RMD Open
Rheumatic & Musculoskeletal Diseases

ORIGINAL RESEARCH

# Value of imaging to guide interventional procedures in rheumatic and musculoskeletal diseases: a systematic literature review informing EULAR points to consider

Philipp Bosch ,[1] Francesco Carubbi ,[2,3] Carlo Alberto Scirè ,[4] Xenofon Baraliakos ,[5] Louise Falzon,[6] Christian Dejaco ,[1,7] Pedro M Machado [8,9,10]

**To cite:** Bosch P, Carubbi F, Scirè CA, *et al*. Value of imaging to guide interventional procedures in rheumatic and musculoskeletal diseases: a systematic literature review informing EULAR points to consider. *RMD Open* 2021;**7**:e001864. doi:10.1136/rmdopen-2021-001864

► Additional supplemental material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/rmdopen-2021-001864).

PB and FC are joint first authors.

Received 9 August 2021
Accepted 5 October 2021



For numbered affiliations see end of article.

**Correspondence to**
Dr Christian Dejaco; christian.dejaco@gmx.net

## ABSTRACT

**Objectives** To summarise current data on the value of imaging to guide interventional procedures in patients with rheumatic and musculoskeletal disease (RMDs) informing an European Alliance of Associations for Rheumatology taskforce.

**Methods** A systematic literature review was conducted to retrieve prospective and retrospective studies published in English and comparing different (imaging) techniques, different settings and procedural protocols to guide interventions in patients with RMDs. MEDLINE, EMBASE, the Cochrane Library and Epistemonikos databases were searched through October 2021. Risk of bias (RoB) was assessed using the Cochrane RoB tool for randomised trials V.2 (ROB2), the RoB tool for Non-Randomised Studies of Interventions and the appraisal tool for cross-sectional studies.

**Results** Sixty-six studies were included (most with moderate/high RoB); 49 were randomised controlled trials, three prospective cohort studies and 14 retrospective studies. Fifty-one studies compared either one imaging technique with another imaging technique, or with palpation-guided interventions. Ultrasound (US) was most frequently studied (49/51), followed by fluoroscopy (10/51). Higher accuracy was found for US or fluoroscopy compared with palpation-guided interventions. Studies comparing different imaging techniques (12/51) did not endorse one specific method. Different settings/equipment for imaging-guided procedures (eg, automatic vs manual syringes) were investigated in three studies, reporting heterogeneous results. Fifteen studies compared different imaging-guided procedures (eg, intra-articular vs periarticular injections).

**Conclusion** Higher accuracy of needle positioning at joints and periarticular structures was seen in most studies when using imaging (especially US) guidance as compared with palpation-guided interventions with the limitation of heterogeneity of data and considerable RoB.

## Key messages

### What is already known about this subject?

- Imaging techniques such as ultrasound, fluoroscopy, CT and MRI can be used to perform interventional procedures in patients with rheumatic and musculoskeletal diseases. However, consensus on when to use imaging, which settings should be preferred and whether certain procedural protocols may be better than others is still unclear.

### What does this study add?

- Using imaging guidance leads to better accuracy compared with palpation-guided interventions.
- Positioning a needle or another instrument in, rather than outside the target not only reduces the risk of adverse events but may also have beneficial effects on short-term and long-term pain, as well as on efficacy outcomes.

### How might this impact on clinical practice or further developments?

- The results of this systematic literature review may help clinicians to decide when and how to use imaging to guide interventional procedures in patients with rheumatic and musculoskeletal diseases.

## INTRODUCTION

Imaging is widely used to guide interventional procedures in patients with rheumatic and musculoskeletal disease (RMDs).[1] However, consensus on when to use imaging, which settings should be preferred and whether certain procedural protocols may be better than others is still unclear.

A number of previous systematic literature reviews (SLRs) have addressed some of these aspects,[2–7] however, the data reported were mostly limited to certain joints or diseases, or did not focus on studies comparing directly two or more techniques.

The objective of this SLR was to gather available data on different imaging methodologies, settings and procedural protocols in RMDs to inform an European Alliance of Associations for Rheumatology (EULAR) task force developing points to consider on the use of imaging for interventional procedures in patients with RMDs.

## METHODS

### Literature review

In the first EULAR task force meeting, the steering group framed three broad key questions according to the Population, Intervention, Comparator, Outcome (PICO) format related to the following aspects[8]: (1) What is the value of imaging methods to guide interventional procedures in patients with RMDs, (2) What is the value of different imaging settings and technical standards and (3) What is the value of different procedural techniques for imaging-guided interventions. See see online supplemental table 1 for details on the PICO questions. Eligible studies were full research articles, short reports and research letters of prospective and retrospective studies. The following studies were excluded from the analysis: studies of interventions on tumours, vessels or glands, studies on vertebroplasty/arthroplasty, studies of interventions with the aim to perform anaesthesia and studies investigating methods not used in routine clinical practice. We also excluded studies not answering any of the PICO questions, for example, due to wrong population or missing comparator.

### Study selection, data extraction and assessment of risk of bias

Two reviewers (PB and FC) conducted the SLR under the guidance of the methodologist (PMM) and the junior methodologist (CAS). The search strategy was developed by an experienced librarian (LF). The databases MEDLINE, Embase, Epistemonikos and the Cochrane Library were searched until September 2019. An update of the original search was conducted with the same search strategy from September 2019 to October 2020. See online supplemental table 2 for the list of key words used.

