landmark- and imaging-guided procedures. We have searched the literature and ascertained whether imaging techniques improve the accuracy of musculoskeletal procedures and whether the accuracy of needle placement can be translated into improved clinical outcome (efficacy).

Introduction

Despite major advances in systemic therapy for the treatment of inflammatory rheumatic diseases, corticosteroid (steroid) injection into the joints, bursae, tendon sheaths or other musculoskeletal soft tissues remains an important tool used in daily clinical practice. These injections are usually guided by the palpation of anatomical landmarks and are termed landmark-guided injection (LMGI) (also known

* Corresponding author. Tel.: +353 14142889.
E-mail address: david.kane@amnch.ie (D. Kane).

http://dx.doi.org/10.1016/j.berh.2016.09.012
1521-6942/

Please cite this article in press as: Kane D, Koski J, Musculoskeletal interventional procedures: With or without imaging guidance?, Best Practice & Research Clinical Rheumatology (2016), http://dx.doi.org/10.1016/j.berh.2016.09.012

as palpation-guided, clinical examination-guided or blind injection techniques). Jones et al., in 1993 were the first to report the success rates of needle placement using a palpation-guided approach [1]. The authors proposed that accurate placement of the needle could diminish the discomfort experienced by the patient and reduce incidental damage to adjacent structures and tissue atrophy within the extra-articular soft tissues.

Ultrasound (US) guidance of aspiration was first reported by Gompels and Darlington in 1981 [2]. The first step of an US-guided procedure is always to confirm and localise the joint or soft tissue pathology. In clinical practice, US has been shown to frequently change the anatomical and pathological diagnosis made on clinical grounds, which alters the decision of whether or not to inject and where to place the needle [3]. The superior diagnostic accuracy of US scanning compared with clinical examination is a major factor that should be examined in future studies that compare the outcomes of LMGIs and US-guided injections (USGIs). In addition to aspiration and steroid injections, it is now possible to perform US-guided percutaneous biopsies of the joints, bursae, tendon sheaths, major salivary glands and muscles; to assist insertion of drainage catheters; to detect soft tissue foreign bodies; and to perform nerve blocks. There are two common methods for USGIs: semi-guided or indirect method (skin surface marking) and needle guidance under direct sonographic vision (direct method) [4,5]. Direct visualisation of the needle is considered to be the superior technique because it confirms the correct position of the needle. The needle is observed in real time while it is passing through the tissue. There are no studies that directly compare the performance of these two USGI techniques.

US is the optimal imaging modality for guiding musculoskeletal interventional procedures because it is extensively available at bed side, provides high definition imaging of both needle and joint tissues, incurs relatively low costs and does not use radiation [6]. In this article, we address whether USGIs improve the accuracy of therapeutic musculoskeletal injections compared with LMGIs and, further, the accuracy of needle placement can be translated into improved clinical outcome (efficacy) in the different anatomical regions. We searched all English language articles published in the last 35 years using PubMed database and collected clinical trials comparing the accuracy and/or efficacy of LMGIs with USGIs. We focused on human rheumatic and musculoskeletal conditions and excluded oncology, traumatology and spinal procedures.

Shoulder

Glenohumeral joint

Accuracy

In a study by Cunnington et al., injections of steroid and contrast agent were given in 184 different joints randomised for LMGIs and USGIs. The accuracy was assessed by radiography of the injected joint, which localised the contrast agent in the injectate. The accuracy of the glenohumeral joint injections reported for USGIs was 63% and for LMGIs was 40% ($p = NS$) [7]. It should be noted that in this study, USGI was performed using the posterior approach by a relatively inexperienced ultrasonographer with one year of practical US experience, and 40% accuracy was achieved by rheumatologists with a median of 14 years of clinical experience in joint injection. It would be expected that the accuracy of a skilled ultrasonographer interventionist would be much higher, and the sample size in this study was small making statistical analysis difficult.

There are eight clinical studies that investigated the use of LMGIs. Three of these used magnetic resonance (MR) arthrography for accurate injection verification, four used contrast medium and fluoroscopy and one used arthroscopy. According to these reports, the mean accuracy of LMGIs to the glenohumeral joint was 67% (variation 10–99%) [1,8–14]. In a paper by Tobola et al. [13], three different injection approaches were investigated (anterior, posterior or supraclavicular), and statistically significant differences were absent between the three approaches. However, the anterior route was the most accurate and was independent of the experience level of the provider.

There are five other studies that have investigated the accuracy of USGIs before MR arthrography [15–19]. The mean reported accuracy of USGIs to the glenohumeral joint were 96% (variation 92–100%). One of these studies compared US- and fluoroscopy-guided techniques and noted that the

Please cite this article in press as: Kane D, Koski J, Musculoskeletal interventional procedures: With or without imaging guidance?, Best Practice & Research Clinical Rheumatology (2016), http://dx.doi.org/10.1016/j.berh.2016.09.012

first attempt was successful in 72% of the injections in the fluoroscopy-guided group and 94% in the US-guided group [18].

In a cadaveric study with 80 shoulder specimens, the accuracy of USGIs and LMGIs were 92.5% and 72.5% ($p = 0.025$), respectively [20]. Two operators injected radiopaque contrast through a posterior approach. After the injections, radiographs of the specimens were obtained to assess the accuracy of the injections.

There are three cadaveric studies that investigated LMGIs to the glenohumeral joint [21–23]. The mean accuracy was 94% (variation 91–96%). One study used superior injection approach and noted that caution for the likelihood of penetrating the long head of biceps tendon should be considered [22].

These findings provide evidence that USGIs to the glenohumeral joint are more accurate than LMGIs (Table 1).

Efficacy

There is a single comparative study of LMGIs and USGIs that investigated the efficacy of glenohumeral joint injections using these techniques. In this trial for patients with adhesive capsulitis, the US group had a lower reduction in pain VAS; however, no significant difference was observed between groups for function at 6 weeks post injection [24]. In Cunnington's study, there was no significant difference for outcome variables between USGIs and LMGIs when all the joints were grouped together. The results for single joints were not reported. However, there was a greater improvement in the VAS score for function in the accurate injection group [7]. A recent Cochrane review reported no significant improvement in efficacy with USGIs to the shoulder [25]. However, the authors did not perform the analysis on the basis of the exact injection location. In addition, there were fewer side effects in the USGI groups.

Presently, there is not enough data to conclude that USGIs are more efficacious than LMGIs in the treatment of glenohumeral joint diseases.

Subacromial space

Accuracy

In assessing the studies on injection into the subacromial space, it should be noted that different studies have used different volumes of injectate, and a larger volume may aid the accuracy but leads to more tissue damage. Two clinical studies have compared LMGIs and USGIs using MR arthrography for verifying the success of the intervention. Rutten et al. reported that both methods were 100% accurate [26], and Dogu et al. found that accurate injections were performed in 65% in the USGI group and 70% in the LMGI group [27].

Four clinical studies have investigated the accuracy of LMGIs into the subacromial space [28–31]. One used MR arthrography and the others used fluoroscopy plus contrast media for verification. The mean accuracy was 61% (variation 29–91%).

Three cadaveric studies have examined the accuracy of LMGIs into the subacromial space [21,32,33]. The mean accuracy was 81% (variation 70–91%). Thus, the accuracy of LMGIs into the subacromial space is sub-optimal and depends on the operator.

There is not enough data to confirm that USGIs are more accurate than LMGIs, and further research is required to clarify this (Table 2).