The reviewers independently screened titles and abstracts to identify eligible studies, which were consecutively assessed for eligibility by reading the full text. Both reviewers independently retrieved data from included studies using a predefined data extraction sheet. The following data were extracted: study design, year of publication, number of patients included, the site where the intervention was performed, details on the procedure including equipment, imaging method(s) and individual settings, in case of injections—the compound(s) administered, data on monitoring and potential outcomes. The extracted outcomes were then assigned to the following categories: accuracy, safety, efficacy and cost/time as detailed in online supplemental table 1. Outcome variables on pain, including procedural, short-term and long-term pain, were altogether considered safety outcomes. Data on arthroscopy were only extracted if it was compared with a second imaging technique (ie, ultrasound (US), CT, MRI or fluoroscopy).

Risk of bias (RoB) was appraised independently by the same reviewers who conducted the SLR. For randomised controlled trials (RCTs), the Cochrane risk-of-bias tool for randomised trials V.2 (RoB 2) was used.[9] The Risk Of Bias tool for Non-Randomised Studies of Interventions (ROBINS-I) was applied to non-randomised trials and the Appraisal tool for cross-sectional studies (AXIS) was used for cross-sectional studies.[10 11] Disagreement on study selection, data extraction and RoB assessment was solved by discussion until a consensus was achieved, the methodologist (PMM) served as a tiebreaker. To homogenise reporting of the different tools for the assessment of RoB, we transformed the items ‘serious concern’ and ‘some concern’ used in the original version of the ROBINS-I tool into ‘high’ and ‘moderate’ RoB, according to the RoB 2 classification. Since the AXIS tool does not provide a global classification of the RoB, but rather includes a series of question addressing possible quality concerns, we grouped the studies according to the number of questions with a positive answer (ie, answer indicating less concern) as follows: <10/20=high RoB, 10-15/20=moderate RoB, >15/20=low RoB. According to this approach studies were classified into the following four RoB categories: low, moderate, high and critical RoB (the latter was used for RCTs only). In tables of the main manuscript, the RoB is depicted by coloured circles in green, yellow, red and black respectively. Quality appraisal was performed for each outcome of every study separately.

## RESULTS

A total of 6049 references (after duplicates removal) were screened for eligibility (see online supplemental figure 1). Sixty-six articles fulfilled the inclusion criteria, with some of them addressing multiple PICO questions. Fifty-one articles compared interventions with imaging or palpation guidance, or interventions assisted by different imaging techniques (PICO1),[12–62] three articles assessed the influence of different settings (PICO2),[25 63 64] while 16 articles compared the value of different procedures for imaging-guided interventions (PICO3).[22 61 65–78] RoB assessment of the retrieved studies is detailed in online supplemental table 3.

### Imaging techniques for interventional procedures (PICO1)

#### Large joints and periarticular structures

Twenty-nine articles (23 RCTs, 4 retrospective cohort studies, 1 retrospective cross-sectional study and 1 RCT-letter) assessed the value of imaging for interventions at large joints, with 20 studies comparing US versus palpation-guided interventions,[18–33 55–58] 5 investigating

US versus fluoroscopy[12–16] and 1 study each comparing fluoroscopy with palpation guidance,[53] fluoroscopy with US and palpation guidance,[59] or fluoroscopy with CT-guided interventions,[54] as well as one study comparing either US or fluoroscopy with palpation guidance.[17] The following large joints and periarticular structures were studied: knee (n=10), shoulder (n=9), sacroiliac joint (SIJ) (n=3) and one study each for elbow, wrist, spine, piriformis muscle, hip, trochanteric bursa and ankle. All interventions were injections with one or more of the following compounds: glucocorticoids (GC), local anaesthetics, viscosupplements and/or contrast media. The most important characteristics of the 29 studies are depicted in table 1, full details on interventions and outcomes can be found in online supplemental table 4.

### Accuracy

Nine studies reported better accuracy for needle placement/injectate location (n=8) or synovial fluid acquisition (n=1) using US as compared with palpation-guided injections (seven with moderate RoB[23–26 29 31 56] and two with high RoB),[33 58] while two studies concluded that there was no difference between the two methods (one moderate, one high RoB).[20 32] Results for correct needle placement were heterogenous for comparisons of US with fluoroscopy: one study favoured US for biceps tendon sheath injections (high RoB),[14] one reported better accuracy for SIJ injections using fluoroscopy (high RoB)[15] and another study reported no difference between the techniques for SIJ injections (moderate RoB).[13] Fluoroscopy was superior to palpation-guided injections for injectate location in patients with painful SIJ (low RoB)[53] and superior to CT when assessing the positive rate of discovertebral biopsy cultures at the lumbar spine in patients with osteomyelitis (high RoB).[54]

### Safety

No difference in the overall frequency of adverse events was observed between US and palpation-guided interventions in eight studies (five high, three moderate RoB),[19 20 22 27 33 55 56 58] while one study reported a lower rate of contact of the needle to the cartilage of the patella by using US (moderate RoB).[24] Four studies (two high, two moderate RoB)[25 28 57 58] reported lower procedural pain using US as compared with palpation-guided injections, while one study (high RoB)[19] found no difference between the groups. Long-term pain (ranging from 1 week to 6 months) was found to be lower in US, compared with palpation-guided interventions according to ten studies (five high, five moderate RoB),[19 21 25 27 28 30 33 56–58] whereas four (two high, two moderate RoB)[20 22 32 55] studies found no difference between the groups. Furthermore, five studies comparing US and fluoroscopy (three high, two moderate RoB)[12–16] and one comparing US or fluoroscopy versus palpation-guided injections (moderate RoB)[17] reported no differences in procedural,[13 16] and long-term pain.[12–17] One study (low RoB) comparing fluoroscopy with palpation-guided injections reported lower pain levels at 3 months in the fluoroscopy group when adjusting data for baseline pain levels.[53]

### Efficacy

Results for efficacy outcomes comparing US and palpation-guided interventions were heterogeneous: Function, quality of life, treatment response/treatment failure and time until the next intervention were better in the US groups according to ten studies (total of 24 distinct outcomes, 7 of them with moderate, 17 with high RoB),[18 20 21 27 28 30 33 55 57 58] while 8 studies reported no difference between these groups for 18 outcomes (3 with moderate, 15 with high RoB).[19–22 27 28 32 55]

In one retrospective cohort study with high RoB, an even worse outcome for US versus palpation-guided injection was found with a higher percentage of patients requiring an additional knee reinjection with hyaluronic acid in the US group (20.3% vs 15%, respectively).[18] In the palpation-guided group, however, more patients received an additional GC injection (34% vs 27.4%, respectively). In another study, it was observed that patients with knee osteoarthritis and US-guided injection had a worse quality of life at 3 months than patients with palpation-guided injections, while walking and standing tests were better in the former than in the latter group.[55]

All four studies comparing US and fluoroscopy guidance of intervention revealed no difference concerning the nine efficacy outcomes assessed (six outcomes with moderate, three with high RoB).[12 13 15 16] In contrast, one study comparing US or fluoroscopy versus palpation-guided injections reported a higher patient satisfaction and patients' judgement of treatment efficacy in the US/fluoroscopy as compared with the palpation group. The need for pain medication and tolerability of the intervention was similar in both groups.[17] A study comparing fluoroscopy with palpation-guided injections (low RoB) in SIJ found no difference between groups concerning function, pain medication and patient satisfaction.[53]

### Cost and time

One RCT with high RoB reported worse cost-effectiveness for US compared with palpation-guided interventions in the USA according to reimbursements by Medicare, and taking into consideration the time that was needed until the next intervention.[19] In another RCT from the USA with moderate RoB, higher annual costs for US were observed only in private practice, whereas costs in hospitals' outpatient clinics were similar for US and palpation-guided interventions. Cost-effectiveness was nevertheless better for US considering a longer therapeutic effect of the injection in case US was used.[28] Costs for US and fluoroscopy were similar in one study (high RoB) from the USA,[14] while higher costs for fluoroscopy as compared with US and/or palpation-guided interventions were reported in another study (high RoB).[59]

Procedural times for US guidance were either similar,[24] or shorter[58] than those for palpation guidance (one high, one moderate RoB). Fluoroscopy-guided injections

**Table 1** Studies comparing different imaging techniques or imaging vs palpation guidance in large joints and periarticular structures (PICO1)