Table 1
The mean accuracies of glenohumeral joint injection in 18 studies. The number of studies are given in parentheses.

	LMGI (%)	USGI (%)
Comparative clinical study (1)	40	63
Clinical LMGIs studies (8)	67	–
Clinical USGIs studies (5)	–	96
Comparative cadaveric study (1)	72.5	92.5
Cadaveric LMGIs studies (3)	94	–

LMGI, landmark-guided injection; USGI, ultrasound-guided injection.

Please cite this article in press as: Kane D, Koski J, Musculoskeletal interventional procedures: With or without imaging guidance?, Best Practice & Research Clinical Rheumatology (2016), http://dx.doi.org/10.1016/j.berh.2016.09.012

Efficacy

Five studies have evaluated the efficacy of USGIs and LMGIs into the subacromial space, and they all showed better outcomes for the USGI procedures in the short term [34–38]. However, two additional studies found that there is no difference in efficacy between accurate and inaccurate injections [27,29].

According to the literature, USGIs into the subacromial space produce a significantly greater improvement in terms of pain reduction and functional gain than LMGIs in chronic shoulder pain, at least in short term.

Biceps tendon sheath, acromioclavicular joint and sternoclavicular joint

Accuracy and efficacy

Injection into the tendon sheath of the long head of the biceps brachii can be more accurately performed by USGI than that by LMGI according to a single study [39]. USGIs showed 87% accuracy, whereas LMGIs showed only 27% accuracy. Computed tomography (CT) with contrast agent was used for the verification of the injection; however, the efficacy of this was not reported.

In one clinical study, the accuracy of LMGIs to the acromioclavicular joint was 43%. This was verified using radiographic contrast material [40]. There are no papers reporting the efficacy of acromioclavicular injections.

The exact position of USGI and LMGI into the acromioclavicular joint has been examined in three cadaver studies [41–43]. The mean accuracies reported were 96% (variation 90–100%) for USGIs and 62% (variation 40–75%) for LMGIs. In a cadaveric study, Partington and Broome found that LMGIs were successful in 67% of the acromioclavicular injections [32].

It can be concluded that LMGIs to the biceps tendon sheath and acromioclavicular joint are suboptimal and USGIs are more accurate; however, efficacy studies for this are missing.

The only study evaluating injection accuracy into the sternoclavicular joint used LMGI approach with a reported accuracy of 78% [44]. This was a cadaveric study (Table 3).

Advanced procedures of the shoulder

Some procedures in the shoulder area require exact imaging guidance. Percutaneous US-guided fenestration and aspiration of calcific tendinosis is an example [45]. It was originally done as a fluoroscopic procedure; however, US has largely replaced fluoroscopy because of its excellent safety profile and clinical efficacy. In the shoulder region, nerve blocks can be performed using US guidance (e.g. suprascapular and dorsal scapular nerve blocks). US may be used to diagnose and aspirate a ganglion cyst compressing the nerve in the suprascapular or spinoglenoid notch. Other injectable therapies such as platelet-rich plasma are now available for rotator cuff tendinopathy; however, further studies are required to clarify their efficacy, and there is no comparison of USGI and LMGI for these therapies.

Elbow

Elbow joint: accuracy and efficacy

Two studies have compared the accuracies of LMGIs and USGIs to the elbow joint. The study by Cunnington [7] reported accuracies of 64% and 91% for LMGI and USGI, respectively ($p = 0.1$). Kim

Table 2
The mean accuracies of subacromial space injection in nine studies. The number of studies are given in parentheses.

	LMGI (%)	USGI (%)
Comparative clinical studies (2)	85	82.5
Clinical LMGIs studies (4)	61	–
Cadaveric LMGIs studies (3)	95	–

LMGI, landmark-guided injection; USGI, ultrasound-guided injection.

Please cite this article in press as: Kane D, Koski J, Musculoskeletal interventional procedures: With or without imaging guidance?, Best Practice & Research Clinical Rheumatology (2016), http://dx.doi.org/10.1016/j.berh.2016.09.012

Table 3
The mean accuracies of injection to the biceps tendon sheath, acromioclavicular and sternoclavicular joints in seven studies. The number of studies are given in parentheses.

	LMGI (%)	USGI (%)
Biceps tendon sheath: comparative clinical study (1)	27	87
Acromioclavicular joint: clinical LMGIs study (1)	43	–
Acromioclavicular joint: comparative cadaveric studies (3)	62	96
Acromioclavicular joint: cadaveric LMGIs study (1)	67	–
Sternoclavicular joint: cadaveric LMGIs study (1)	78	–

LMGI, landmark-guided injection; USGI, ultrasound-guided injection.

reported an accuracy of 100% using USGI and 77.5% using LMGI by posterior (olecranon) approach. They verified the injection accuracy using the fluoroscopic contrast method in 80 patients [46].

Two studies have evaluated LMGI accuracy to the elbow joint, and the mean accuracy was 92% (variation 84–100%) [1,10]. Both the studies used radiographic contrast media to verify the success of the intra-articular injection. Of these, only Lopes et al. reported the efficacy and noted significant improvement in the VAS for pain at rest and during movement, VAS for oedema and morning stiffness [10].

It appears that LMGIs and USGIs to the elbow joint do not differ much in accuracy, although the number of studies is small (Table 4).

Lateral epicondylitis and advanced procedures around the elbow

Lateral epicondylitis is a common condition in which different types of treatments have been investigated with varying results. There are no studies of the accuracy of LMGIs and USGIs in this area. The definition of accuracy is also complex given that some injection approaches target the surface of the common extensor origin, whereas others aim to penetrate and disrupt the tendon structure. US scanning plays an important role in the differential diagnosis of lateral elbow pain given that the CEO, lateral collateral ligament and humeroradial joint are so closely apposed.

Different types of US-guided procedures such as needle tendon fenestration and platelet-rich plasma injections have been and are to be investigated in the treatment of lateral epicondylitis.

US guidance has an important role in performing nerve blocks at the elbow level such as blocking of the posterior interosseous nerve and radial nerve at the spiral groove. Ganglion cysts compressing nerves can be diagnosed using US and also aspirated under US guidance.

Wrist and hand

Wrist and hand joints: accuracy

Cunnington et al. achieved 79% and 75% accuracy using USGI and LMGI, respectively, in the wrist joint ($p = 0.8$) [7]. In two studies, LMGIs to the wrist joint resulted in accuracies of 97% and 50% [10,1]. In these three papers, the radiographic contrast medium method was used for verifying the success of intra-articular injection. Choudur et al. used US guidance in MR arthrography and found that 99% were successfully injected into the wrist [15].

Smith et al. studied the accuracy of USGIs and LMGIs to the scaphotrapeziotrapezoid joint [47]. This cadaver study showed that USGIs were 100% accurate, whereas LMGIs were only 80% accurate. There

Table 4
The mean accuracies of elbow joint injection in four studies. The number of studies are given in parentheses.

	LMGI (%)	USGI (%)
Clinical comparative studies (2)	71	96
Clinical LMGIs studies (2)	92	–

LMGI, landmark-guided injection.

Please cite this article in press as: Kane D, Koski J, Musculoskeletal interventional procedures: With or without imaging guidance?, Best Practice & Research Clinical Rheumatology (2016), http://dx.doi.org/10.1016/j.berh.2016.09.012

are two additional cadaver studies examining the accuracies of USGIs to the trapeziometacarpal and distal radioulnar joints, and the accuracies were 94% and 100%, respectively [48,49].

A single study compared the accuracy of LMGIs and USGIs to PIP and MCP joints [50]. The needle position was intra-articular in 50% of PIP joints and 80% of MCP joints using LMGI, and the corresponding figures for USGIs were 92% and 100%. In this study, visualisation of the needle tip within the joint space and distension of the joint capsule following steroid injection defined intra-articular positioning of the needle.

The accuracies of USGIs to the wrist and hand are overall higher than LMGIs, but because of the paucity of studies, further research is required to make definite conclusions (Table 5).

Wrist and hand joints: efficacy

Four studies have compared USGIs and LMGIs to the wrist joint [7,51–53]. These studies report a statistically and clinically significant benefit of USGI over LMGI in the reduction of wrist pain and achievement of minimal clinically important improvement.

High-quality studies of other hand joints on the efficacy of LMGIs and USGIs are missing.

Soft tissues of the hand: efficacy and accuracy

Kume's randomised prospective study compared USGIs and LMGIs to 44 wrists with de Quervain's disease (separate extensor pollicis brevis). Pain was significantly reduced more in the USGI group after 4 weeks in this prospective open-label study [54].

In another study, 77 symptomatic carpal tunnels were randomised to be injected by either LMGIs or USGIs [55]. There were no complications in either treatment group. Compared with LMGIs, USGIs resulted in a 77% reduction in injection pain, 63% reduction in pain scores, 93% increase in the responder rate, 85% reduction in the non-responder rate, 71% increase in therapeutic duration and 59% reduction in cost/responder/year for a hospital outpatient. All the figures were statistically significant.

In a study by Ustün et al., 46 patients with carpal tunnel syndrome were randomised to receive either LMGI or USGI into the carpal tunnel [56]. The improvement in symptom severity scores in the USGI group at 12 weeks was higher than those in the LMGI group ($p < 0.05$). Average time to symptom relief was shorter in the USGI group ($p < 0.05$).

Lee et al. injected methylene blue dye into 40 flexor tendon sheaths of 5 cadavers using blind or sonographic guidance. Dissection revealed that 70% of USGIs were successful, whereas only 15% LMGIs were successful [57].

It can be concluded that USGIs are more accurate and efficient than LMGIs in carpal tunnel and tendon sheath injections of the hand.

Advanced procedures in the hand

All advanced procedures require USGI to be performed, and therefore, there is no comparative study with LMGI. Deeply located ganglion cysts can be aspirated and fenestrated with the help of US. Ulnar and median nerve hydrodissections can be performed using a large volume of injectate to release the nerve from

Table 5
The mean accuracies of injection to the wrist and hand joints in 8 studies. The number of studies are given in parentheses.

	LMGI (%)	USGI (%)
Wrist joint: clinical comparative study (1)	75	79
PIP and MCP joints: clinical comparative study (1)	65	96
Wrist joint: clinical LMGIs studies (2)	74	–
Wrist joint: clinical USGIs study (1)	–	99
Scaphotrapeziotrapezoid joint: comparative cadaveric study (1)	80	100
Trapeziometacarpal joint: cadaveric USGIs study (1)	–	94
Distal radioulnar joint: cadaveric USGIs study (1)	–	100

LMGI, landmark-guided injection; USGI, ultrasound-guided injection.

Please cite this article in press as: Kane D, Koski J, Musculoskeletal interventional procedures: With or without imaging guidance?, Best Practice & Research Clinical Rheumatology (2016), http://dx.doi.org/10.1016/j.berh.2016.09.012

the adjacent soft tissue. US-guided techniques have been developed to release A1 pulleys with a surgical hook knife or needle, and even carpal tunnel flexor retinaculum dissections can be performed under US guidance. Further research is required to determine the efficacy, safety profile and cost-effectiveness of these new procedures compared with traditional open procedures. US imaging plays an important role in foreign body removal in the hand because it can detect all kinds of foreign bodies (metal, wood and glass).

Hip

Hip joint: accuracy and efficacy

There are no studies that directly compare USGIs and LMGIs to the hip joint. Five studies have investigated LMGIs to the hip joint [58–62]. There is a great variation in the accuracies (51–93%), and the mean figure of accuracy is 71% for LMGIs to the hip joint.

Four papers have investigated USGIs using MR arthrography or contrast-enhanced fluoroscopic/CT for verifying the success of the injections [15,63–65]. Accuracies are very high, and the mean value is 99% (variation 97–100%).

Thus, intra-articular injections to the hip joint can be performed with high accuracy using USGIs, whereas the accuracy of LMGIs is sub-optimal (Table 6).

There are no high-quality studies comparing the efficacy of USGI and LMGI to hip joints. In clinical work, the diagnostic importance of US is highlighted because the clinical evaluation of hip joint arthritis is very difficult because of its deep-lying position and complex surrounding structures in the deep gluteal and femoral areas.

Soft tissue injections around the hip: efficacy and accuracy

Effectiveness of peritendinous USGI of corticosteroid for the treatment of gluteus medius tendinopathy has been investigated in 54 consecutive patients [66]. There was a 55% average reduction of pain level after treatment ($p < 0.001$), and 1 month after treatment, 72% of the patients showed a clinically significant improvement in pain level.

Finnoff compared the accuracy of US-guided piriformis injections with fluoroscopically guided contrast-controlled piriformis injections in a cadaveric model [67]. Nineteen of the 20 USGIs (95%) were correctly placed, and the liquid latex was found within the piriformis muscle, whereas only 6 of the 20 fluoroscopically guided injections (30%) were accurate ($p = 0.001$).

In another study, a single experienced operator completed 10 sonographically guided obturator internus injections in five unembalmed cadaveric pelvis specimens [68]. The results showed that USGIs to the obturator internus or its bursa are feasible and may play a role in the diagnosis and management of patients presenting with deep gluteal pain syndromes.

USGIs are more accurate than LMGIs to and around the hip joint; however, there is a lack of good quality efficacy studies.

Sacroiliac joint

Sacroiliac joint: accuracy and efficacy

There are considerable challenges in assessing the injection accuracy of the sacroiliac joint (SIJ). The definition of accurate injection needs clarification as most techniques are reported for intra-articular

Table 6
The mean accuracies of injection to the hip joint in nine studies. The number of studies are given in parentheses.

	LMGI (%)	USGI (%)
Clinical LMGIs studies (5)	71	–
Clinical USGIs studies (4)	–	99

LMGI, landmark-guided injection; USGI, ultrasound-guided injection.

Please cite this article in press as: Kane D, Koski J, Musculoskeletal interventional procedures: With or without imaging guidance?, Best Practice & Research Clinical Rheumatology (2016), http://dx.doi.org/10.1016/j.berh.2016.09.012

injection into the more caudal synovial cavity, although in spondyloarthritis, there may be more marked inflammation in the superior fibrous part of the joint, which requires a periarticular injection because of the lack of a joint cavity. Moreover, in assessing the accuracy, the use of contrast is limited by the small volume capacity of the joint.

There is a lack of high-quality evaluating the accuracy of LMGIs. Three studies have investigated the accuracy of USGIs to the SIJ [69–71]. Pekkafahli et al. injected 60 SIJs, and the accuracy of USGIs was 76%, and the efficacy of injection was not reported [69]. Hartung et al. achieved an accuracy of 40% in USGIs to SIJs with a reduction in pain score from 6.9 to 3.9 on a 0–10 scale 1 month later ($p < 0.009$). Verification of the success of the injection (steroid plus gadolinium) was confirmed with MR scanning. They noted that USGIs to the SIJ is challenging. Surprisingly, the pain and symptom control was equal in both intra-articular and periarticular injections [70]. Klauser et al. injected SIJs in cadavers and reported an accuracy of 80% with CT confirming the correct intra-articular needle position. The mean pain relief was 8.6 on a 0–10 scale after 3 months [71]. Thus, more studies are required to confirm the position of LMGI and USGI to the SIJ in terms of accuracy and efficacy.