| Year author | Study design | Imaging | Comparator | Disease | No Imaging/ Comparator | Intervention (COMPOUND) | SITE | FAVORS imaging* | FAVORS comparator* | No difference between imaging and comparator* | RoB† |
|---|---|---|---|---|---|---|---|---|---|---|---|
| US vs palpation guidance | | | | | | | | | | | |
| 2017 Raeissadat[20] | RCT | US | Palpation guidance | Adhesive capsulitis | 20/21 | Injection (contrast medium, triamcinolone, lidocaine) | shoulder joint | 1x Efficacy (1,4w) | – | 1x Accuracy (BSL)<br>2x Safety (BSL,1,4w)<br>5x Efficacy (BSL,1,4w) | red |
| 2009 Lee[30] | RCT | US | Palpation guidance | Adhesive capsulitis | 20/20 | injection (triamcinolone, lidocaine, saline hyaluronic acid) | shoulder joint | 2x Safety (1,2w)<br>5x Efficacy (1,2,3,4w) | – | – | yellow |
| 2014 Saeed[21] | RCT | US | Palpation guidance | Shoulder impingement | 41/39 | injection (methylprednisolone, lidocaine) | glenohumeral joint, biceps tendon sheath, AC joint) | 1x Safety (6,12w)<br>2x Efficacy (6,12w) | – | 1x Efficacy (12w) | red |
| 2004 Naredo[33] | RCT | US | Palpation guidance | Periarticular shoulder disorders | 21/20 | injection (triamcinolone) | SA-SD bursa | 1x Accuracy (BSL)<br>1x Safety (6w)<br>1x Efficacy (6w) | – | 1x Safety (BSL) | yellow, red |
| 2011 Hashiuchi[29] | RCT | US | Palpation guidance | Anterior shoulder pain | 15/15 | injection (contrast agent) | biceps tendon sheath | 1x Accuracy (BSL) | – | – | yellow |
| 2011 Zhang[27] | RCT | US | Palpation guidance | Biceps brachii tendinitis | 53/45 | injection (lidocaine, triamcinolone) | brachial bicipital groove | 1x Safety (n.a.)<br>2x Efficacy (n.a.) | – | 1x Safety (n.a.)<br>1x Efficacy (n.a.) | red |
| 2019 Yiannakopoulos[58] | RCT | US | Palpation guidance | Tendinosis of the long head of the biceps | 22/22 | injection (triamcinolone, bupivacaine) | long biceps tendon | 1x Accuracy (BSL)<br>1x Safety (BSL,4w,6m)<br>2x Efficacy (4w,6m)<br>1x Cost/Time (BSL) | – | 1x Safety (up to 6m) | red |
| 2014 Chang[22] | RCT | US | Palpation guidance | Scapular pain | 18/18 | injection (triamcinolone, lidocaine) | subscapularis muscle | – | – | 2x Safety (BSL,1,2,3w,3m)<br>1x Efficacy (1w,3m) | yellow |
| 2013 Kim[23] | RCT | US | Palpation guidance | Elbow OA | 40/40 | Injection (dexamethasone, lidocaine, contrast medium) | Elbow joint | 1x Accuracy (BSL) | – | – | yellow |
| 2008 Luz[32] | RCT (letter) | US | Palpation guidance | RA with wrist synovitis | 30/30 | injection (lidocaine, triamcinolone, contrast medium, air) | wrist joint | – | – | 1x Accuracy (BSL)<br>2x Safety (BSL,1,4,8,12w)<br>1x Efficacy (BSL,1,4,8,12w) | yellow |
| 2018 Mitchell[19] | RCT | US | Palpation guidance | Trochanteric bursitis | 15/15 | injection (lidocaine, methylprednisolone) | Trochanteric bursa | 1x Safety (6m) | 1x Cost/Time (n.a.) | 1x Safety (n.a.)<br>2x Efficacy (6m,12 m) | red |
| 2011 Sibbitt[28] | RCT | US | Palpation guidance | Knee OA | 46/46 | injection (Xylocaine, triamcinolone) | knee joint | 1x Safety (BSL,2w,6m)<br>1x Efficacy (BSL to 6m) | 1x Cost/Time (BSL to 12m) | 1x Efficacy (BSL to 12m)<br>1x Cost/Time (BSL to 12m) | yellow |
| 2011 Bum Park, [26] | RCT | US | Palpation guidance | Knee OA | 50/49 | injection (hyaluronic acid, contrast dye) | knee joint | 1x Accuracy (BSL) | – | – | yellow |
| 2013 Jang[24] | RCT | US | Palpation guidance | Knee joint OA | 41/44/41 | injection (lidocaine, triamcinolone, contrast agent) | knee joint | 1x Accuracy (BSL)<br>1x Safety (BSL) | – | 1x Cost/Time (BSL) | yellow |
| 2020 Cankurtaran[55] | RCT | US | Palpation guidance | Chronic knee OA | 11/12 | injection (triamcinolone, lidocaine) | knee joint | 2x Efficacy (1,3m) | 3x Efficacy (3m) | 2x Safety (BSL,1m,3m)<br>6x Efficacy (1m,3m) | red |
| 2012 Sibbitt[25] | RCT | US | Palpation guidance | Knee effusion | 42/22 | aspiration, injection (lidocaine, triamcinolone) | knee joint | 2x Accuracy (BSL)<br>1x Safety (BSL,2w) | – | – | yellow |
| 2009 Im[31] | RCT | US | Palpation guidance | Knee joint OA | 45/44 | injection (Hyaluronic acid, contrast dye) | knee joint | 1x Accuracy (BSL) | – | – | yellow |
| 2019 Lundstrom[18] | Retrospective cohort study | US | Palpation guidance | Receiving knee injection | 500/647 | injection (hyaluronic acid formulas) | knee joint | 2x Efficacy (up to 6y) | 1x Efficacy (up to 6 y) | – | red |