The difficulty of visualising the needle in the SIJ can be addressed using an image fusion technique where real-time US scanning can be matched to previously obtained CT or MR images. Klauser et al. found this new technique to be reliable in both cadavers and patients, and intra-articular needle positioning was possible [72].

Knee

Knee joint: accuracy

There are five clinical studies that have compared the accuracies of LMGIs and USGIs to knee joints [7,73–76]. All the studies used contrast agent with radiography for the verification of the intra-articular injection except one study that used positive aspiration as a sign of right needle position [76]. The mean accuracies for LMGIs and USGIs were 70% (variation 32–84%) and 95% (91–97%), respectively.

Four clinical studies have examined the accuracy of LMGIs to the knee joint [1,10,77,78]. Contrast agents with radiographs were used for the verification of the injections. The mean accuracy was 84%, but again the variation was wide (66–100%). Toda et al. highlighted the need to change the injection approach according to the severity of knee osteoarthritis (OA) to achieve injection accuracy [78].

Two clinical studies have investigated the accuracy of USGIs to the knee joint. One used US-guided gadolinium for MR arthrography and reported an accuracy of 100% in the knee joints [15]. The other study used contrast agent and radiographs, and the rate of injection accuracy varied depending on the site injected [79]. Injections to the superolateral (100%) and mid-lateral portals (95%) showed significantly higher accuracy than injections to the medial portal (75%).

One cadaver study reported an accuracy of 100% for USGIs and 55–100% for LMGIs depending on the experience of the operators [80]. Another cadaver study examined the accuracy for four different intra-articular injection sites in the knee using LMGIs [81]. This study included 156 knees from 78 fresh cadavers. Perfect accuracy could not be obtained through any of the portals. The best accuracy rate was in the anterolateral injection portal (85%) and lowest was in the medial mid-patellar portal (56%).

A single study investigated injections to proximal tibiofibular joint in unembalmed cadavers [82]. All 12 US-guided latex injections were placed into the target (100% accuracy), whereas only 7of 12 injections were placed using LMGIs (58%).

According to the literature, USGIs to the knee joint are more accurate than LMGIs (Table 7).

Knee joint: efficacy and cost-effectiveness

Sibbitt [83] randomised 94 non-effusive knees with OA to corticosteroid injection by LMGI and USGI. In this study, USGIs resulted in a 48% reduction in procedural pain ($p < 0.001$), 107% increase in the responder rate ($p < 0.001$), 52% reduction in the non-responder rate ($p < 0.001$), 36% increase in therapeutic duration ($p = 0.01$), 13% reduction ($17) in cost per patient per year and 58% ($224) reduction in cost per responder per year for a hospital outpatient ($p < 0.001$). The follow-up period was 6 months. In another study [84], 64 knees with palpable effusions were randomised to receive LMGIs or

Please cite this article in press as: Kane D, Koski J, Musculoskeletal interventional procedures: With or without imaging guidance?, Best Practice & Research Clinical Rheumatology (2016), http://dx.doi.org/10.1016/j.berh.2016.09.012

USGIs with corticosteroid. USGI resulted in 48% less procedural pain (VAS; palpation guided: 5.8 ± 3.0 cm, US guided: 3.0 ± 2.8 cm, $p < 0.001$), 183% increase in aspirated synovial fluid volumes ($p < 0.0001$) and improved outcomes at 2 weeks ($p = 0.034$).

In contrast, Toda et al. demonstrated no difference in efficacy between accurate and inaccurate hyaluronic acid injections to the knee in patients with OA [78].

Soft tissues around the knee joint and advanced procedures

A study assessed using US the clinical changes of Baker's cyst of patients with knee OA after steroid injection. In all patients, the cyst was aspirated under US guidance first. Twenty patients received corticosteroid injection into the Baker's cyst and 20 received intra-articular injections [85]. At 4 and 8 weeks, cyst diameters measured by US were lower when the cyst was directly infiltrated than with intra-articular injection ($p < 0.01$).

In a cadaveric model, 12 US-guided and 12 unguided pes anserinus bursa injections using coloured liquid latex were performed on 24 unembalmed adult cadaveric lower extremity specimens. The order of the injection techniques was randomised. After dissection, it was revealed that the accuracy rate was 92% (11 of 12 specimens) for USGI and 17% (2 of 12 specimens) for LMGI [86].

In another cadaveric study [87], a single experienced operator completed 24 USG popliteus tendon sheath injections with diluted coloured latex: 12 using a longitudinal approach and 12 using a transverse approach relative to the tendon. The results showed that USGI can be used to inject the popliteus tendon sheath with a high degree of accuracy. The longitudinal approach was potentially more accurate. Both approaches may result in injectate overflow into the knee joint, most likely through the popliteus hiatus.

There is a current trend towards expanded applications of interventional musculoskeletal USG procedures such as percutaneous patellar tenotomy, patellar tendon-Hoffa's fat pad hydrodissection, meniscal cyst aspiration, pericruciate ganglion cyst aspiration, fibulotibial joint injection and fibular nerve hydrodissection at the knee joint level. There is a paucity of high-quality studies on these techniques, but research is ongoing.

Soft tissue anatomic structures around the knee joint can be more accurately injected using USGIs, but in terms of efficacy, the final conclusion on the role of USGI and LMGI cannot be made.

Ankle and foot

Ankle and foot: clinical studies of accuracy and efficacy

Relatively few clinical studies have been conducted in this area. One study compared LMGIs and USGIs to the ankle joint and found that the accuracies were 58% and 85% ($p = NS$), respectively [7]. In the paper by Jones et al. [1], the accuracy of ankle joint LMGIs was 66%. A single paper has examined both the accuracy and efficacy of LMGIs to the ankle joint [10] and reported an accuracy of 77%. The authors noted that significant improvement was seen in the VAS for pain, oedema and morning stiffness. The accuracy of the LMGIs to the ankle joint in clinical studies seems sub-optimal, but the benefit of USGIs with respect to accuracy and efficacy requires further investigation.

Table 7
The mean accuracies of injection to knee join in 13 studies. The number of studies are given in parentheses.

	LMGI (%)	USGI (%)
Comparative clinical studies (5)	70	95
Clinical LMGIs studies (4)	84	–
Clinical USGIs studies (2)	–	91
Comparative cadaveric study (1)	77.5	100
Cadaveric LMGIs study (1)	85	–

LMGI, landmark-guided injection; USGI, ultrasound-guided injection.

Please cite this article in press as: Kane D, Koski J, Musculoskeletal interventional procedures: With or without imaging guidance?, Best Practice & Research Clinical Rheumatology (2016), http://dx.doi.org/10.1016/j.berh.2016.09.012

Four comparative studies of LMGIs and USGIs concerning the efficacy of injections to the plantar fasciitis have been performed [88–91]. In these studies, there were altogether 140 patients randomised to USGIs or LMGIs. The mean follow-up was 26 weeks (12–56 weeks). In all papers, the result showed that LMGIs were as efficient as the USGIs. In one paper, the recurrence rate of plantar fasciitis was significantly higher when using LMGIs [89].

Ankle and foot: cadaveric studies of injection accuracy

There are a considerable number of cadaveric studies of injection accuracies in the foot and ankle. Four studies compared LMGIs and USGIs to different joints and soft tissues using coloured latex solution and dissection after the injection procedure (the dissecting anatomists were blinded to the injection technique) [92–95]. One paper investigated the accuracy of LMGIs and USGIs to the ankle joint with reported accuracies of 85% and 100%, respectively [92]. They also noted that the injection accuracy into the sinus tarsi was 90% for USGIs and 35% for LMGIs. Khosla et al. concluded that intra-articular injections to the subtalar and ankle joints can be successfully performed using palpation alone (100% accuracy for both USGI and LMGI) [93], but USGI was superior for injection to the first and second tarsometatarsal joints (accuracy: LMGI 27% vs USGI 64%; $p = 0.003$). A third paper examined LMGIs and USGIs to the peroneal tendon sheaths in 20 cadaveric lower limbs [95]. Their accuracies were 60% and 100%, respectively. In the fourth study, LMGIs and USGIs were performed into the deep and superficial posterior leg compartments by a less experienced and a more experienced clinician [94]. The result showed that these injections were equally accurate with palpation guidance regardless of the level of experience and did not improve with the use of US guidance.

Accuracies of the LMGIs in cadaveric models have been investigated in two studies [96,97]. Heidari et al. [97] examined whether an anteromedial or anterolateral approach is better when injecting into the ankle joint. They used 76 ankles from 38 cadavers and noted accuracies of 77.5% and 86%, respectively ($p = NS$). Another paper investigated anterolateral and postero-lateral approaches to the subtalar joint [96]. Twenty-three of 34 anterolateral injections (68%) and 31 of 34 (91%) postero-lateral injections were successful ($p = 0.016$).

USGIs have been investigated in three studies using cadaveric models [98–100]. Wempe et al. [98] injected the first Metatarsophalangeal (MTP) joint in five cadavers and found that the USGIs showed 100% accuracy and that the latex injectate penetrated to the articular surfaces of the metatarsosesamoid articulations. Smith et al. [99] examined the accuracies of three injection techniques to the posterior subtalar joint. They found that anterolateral, postero-lateral and postero-medial approach routes can be used equally by USGI with a high degree of accuracy. Finally, the paper by Reach et al. [100] revealed that USGIs are 100% accurate when injecting into the first and second MTP joints, ankle, Achilles peritendineous space, posterior tibial tendon sheath and flexor hallucis longus sheath. The subtalar joint injections were 90% accurate.

The cadaveric studies confirm that USGIs to the foot and ankle joints and soft tissues are more accurate than LMGIs (Table 8).

Synovial biopsies

Synovial biopsy and analysis of synovial tissue can provide valuable insights into the pathophysiologic mechanism, disease status, therapy effect and prognosis of inflammatory joint diseases. The most famous instrument for landmark-guided needle biopsy of synovium was designed by Parker and Pearson [101], although its use is largely confined to the knee joint. The success rate reported for collecting sufficient synovial tissue was 95% in the knee joint, but lower rates (81%) have been published by Schumacher and Kulka in the elbow, wrist and ankle joints using this needle [102]. Moon et al. used a Franklin–Silverman needle in elbow, wrist and ankle biopsies, and the success rate was 68% [103]. Needle biopsy of the synovium can be performed under fluoroscopy control using the Tru-Cut needle. Beaule et al. obtained samples from the glenohumeral, elbow, wrist, hip, knee and ankle joints using the Tru-Cut needle and reported a success rate of 81% [104]. The difference in the success rates of synovial biopsy is because of technical difficulties, variable intra-articular inflammation of the synovium and the fact that the operator is blind the macroscopic features of the synovium.

Please cite this article in press as: Kane D, Koski J, Musculoskeletal interventional procedures: With or without imaging guidance?, Best Practice & Research Clinical Rheumatology (2016), http://dx.doi.org/10.1016/j.berh.2016.09.012

Table 8
The mean accuracies of the injections to the ankle and foot joints and soft tissues in 12 studies. The number of studies are given in parentheses.

	LMGI (%)	USGI (%)
Ankle joint: clinical comparative study (1)	58	85
Ankle joint: clinical LMGIs study (2)	71.5	–
Ankle joint	85	100
Sinus tarsi	35	90
Cadaveric comparative study (1)		
Ankle and subtalar joints	100	100
I, II tarsometatarsal joint	27	64
Cadaveric comparative study (1)		
Peroneal tendon sheaths	60	100
Cadaveric comparative study (1)		
Posterior leg compartments	90	88
Cadaveric comparative study (1)		
Ankle joint: anteromedial	77.5	–
Ankle joint: anterolateral	86	–
Cadaveric LMGIs study (1)		
Subtalar joint: anterolateral	68	–
Anteroposterior	91	–
Cadaveric LMGIs study (1)		
MTP 1 joint	–	100
Cadaveric USGIs study (1)		
Subtalar joint: different approaches	–	100
Cadaveric USGIs study (1)		
I, II MTP, ankle, Achilles peritend, tibialis posterior, flexor halluces longus tendon sheaths. Subtalar joint	–	100
Cadaveric USGIs study (1)	–	90

MTP, Metatarsophalangeal; LMGI, landmark-guided injection; USGI, ultrasound-guided injection.

Koski et al. developed a US-guided biopsy method using portal and forceps, and representative synovial tissue in adequate amounts for histopathological evaluation was obtained from 33 of 37 cases, showing a success rate of 89.2% [105]. Kelly et al. recently demonstrated that an US-guided needle biopsy approach could be successfully used in a large prospective clinical study to harvest good quality synovial tissue and RNA from patients with early inflammatory arthritis [106]. Ninety-three sequential biopsy procedures were assessed from a total of 57 patients. Five different joint sites were biopsied (knee, elbow, wrist, metacarpophalangeal and proximal interphalangeal). No significant complications were reported following the procedure. No difference in pain, swelling and stiffness of the biopsied joint before and after the procedure was demonstrated. A median of 14 biopsy samples was retrieved from each procedure, with 93% of biopsy procedures yielding good quality tissue. The accuracy of US-guided synovial biopsy is somewhere between those of the blind needle biopsy and two-portal system needle arthroscopy. Similar to the needle arthroscopy, US also reveals the synovial hypertrophy and vascularisation (using Doppler mode in US imaging), and the best biopsy site can thus be chosen. The advantage of the US-guided biopsy method of the synovium is that it can be performed not only in the knee but also in most joints of the body and even bursae and tendon sheaths [105,106]. The US-guided synovium biopsy methods are interesting alternatives to other biopsy methods. These methods are well-tolerated techniques that can be performed on an outpatient basis with low running costs. However, there are currently limited data regarding the performance of US-guided synovial biopsy, mainly from observational studies. Thus, it remains critical to evaluate its performance within the clinical trials context against the current gold standard of arthroscopic biopsy [107].