Continued

**Table 1** Continued

| Year author | Study design | Imaging | Comparator | Disease | No Imaging/ Comparator | Intervention (COMPOUND) | SITE | FAVORS imaging* | FAVORS comparator* | No difference between imaging and comparator* | RoB† |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2020 Sheth[57] | RCT | US | Palpation guidance | Receiving knee injection | 19/18 | aspiration and injection (depomedrol, lidocaine) | knee joint | 1 x Safety (BSL,4–6 w)<br>6 x Efficacy (BSL,4–6 w) | – | – | ● (red) |
| 2019 Lee[56] | RCT | US | Palpation guidance | Pes anserinus tendinobursitis | 27/27 | injection (triamcinolone, lidocaine) | Pes anserinus bursa | 1 x Accuracy (BSL)<br>1 x Safety (BSL,1,4w) | – | 1 x Safety (up to 4 w) | ● (yellow) |
| US vs fluoroscopy | | | | | | | | | | | |
| 2016 Petscavage-Thomas[14] | Retrospective cohort study | US | Fluo. | Anterior shoulder pain | 51/50 | injection (triamcinolone, lidocaine) | biceps tendon sheath | 1 x Accuracy (BSL) | – | 2 x Safety (1–3 m,n.a.)<br>1 x Cost/Time (n.a.) | ● (red) |
| 2014 Fowler[16] | RCT | US | Fluo. | Piriformis syndrome | 15/12 | injection, nerve stimulation (lidocaine, triamcinolone) | piriformis muscle | – | – | 2 x Safety (BSL,1,2w,3m)<br>2 x Efficacy (BSL,1,2w,3m)<br>1 x Cost/Time (BSL,1,2w,3m) | ● (red) |
| 2016 Soneji[13] | RCT | US | Fluo. | Chronic SIJ arthritis | 20/20 | injection (methylprednisolone, bupivacaine, epinephrine) | SIJ | – | 1 x Cost/Time (BSL) | 1 x Accuracy (BSL)<br>2 x Safety (BSL,1,3d,1w,1,3m)<br>2 x Efficacy (BSL, 1 m) | ● (yellow) |
| 2014 Jee[15] | RCT | US | Fluo. | Non-inflamm. SIJ dysfunction | 55/55 | injection (contrast media, lidocaine, dexamethasone) | SIJ | – | 1 x Accuracy (BSL) | 2 x Safety (BSL,2,12w)<br>2 x Efficacy (BSL,2,12w) | ● (yellow) ● (red) |
| 2019 Kim[12] | RCT | US | Fluo. | Chronic knee OA | 38/33 | injection, genicular nerve block (lidocaine, triamcinolone) | knee joint | – | – | 2 x Safety (BSL,3,6m)<br>5 x Efficacy (BSL,3,6m) | ● (yellow) |
| US/fluoroscopy vs palpation guidance | | | | | | | | | | | |
| 2016 Bossert[17] | Retro spective cross sectional study | Fluo./US | Palpation guidance | Ankle OA | 29/9/12 | injection (viscosupplement) | ankle | 2 x Efficacy (BSL, n.a.) | – | 1 x Safety (n.a.)<br>3 x Efficacy (n.a.) | ● (yellow) |
| Fluoroscopy vs palpation guidance | | | | | | | | | | | |
| 2019 Cohen[53] | RCT | Fluo. | Palpation guidance | painful SIJ | 64/61 | injection (depomethylprednisolone, bupivacaine) | SIJ | 1 x Accuracy (BSL)<br>2 x Safety (1,3 m) | – | 3 x Safety (BSL,1,3m)<br>4 x Efficacy (BSL,1,3m) | ● (green) |
| US vs fluoroscopy vs palpation guidance | | | | | | | | | | | |
| 2020 Henne[59] | Retrospective cohort study | Fluo. | US, Palpation guidance | Hip OA or FAI | 302 855 | injection (corticosteroid,or hyaluronic acid) | Hip | – | 2 x Cost/Time (post-procedure) | – | ● (red) |
| Fluoroscopy vs CT | | | | | | | | | | | |
| 2020 Diffre[54] | retrospective cohort study | Fluo. | CT | pyogenic vertebral osteomyelitis | 51/37 | Biopsy | disco-vertebral tissue | 1 x Accuracy (BSL) | – | 1 x Safety (n.a.) | ● (red) |

*These columns indicate the number of outcomes studied and their categories (eg, 6× efficacy indicates that six different outcomes related to the efficacy category were studied), with the respective time point(s) when the outcome was determined (parenthesis). The term 'BSL' refers to differences concerning the outcomes at BL. A detailed description of studies and outcomes can be found in supplement.

†A green, yellow, red and black circle indicate low, moderate, high and critical risk of bias, respectively. In case multiple circles are depicted, certain outcomes within one study had different risk of bias.

BSL, baseline; FAI, femoroacetabular impingement; n.a., not applicable; OA, osteoarthritis; PICO, Population, Intervention, Comparator, Outcome; RA, rheumatoid arthritis; RCT, randomised controlled trial; RoB, Risk of Bias; SA-SD, subacromial-subdeltoid bursa; SIJ, sacroiliac joint(s); US, ultrasound.;

required similar or less time than procedures using US according to two studies (one high, one moderate RoB).[13 16]

### Small joints and periarticular structures

Seven studies (four RCTs, two retrospective cohort studies and one retrospective cross-sectional study) compared the value of imaging versus palpation-guided interventions at small joints: five concerned US,[42 48–51] one US or CT[52] and one US or fluoroscopy.[62] The majority of studies were related to GC injections at[48 51] or percutaneous release of[42 49] the first annular (A1) pulley (n=4), while the effects of GC injections at the acromioclavicular joint (AC),[50] temporomandibular joint (TMJ)[52] and the carpometacarpal joint of the thumb[62] were investigated in one study each. A summary of study characteristics is depicted in table 2 while full details of the studies including all outcomes can be found in online supplemental table 5.

#### *Accuracy*

A single study with high RoB reported a higher accuracy (defined as the percentage of intra-articular needle placement) of US as compared with palpation-guided injections at the AC joint (96% vs 60.5%).[50]

#### *Safety*

Safety outcomes were addressed in five studies. In two of them (one with moderate, one with high RoB), lower long-term pain levels were found in the groups receiving US-guided injections as compared with those receiving palpation-guided injections.[49 50] The rate of other adverse events was comparable between groups. The other three studies (two with moderate and one with high RoB) found no difference concerning long-term pain or other adverse events when comparing US or US/CT with palpation-guided procedures.[48 51 52]

#### *Efficacy*

One study with moderate RoB reported slightly higher patient satisfaction (4.1±0.8 vs 3.7±0.8, based on a 5-point Likert scale with 1=worst, 5=best) when performing US-guided rather than palpation-guided injections,[48] while five studies (three moderate, two high RoB) revealed similar results concerning function, treatment failure and other efficacy outcomes when comparing US, and US or CT-guided interventions with palpation-guided interventions, as detailed in online supplemental table 5.[42 48 49 51 52] One retrospective cohort study with high RoB described longer duration of treatment effects for palpation and fluoroscopy-guided injections as compared with US guidance at the carpometacarpal joint of the thumb.[62]

#### *Cost and time*

One study with moderate RoB reported longer procedural time for TMJ injections using US or CT guidance as compared with palpation-guided injections,[52] while in another study with high RoB, longer operational durations were found when performing an US-guided release of trigger finger using a needle-knife, as compared with performing the procedure without imaging.[42] One study (high RoB) described higher costs including physician and facility charges for US as compared with fluoroscopy and palpation-guided injections, however, the difference was not tested by statistical means.[62]

### Studies on multiple (small and large) joints and periarticular structures

Seven studies (four RCTs,[34–37] one prospective cross-sectional study,[28] one retrospective cross-sectional study[60] and one retrospective cohort study)[39] were identified that compared different methods to guide interventions at multiple (large and small, or unknown) joints. See table 3 and online supplemental table 6 for details. Five of them (all with moderate RoB)[34–38] compared US with palpation-guided injections and/or aspirations. One study (with high RoB)[60] investigated the performance of US and CT to guide synovial biopsies, while one study (with critical RoB) compared US with palpation, or arthroscopic guidance for synovial tissue biopsies.[39]

#### *Accuracy*

A better needle placement[36] and more successful aspirations[38] were observed in the US groups of two studies as compared with those undergoing palpation-guided injections, however, two other studies (one critical, one high RoB) reported similar performance of US versus palpation or arthroscopic guidance concerning the amount and quality of synovial tissue,[39] as well as US versus CT[60] for the yield of synovial tissue in the biopsy samples.

#### *Safety*

Two studies reported lower procedural and long-term pain in the US group as compared with palpation-guided interventions,[35 37] while another study revealed no difference in pain between US and palpation guidance[36] (all moderate RoB).

#### *Efficacy*

A longer therapeutic effect after joint aspiration (defined by the time until the next intervention or a Visual Analogue Scale ≥2),[35] better quality of life[36] and a better treatment response[37] were found after US as compared with palpation-guided joint interventions. In one study, however, joint function was similar in both groups[36] (all moderate RoB).

#### *Cost and time*

In the USA, costs per year were higher for US as compared with palpation-guided interventions in a physician's office, while costs were similar in hospitals' outpatient clinic.[35]

### Nerves

Eight studies (seven RCTs),[40–42 44–47 61] one prospective cohort study[43] compared US and palpation guidance for injections of the carpal tunnel syndrome. For details see table 4 and online supplemental table 7. Accuracy

**Table 2** Studies comparing different imaging techniques or imaging versus palpation guidance at small joints and periarticular structures (PICO1)

| Year author | STUDY DESIGN | Imaging | Comparator | Disease | No Imaging/ Comparator | Intervention (COMPOUND) | SITE | FAVORS imaging* | FAVORS comparator* | No difference between imaging and comparator* | RoB† |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **US vs palpation guidance** | | | | | | | | | | | |
| 2015 Park[50] | Retrospective cohort study | US | Palpation guidance | AC joint OA | 50/50 | injection (lidocaine, triamcinolone, contrast material) | AC joint | 1 x Accuracy (BSL)<br>3 x Safety (3,6 m) | – | 1 x Safety (BSL,1,3,6m) | red |
| 2019 Roh[48] | RCT | US | Palpation guidance | trigger finger | 41/38 | injection (triamcinolone) | finger flexor tendon sheath | 1 x Efficacy (n.a.) | – | 2 x Safety (BSL,12,24w)<br>2 x Efficacy (BSL,12,24w) | yellow |
| 2018 Lee[49] | RCT | US | Palpation guidance | trigger finger | 20, 23 fingers /21, 25 fingers | percutaneous pulley release (lidocaine) | A1 pulley | 1 x Safety (2,4 w) | – | 1 x Safety (n.a.)<br>2 x Efficacy (BSL, n.a.) | yellow |
| 2015 Cecen[51] | RCT | US | Palpation guidance | trigger finger | 35/35 | injection (methylprednisolone) | A1 pulley | – | – | 2 x Safety (BSL,6w,6m)<br>2 x Efficacy (BSL,6w,6m) | red |
| 2019 Pan[42] | RCT | US | Palpation guidance | trigger finger (A1 pulley) | 20/21 | cutting (trigger finger release through needle knife) | A1 pulley | – | 1 x Cost/Time (BSL) | 1 x Efficacy (BSL) | red |
| **US vs fluoroscopy vs palpation guidance** | | | | | | | | | | | |
| 2019 Gershkovich[62] | Retrospective cohort study | US | Fluo., Palpation guidance | Thumb CMC arthritis | 8099/2533/51701 | Injection (n.a.) | CMC joint of the thumb | – | 1 x Efficacy for palpation guidance (n.a.)<br>1 x Efficacy for Fluo. (n.a.)<br>1 x Cost/Time (n.a.) | 1 x Efficacy (n.a.) | red |
| **US/CT vs palpation guidance** | | | | | | | | | | | |
| 2017 Resnick[52] | Restrospective cross-sectional study | US or CT | Palpation guidance | JIA | 22/23 | injection (triamcinolone) | TMJ | – | 2 x Cost/Time (BSL) | 1 x Safety (n.a.)<br>2 x Efficacy (n.a.) | yellow |

*These columns indicate the number of outcomes studied and their categories (eg, 6 × efficacy indicates that six different outcomes related to the efficacy category were studied), with the respective time point(s) when the outcome was determined (parenthesis). The term 'BSL' refers to differences concerning the outcomes at BSL. A detailed description of studies and outcomes can be found in supplement.
†A green, yellow, red and black circle indicate low, moderate, high and critical risk of bias, respectively. In case multiple circles are depicted, certain outcomes within one study had different risk of bias.
AC, acromioclavicular joint; BSL, baseline; CMC, carpometacarpal; JIA, juvenile idiopathic arthritis; n.a., not applicable; OA, osteoarthritis; PICO, Population, Intervention, Comparator, Outcome; RCT, randomised controlled trial; RoB, Risk of Bias; TMJ, temporomandibular joint; US, ultrasound.;