Summary

US is the most applicable and feasible imaging modality for routine clinical use in guiding musculoskeletal procedures. Although many studies have examined the role of imaging guidance for injection, more studies are required regarding the use of US prior to injection that can alter the pathological and anatomical diagnosis. This is a fundamental advantage of US over other imaging

Please cite this article in press as: Kane D, Koski J, Musculoskeletal interventional procedures: With or without imaging guidance?, Best Practice & Research Clinical Rheumatology (2016), http://dx.doi.org/10.1016/j.berh.2016.09.012

modalities in guiding injection. We have examined the literature on landmark-guided and US-guided procedures in musculoskeletal diseases of the upper and lower limbs and of the SIJ. According to the clinical and cadaveric studies, the US-guided technique is more accurate than the landmark-guided technique in the glenohumeral, acromioclavicular, wrist, hand, hip, knee and foot joints, and in the tendons of the biceps, wrist, hand hip, knee and ankle. Synovial biopsies are more accurate using an US-guided method. In terms of accuracy, both methods work equally and the data are insufficient to conclude for superiority of US-guided techniques in subacromial bursa, sternoclavicular, elbow, ankle and SIJ injections. The superiority of the efficacy of USGI has been shown in a minority of the joint regions including the subacromial bursa, wrist and hand (tendon sheath injections included), and knee joint injections. Plantar fascia injection is equally efficacious using both methods. The data for other anatomical area are presently insufficient to make any further conclusions. There is a trend towards an expanded number of advanced applications of interventional musculoskeletal US that can also be performed by a rheumatologist.

Practice points:

- There is clear evidence that the accuracy of LMGIs is sub-optimal, and USGIs are more accurate in most anatomical areas
- Much less is known about the efficacy of the USGIs.

Research agenda:

- More studies are required to assess how US alters the pathological anatomical diagnosis and the accuracy and efficacy of USGIs in different anatomical areas.
- Which US-guided technique (direct or semi-guided) is the most appropriate in different anatomical areas and clinical settings requires further research.

Conflict of interest

Prof Kane, Dr. Koski: No conflict of interest.

References

*[1] Jones A, Regan M, Ledingham J, et al. Importance of placement of intra-articular steroid injections. BMJ 1993;307:1329–30.
[2] Gompels BM, Darlington LG. Septic arthritis in rheumatoid disease causing bilateral shoulder dislocation: diagnosis and treatment assisted by grey scale ultrasonography. Ann Rheum Dis 1981;40:609–11.
*[3] d'Agostino MA, Ayral X, Baron G, et al. Impact of ultrasound imaging on local corticosteroid injections of symptomatic ankle, hind-, and mid-foot in chronic inflammatory diseases. Arthritis Rheum 2005;53:284–92.
*[4] Koski JM. Ultrasound guided injections in rheumatology. J Rheumatol 2000;27:2131–8.
[5] Fessell DP, Jacobson JA, Craig J, et al. Using sonography to reveal and aspirate joint effusions. AJR Am J Roentgenol 2000;174:1353–62.
[6] Weidner S, Kellner W, Kellner H. Interventional radiology and the musculoskeletal system. Best Pract Res Clin Rheumatol 2004;18:945–56.
*[7] Cunnington J, Marshall N, Hide G, et al. A randomized, double-blind, controlled study of ultrasound-guided corticosteroid injection into the joint of patients with inflammatory arthritis. Arthritis Rheum 2010;62:1862–9.
[8] Sethi PM, Kingston S, Elattrache N. Accuracy of anterior intra-articular injection of the glenohumeral joint. Arthroscopy 2005;21:77–80.
[9] 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.

Please cite this article in press as: Kane D, Koski J, Musculoskeletal interventional procedures: With or without imaging guidance?, Best Practice & Research Clinical Rheumatology (2016), http://dx.doi.org/10.1016/j.berh.2016.09.012

[10] Lopes RV, Furtado RN, Parmigiani L, et al. Accuracy of intra-articular injections in peripheral joints performed blindly in patients with rheumatoid arthritis. Rheumatol Oxf 2008;47:1792–4.
[11] Jo CH, Shin YH, Shin JS. Accuracy of intra-articular injection of the glenohumeral joint: a modified anterior approach. Arthroscopy 2011;27:1329–34.
[12] Porat S, Leupold JA, Burnett KR, Nottage WM. Reliability of non-imaging-guided glenohumeral joint injection through rotator interval approach in patients undergoing diagnostic MR arthrography. AJR Am J Roentgenol 2008;191:W96–9.
[13] Tobola A, Cook C, Cassas KJ, et al. Accuracy of glenohumeral joint injections: comparing approach and experience of provider. J Shoulder Elb Surg 2011;20:1147–54.
[14] Johnson TS, Mesfin A, Farmer KW, et al. Accuracy of intra-articular glenohumeral injections: the anterosuperior technique with arthroscopic documentation. Arthroscopy 2011;27:745–9.
[15] Choudur HN, Ellins ML. Ultrasound-guided gadolinium joint injections for magnetic resonance arthrography. J Clin Ultrasound 2011;39:6–11.
[16] Gokalp G, Dusak A, Yazici Z. Efficacy of ultrasonography-guided shoulder MR arthrography using a posterior approach. Skelet Radiol 2010;39:575–9.
[17] Perdikakis E, Drakonaki E, Maris T, Karantanas A. MR arthrography of the shoulder: tolerance evaluation of four different injection techniques. Skelet Radiol 2013;42:99–105.
[18] 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.
[19] Souza PM, Aguiar RO, Marchiori E, Bardoe SA. Arthrography of the shoulder: a modified ultrasound guided technique of joint injection at the rotator interval. Eur J Radiol 2010;74:e29–32.
[20] Patel DN, Nayyar S, Hasan S, et al. Comparison of ultrasound-guided versus blind glenohumeral injections: a cadaveric study. J Shoulder Elb Surg 2012;21:1664–8.
[21] Hanchard N, Shanahan D, Howe T, et al. Accuracy and dispersal of subacromial and glenohumeral injections in cadavers. J Rheumatol 2006;33:1143–6.
[22] Kim JS, Yun JS, Kim JM, et al. Accuracy of the glenohumeral injection using the superior approach: a cadaveric study of injection accuracy. Am J Phys Med Rehabil 2010;89:755–8.
[23] Esenyel CZ, Ozturk K, Demirhan M, et al. Accuracy of anterior glenohumeral injections: a cadaver study. Arch Orthop Trauma Surg 2010;130:297–300.
*[24] Lee HJ, Lim KB, Kim DY, Lee KT. Randomized controlled trial for efficacy of intra-articular injection for adhesive capsulitis: ultrasonography-guided versus blind technique. Arch Phys Med Rehabil 2009;90:1997–2002.
[25] Bloom JE, Rischin A, Johnston RV, Buchbinder R. Image-guided versus blind glucocorticoid injection for shoulder pain. Cochrane Database Syst Rev 2012;8:CD009147.
[26] Rutten MJ, Maresch BJ, Jager GJ, et al. Injection of the subacromial-subdeltoid bursa: blind or ultrasound-guided? Eur J Radiol 2007;62:427–36.
[27] Dogu B, Yucel SD, Sag SY, et al. Blind or ultrasound-guided corticosteroid injections and short-term response in subacromial impingement syndrome: a randomized, double-blind, prospective study. Am J Phys Med Rehabil 2012;91:658–65.
[28] Eustace JA, Brophy DP, Gibney RP, et al. Comparison of the accuracy of steroid placement with clinical outcome in patients with shoulder symptoms. Ann Rheum Dis 1997;56:59–63.
[29] Yamakado K. The targeting accuracy of subacromial injection to the shoulder: an arthrographic evaluation. Arthroscopy 2002;18:887–91.
[30] Henkus HE, Cobben LP, Coerkamp EG, et al. The accuracy of subacromial injections: a prospective randomized magnetic resonance imaging study. Arthroscopy 2006;22:277–82.
[31] Kang MN, Rizio L, Prybicien M, et al. The accuracy of subacromial corticosteroid injections: a comparison of multiple methods. J Shoulder Elb Surg 2008;17(1 Suppl):61S–6S.
[32] Partington PF, Broome GH. Diagnostic injection around the shoulder: hit and miss? A cadaveric study of injection accuracy. J Shoulder Elb Surg 1998;7:147–50.
[33] Mathews PV, Glousman RE. Accuracy of subacromial injection: anterolateral versus posterior approach. J Shoulder Elb Surg 2005;14:145–8.
*[34] Naredo E, Cabero F, Beneyto P, et al. 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.
[35] Zufferey P, Revaz S, Degailler X, et al. A controlled trial of the benefits of ultrasound-guided steroid injection for shoulder pain. Jt Bone Spine 2012;79:166–9.
[36] Chen MJ, Lew HL, Hsu TC, et al. Ultrasound-guided shoulder injections in the treatment of subacromial bursitis. Am J Phys Med Rehabil 2006;85:31–5.
[37] Ucuncu F, Capkin E, Karkucak M, et al. A comparison of the effectiveness of landmark-guided injections and ultrasonography guided injections for shoulder pain. Clin J Pain 2009;25:786–9.
[38] 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.
[39] Hashiuchi T, Sakurai G, Morimoto M, et al. Accuracy of the biceps tendon sheath injection: ultrasound-guided or unguided injection? A randomized controlled trial. J Shoulder Elb Surg 2011;20:1069–73.
[40] Wasserman BR, Pettrone S, Jazrawi LM, et al. Accuracy of acromioclavicular joint injections. Am J Sports Med 2013;41:149–52.
[41] Peck E, Lai JK, Pawlina W, Smith J. Accuracy of ultrasound-guided versus palpation-guided acromioclavicular joint injections: a cadaveric study. PM R 2010;2:817–21.
[42] 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.
[43] Borbas P, Kraus T, Clement H, et al. The influence of ultrasound guidance in the rate of success of acromioclavicular joint injection: an experimental study on human cadavers. J Shoulder Elb Surg 2012;21:1694–7.

Please cite this article in press as: Kane D, Koski J, Musculoskeletal interventional procedures: With or without imaging guidance?, Best Practice & Research Clinical Rheumatology (2016), http://dx.doi.org/10.1016/j.berh.2016.09.012

[44] Weinberg AM, Pichler W, Grechenig S, et al. Frequency of successful intra-articular puncture of the sternoclavicular joint: a cadaver study. Scand J Rheumatol 2009;38:396–8.
[45] Serafini G, Sconfienza LM, Lacelli F, et al. Rotator cuff calcific tendonitis: short-term and 10-year outcomes after two-needle us-guided percutaneous treatment–nonrandomized controlled trial. Radiology 2009;252:157–64.
[46] 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.
[47] Smith J, Brault JS, Rizzo M, et al. Accuracy of sonographically guided and palpation guided scaphotrapeziotrapezoid joint injections. J Ultrasound Med 2011;30:1509–15.
[48] Umphrey GL, Brault JS, Hurdle MF, Smith J. Ultrasound-guided intra-articular injection of the trapeziometacarpal joint: description of technique. Arch Phys Med Rehabil 2008;89:153–6.
[49] Smith J, Rizzo M, Sayeed YA, Finnoff JT. Sonographically guided distal radioulnar joint injection: technique and validation in a cadaveric model. J Ultrasound Med 2011;30:1587–92.
[50] Raza K, Lee CY, Pilling D, et al. Ultrasound guidance allows accurate needle placement and aspiration from small joints in patients with early inflammatory arthritis. Rheumatol Oxf 2003;42:976–9.
[51] Luz KR, Furtado RN, Nunes CC, et al. Ultrasound-guided intra-articular injections in the wrist in patients with rheumatoid arthritis: a double-blind, randomised controlled study. Ann Rheum Dis 2008;67:1198–2000.
*[52] Sibbitt Jr WL, Band PA, Chavez-Chiang NR, et al. A randomized controlled trial of the cost-effectiveness of ultrasound-guided intraarticular injection of inflammatory arthritis. J Rheumatol 2011;38:252–63.
[53] Sibbitt Jr WL, Peisajovich A, Michael AA, et al. Does sonographic needle guidance affect the clinical outcome of intraarticular injections? J Rheumatol 2009;36:1892–902.
[54] Kume K, Amano K, Yamada S, et al. de Quervain's with a separate EPB compartment, ultrasound-guided steroid injection is more effective than a clinical injection technique: a prospective open-label study. J Hand Surg Eur 2012;37:523–7.
[55] Makhlouf T, Emil NS, Sibbitt Jr WL, et al. Outcomes and cost-effectiveness of carpal tunnel injections using sonographic needle guidance. Clin Rheumatol 2014;33:849–58.
[56] Ustün N, Tok F, Yagz AE, et al. Ultrasound-guided vs. blind steroid injections in carpal tunnel syndrome: a single-blind randomized prospective study. Am J Phys Med Rehabil 2013;92:999–1004.
[57] Lee DH, Han SB, Park JW, et al. Sonographically guided tendon sheath injections are more accurate than blind injections: implications for trigger finger treatment. J Ultrasound Med 2011;30:197–203.
[58] Kurup H, Ward P. Do we need radiological guidance for hip joint injections? Acta Orthop Belg 2010;76:205–7.
[59] Diraçoğlu D, Alptekin K, Dikici F, et al. Evaluation of needle positioning during blind intra-articular hip injections for osteoarthritis: fluoroscopy versus arthrography. Arch Phys Med Rehabil 2009;90:2112–5.
[60] 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.
[61] Singh J, Khan WS, Marwah S, et al. Do we need radiological guidance for intra-articular hip injections? Open Orthop J 2014;8:114–7.
[62] 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.
[63] Pourbagher MA, Ozalay M, Pourbagher A. Accuracy and outcome of sonographically guided intra-articular sodium hyaluronate injections in patients with osteoarthritis of the hip. J Ultrasound Med 2005;24:1391–5.
[64] Smith J, Hurdle MF, Weingarten TN. Accuracy of sonographically guided intra-articular injections in the native adult hip. J Ultrasound Med 2009;28:329–35.
[65] Kantarci F, Ozbayrak M, Gulsen F, et al. Ultrasound-guided injection for MR arthrography of the hip: comparison of two different techniques. Skelet Radiol 2013;42:37–42.
[66] Labrosse JM, Cardinal E, Leduc BE, et al. Effectiveness of ultrasound-guided corticosteroid injection for the treatment of gluteus medius tendinopathy. AJR Am J Roentgenol 2010;194:202–6.
[67] Finnoff JT, Hurdle MF, Smith J. Accuracy of ultrasound-guided versus fluoroscopically guided contrast-controlled piriformis injections: a cadaveric study. J Ultrasound Med 2008;27:1157–63.
[68] Smith J, Wisniewski SJ, Wempe MK, et al. Sonographically guided obturator internus injections: techniques and validation. J Ultrasound Med 2012;31:1597–608.
[69] Pekkafahli MZ, Kiralp MZ, Başekim CC, et al. Sacroiliac joint injections performed with sonographic guidance. J Ultrasound Med 2003;22:553–9.
[70] Hartung W, Ross CJ, Straub R, et al. Ultrasound-guided sacroiliac joint injection in patients with established sacroiliitis: precise IA injection verified by MRI scanning does not predict clinical outcome. Rheumatol Oxf 2010;49:1479–82.
[71] Klauser A, De Zordo T, Feuchtner G, et al. Feasibility of ultrasound-guided sacroiliac joint injection considering sonoanatomic landmarks at two different levels in cadavers and patients. Arthritis Rheum 2008;59:1618–24.
[72] Klauser AS, De Zordo T, Feuchtner GM, et al. Fusion of real-time US with CT images to guide sacroiliac joint injection in vitro and in vivo. Radiology 2010;256:547–53.
[73] Bum Park Y, Ah Choi W, Kim YK, et al. Accuracy of blind versus ultrasound-guided suprapatellar bursal injection. J Clin Ultrasound 2012;40:20–5.
[74] Im SH, Lee SC, Park YB, et al. Feasibility of sonography for intra-articular injections in the knee through a medial patellar portal. J Ultrasound Med 2009;28:1465–70.
[75] Jang SH, Lee SC, Lee JH, et al. Comparison of ultrasound (US)-guided intra-articular injections by in-plain and out-of-plain on medial portal of the knee. Rheumatol Int 2013;33:1951–9.
[76] Balint PV, Kane D, Hunter J, et al. Ultrasound guided versus conventional joint and soft tissue fluid aspiration in rheumatology practice: a pilot study. J Rheumatol 2002;29:2209–13.
[77] Luc M, Pham T, Chagnaud C, et al. Placement of intra-articular injection verified by the backflow technique. Osteoarthr Cartil 2006;14:714–6.
[78] Toda Y, Tsukimura N. A comparison of intra-articular hyaluronan injection accuracy rates between three approaches based on radiographic severity of knee osteoarthritis. Osteoarthr Cartil 2008;16:980–5.