**Table 3** Studies comparing different imaging techniques or imaging versus palpation guidance at multiple joints and periarticular structures (PICO1)

| Year author | STUDY DESIGN | Imaging | Comparator | Disease | No Imaging/ Comparator | Intervention (COMPOUND) | SITE | FAVORS imaging* | FAVORS comparator* | No difference between imaging and comparator* | RoB† |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **US vs palpation guidance** | | | | | | | | | | | |
| 2011 Sibbitt[35] | RCT | US | Palpation guidance | Inflammatory Arthritis | 124/120 | aspiration | joints | 1 x Safety (BSL, 2 w, 6 m)<br>2 x Efficacy (BSL to 12 m) | 1 x Cost/Time (BSL to 12 m) | 1 x Cost/Time (BSL to 12 m) | 🟡 |
| 2010 Cunnington[36] | RCT | US | Palpation guidance | Inflammatory Arthritis | 91/89 | injection (triamcinolone, lidocaine, contrast agent iohexol) | joints | 1 x Accuracy (BSL)<br>1 x Efficacy (6 w) | 1 x Efficacy (2 w) | 1 x Safety (BSL, 2, 6 w)<br>3 x Efficacy (BSL, 2, 6 w) | 🟡 |
| 2009 Sibbitt[37] | RCT | US | Palpation guidance | Painful arthritic joints (100 RA, 48 OA) | 74/74 | aspiration, injection (lidocaine, triamcinolone) | large and small joints | 1 x Safety (BSL,2w)<br>2 x Efficacy (2 w) | – | – | 🟡 |
| 2018 Nordberg[34] | Secondary analysis of RCT | US | Palpation guidance | Early RA | 118 (285 joints) /112 (338 joints) | injection (triamcinolone) | joints | – | – | 1 x Efficacy (BSL,12m) | 🟡 |
| 2002 Balint[38] | Prospective cross-sectional study | US | Palpation guidance | Patients for joint/soft tissue aspiration | 31/30 | aspiration and injection | joints/soft tissue | 1 x Accuracy (BSL) | – | 1 x Accuracy (BSL) | 🟡 |
| **US vs CT** | | | | | | | | | | | |
| 2020 McKnee[60] | Retrospective cross-sectional study | US | CT | Receiving imaging-guided synovial biopsy | 18/36 | synovial biopsy | joints | – | – | 1 x Accuracy (BSL) | 🔴 |
| **US vs palpation guidance vs arthroscopy** | | | | | | | | | | | |
| 2018 Humby[39] | Retrospective cohort study | US-NB/ US-P&F | Palpation guidance/ Arthroscopy | Inflammatory arthritis | US-NB: 31<br>US-P&F: 46<br>Palpation guidance: 23<br>Arthroscopy: 25 | Synovial biopsy | Small/ large joints | – | – | 6 x Accuracy (BSL) | ⚫ |

*These columns indicate the number of outcomes studied and their categories (eg, 6 x efficacy indicates that six different outcomes related to the efficacy category were studied), with the respective time point(s) when the outcome was determined (parenthesis). The term ‘BSL’ refers to differences concerning the outcomes at BSL. A detailed description of studies and outcomes can be found in supplement.
†A green, yellow, red and black circle indicate low, moderate, high and critical risk of bias, respectively. In case multiple circles are depicted, certain outcomes within one study had different risk of bias.
NB; needle biopsy; BSL, baseline; n.a., not applicable; OA, osteoarthritis; P&F, portal and forceps; PICO, Population, Intervention, Comparator, Outcome; RA, rheumatoid arthritis; RCT, randomised controlled trial; RoB, Risk of Bias; US, ultrasound.;