Please cite this article in press as: Kane D, Koski J, Musculoskeletal interventional procedures: With or without imaging guidance?, Best Practice & Research Clinical Rheumatology (2016), http://dx.doi.org/10.1016/j.berh.2016.09.012

[79] Park Y, Lee SC, Nam HS, et al. Comparison of sonographically guided intra-articular injections at 3 different sites of the knee. J Ultrasound Med 2011;30:1669–76.
[80] 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.
[81] Esenyel C, Demirhan M, Esenyel M, et al. Comparison of four different intra-articular injection sites in the knee: a cadaver study. Knee Surg Sports Traumatol Arthrosc 2007;15:573–7.
[82] Smith J, Finnoff JT, Levy BA, Lai JK. Sonographically guided proximal tibiofibular joint injection: technique and accuracy. J Ultrasound Med 2010;29:783–9.
*[83] Sibbitt Jr WL, Band PA, Kettwich LG, et al. A randomized controlled trial evaluating the cost-effectiveness of sonographic guidance for intra-articular injection of the osteoarthritic knee. J Clin Rheumatol 2011;17:409–15.
[84] Sibbitt Jr WL, Kettwich LG, Band PA, et al. Does ultrasound guidance improve the outcomes of arthrocentesis and corticosteroid injection of the knee? Scand J Rheumatol 2012;41:66–72.
[85] Bandinelli F, Fedi R, Generini S, et al. Longitudinal ultrasound and clinical follow-up of Baker's cysts injection with steroids in knee osteoarthritis. Clin Rheumatol 2012;31:727–31.
[86] Finnoff JT, Nutz DJ, Henning PT, et al. Accuracy of ultrasound-guided versus unguided pes anserinus bursa injections. PM R 2010;2:732–9.
[87] Smith J, Finnoff JT, Santaella-Sante B, et al. Sonographically guided popliteus tendon sheath injection: techniques and accuracy. J Ultrasound Med 2010;29:775–82.
[88] Kane D, Greaney T, Shanahan M, et al. The role of ultrasonography in the diagnosis and management of idiopathic plantar fasciitis. Rheumatol Oxf 2001;40:1002–8.
[89] Tsai WC, Hsu CC, Chen CP, et al. Plantar fasciitis treated with local steroid injection: comparison between sonographic and palpation guidance. J Clin Ultrasound 2006;34:12–6.
[90] Yucel I, Yazici B, Degirmenci E, et al. Comparison of ultrasound-, palpation-, and scintigraphy-guided steroid injections in the treatment of plantar fasciitis. Arch Orthop Trauma Surg 2009;129:695–701.
*[91] Ball EM, McKeeman HM, Patterson C, et al. Steroid injection for inferior heel pain: a randomised controlled trial. Ann Rheum Dis 2013;72:996–1002.
[92] 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.
[93] Khosla S, Thiele R, Baumhauer JF. Ultrasound guidance for intra-articular injections of the foot and ankle. Foot Ankle Int 2009;30:886–90.
[94] Peck E, Finnoff JT, Smith J, et al. Accuracy of palpation-guided and ultrasound-guided needle tip placement into the deep and superficial posterior leg compartments. Am J Sports Med 2011;39:1968–74.
[95] 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;90:564–71.
[96] Kraus T, Heidari N, Borbas P, et al. Accuracy of anterolateral versus posterolateral subtalar injection. Arch Orthop Trauma Surg 2011;131:759–63.
[97] Heidari N, Pichler W, Grechenig S, et al. Does the anteromedial or anterolateral approach alter the rate of joint puncture in injection of the ankle?: A cadaver study. J Bone Jt Surg Br 2010;92:176–8.
[98] Wempe MK, Sellon JL, Sayeed YA, Smith J. Feasibility of first metatarsophalangeal joint injections for sesamoid disorders: a cadaveric investigation. PM R 2012;4:556–60.
[99] Smith J, Finnoff JT, Henning PT, Turner NS. Accuracy of sonographically guided posterior subtalar joint injections: comparison of 3 techniques. J Ultrasound Med 2009;28:1549–57.
[100] Reach JS, Easley ME, Chuckpaiwong B, Nunley 2nd JA. Accuracy of ultrasound guided injections in the foot and ankle. Foot Ankle Int 2009;30:239–42.
[101] Parker RH, Pearson CM. A simplified synovial biopsy needle. Arthritis Rheum 1963;6:172–6.
[102] Schumacher Jr HR, Kulka JP. Needle biopsy of the synovial membrane. Experience with the Parker-Pearson technic. N Engl J Med 1972;286:416–9.
[103] Moon MS, Kim I, Kim JM, et al. Synovial biopsy by Franklin-Silverman needle. Clin Orthop Relat Res 1980;150:224–8.
[104] Beaulé V, Larédo JD, Cywiner C, et al. Synovial membrane: percutaneous biopsy. Radiology 1990;177:581–5.
[105] Koski JM, Helle M. Ultrasound guided synovial biopsy using portal and forceps. Ann Rheum Dis 2005;64:926–9.
*[106] Kelly S, Humby F, Filer A, et al. Ultrasound-guided synovial biopsy: a safe, well-tolerated and reliable technique for obtaining high-quality synovial tissue from both large and small joints in early arthritis patients. Ann Rheum Dis 2015;74:611–7.
[107] Humby F, Kelly S, Bugatti S, et al. Evaluation of minimally invasive, ultrasound-guided synovial biopsy techniques by the OMERACT filter - determining validation requirements. J Rheumatol 2016;43:208–13.

Please cite this article in press as: Kane D, Koski J, Musculoskeletal interventional procedures: With or without imaging guidance?, Best Practice & Research Clinical Rheumatology (2016), http://dx.doi.org/10.1016/j.berh.2016.09.012