**Table 4** Studies comparing imaging versus palpation guidance at peripheral nerves (PICO1)

| Year author | STUDY DESIGN | Imaging | Comparator | Disease | No Imaging/ Comparator | Intervention (COMPOUND) | SITE | FAVORS imaging* | FAVORS comparator* | No difference between imaging and comparator* | RoB† |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **US vs palpation guidance** | | | | | | | | | | | |
| 2017 Eslamian[45] | RCT | US | Palpation guidance | CTS | 27/20 | injection (methylprednisolone) | carpal tunnel | 1 x Efficacy (3 m) | – | 1 x Safety (BSL,3 m)<br>1 x Efficacy (BSL,3 m) | 🟡 |
| 2019 Vahdatpour[40] | RCT | US | Palpation guidance | CTS | 29/23 | injection (methylprednisolone) | carpal tunnel | 1 x Efficacy (4,12 w) | 1 x Efficacy (4,12 w) | 2 x Safety (BSL, 4, 12 w)<br>4 x Efficacy (BSL, 4, 12 w) | 🔴 |
| 2019 Roh[41] | RCT | US | Palpation guidance | CTS | 39/35 | injection (lidocaine, triamcinolone) | carpal tunnel | 1 x Safety (4 w) | – | 1 x Safety (24 w)<br>2 x Efficacy (BSL, 4, 12,24 w)<br>1 x Efficacy (24 w) | 🔴 |
| 2018 Chen[44] | RCT | US | Palpation guidance | CTS | 17 (22 wrists) /14 (17 wrists) | injection (betamethasone) | carpal tunnel | 1 x Safety (1 w) | – | 4 x Safety (BSL,1 w,1,3,6 m)<br>20 x Efficacy (BSL,1,3,6 m) | 🟡 |
| 2013 Makhlouf[46] | RCT | US | Palpation guidance | CTS | 37 wrists /40 wrists | injection, hydrodissection (lidocaine, triamcinolone) | carpal tunnel | 6 x Safety (BSL,2 w,6 m)<br>3 x Efficacy (2 w, 6 m,12 m)<br>1 x Cost/Time (12 m) | 1 x Cost/Time (12 m) | 1 x Safety (12 m)<br>2 x Cost/Time (12 m) | 🔴 |
| 2018 Omar[43] | Prospective cohort study | US | Palpation guidance | CTS | 15/15 | injection (lidocaine, triamcinolone) | carpal tunnel | 2 x Efficacy (4 w) | 1 x Efficacy (4 w) | 2 x Safety (BSL,4w)<br>8 x Efficacy (BSL,4w) | 🔴 |
| 2013 Üstün[47] | RCT | US | Palpation guidance | CTS | 23/23 | injection (methylprednisolone) | carpal tunnel | 1 x Efficacy (6 w) | – | 2 x Safety (BSL,6,12w)<br>1 x Efficacy (BSL,6,12w) | 🟡 |
| 2019 Rayegani[61] | RCT | US | Palpation guidance | CTS | 54/27 | injection (triamcinolone, lidocaine) | carpal tunnel | – | – | 3 x Safety (BSL,10w)<br>7 x Efficacy (BSL,10w) | 🟡 |

*These columns indicate the number of outcomes studied and their categories (eg, 6× efficacy indicates that six different outcomes related to the efficacy category were studied), with the respective time point(s) when the outcome was determined (parenthesis). The term 'BSL' refers to differences concerning the outcomes at BSL. A detailed description of studies and outcomes can be found in supplement.
†A green, yellow, red and black circle indicate low, moderate, high and critical risk of bias, respectively. In case multiple circles are depicted, certain outcomes within one study had different risk of bias.
BSL, baseline; CTS, carpal tunnel syndrome; n.a., not applicable; PICO, Population, Intervention, Comparator, Outcome; RCT, randomised controlled trial; RoB, Risk of Bias; US, ultrasound.;

outcomes were not assessed in these studies. No studies were found for interventions at nerves at other sites.

### Safety

Procedural pain was assessed in one study (high RoB) favouring US over palpation-guided injections.[46] Long-term pain and symptom severity, mostly assessed by the Boston Carpal Tunnel Questionnaire, were similar in US and palpation groups according to six studies (four moderate, two high RoB),[40 43–45 47 61] while higher symptom severity[41] and long-term pain[46] in the palpation as compared with the US groups were observed in two studies (both with high RoB). Furthermore, one study with moderate RoB, reported a higher rate of hand weakness in patients who underwent palpation as compared with US-guided injections (18% vs 0%),[44] and another study with high RoB revealed higher cumulative adverse events including finger numbness, skin discolouration, subcutaneous fat atrophy and pain caused by steroid injection (steroid flares) in patients undergoing palpation (25%) as compared with the US-guided interventions (8%).[41] Other adverse events did not differ between groups.[43 46 47]

### Efficacy

Hand function, quality of life and treatment response were similar between US and palpation-guided injections,[41 43 44 47 61] while two studies described greater symptom relief[47] and longer duration until another intervention was required in the US groups.[46] Studies assessing electrophysiological parameters[40 44 45 61] and median nerve thickness[43] revealed heterogeneous results, without a clear signal for any method.

### Cost and time

Costs for US-guided injections in private practice and hospital based outpatient clinics were higher than for palpation guidance according to one study in the USA.[46] No data were available on cost-effectiveness.

## Imaging settings and technical standards (PICO2)

Only three studies comparing different technical settings/equipment for imaging-guided interventions were found.[25 63 64] Study characteristics and detailed results are depicted in table 5 and online supplemental table 8, respectively. According to one RCT with moderate RoB, a one-needle technique to dissolute calcific depositions in rotator cuff calcific tendinopathy resulted in a higher rate of needle obstruction (15% vs 3.6%) as compared with a two-needle method (one needle for injection, one for aspiration). Other outcomes such as the duration of the procedure, accuracy and safety were similar.[63]

A second RCT with moderate RoB investigated the performance of a 25 mL mechanical as compared with a 60 mL automatic syringe for US-guided aspiration of knee effusion. No differences were found concerning pain or gathered amount of synovial fluid.[25]

Just *et al* performed a retrospective cohort study (high RoB) to compare an US-guided needle—an US-guided

**Table 5** Studies on imaging settings and technical standards (PICO2)

| Year author | Study design | Setting | Alternative setting | Disease | No Setting/ Alternative setting | Intervention (COMPOUND) | SITE | FAVORS setting* | FAVORS alternative setting* | No difference between settings* | RoB† |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Large joints and periarticular structures** | | | | | | | | | | | |
| 2017 Orlandi[63] | RCT | One Needle | Two Needles | Rotator cuff calcific tendinopathy | 100/111 | US aspiration/ injection (heated saline, mepivacaine, triamcinolone) | subacromial/ subdeltoid bursa | – | 2x Efficacy (BSL) | 1x Accuracy (BSL)<br>3x Safety (BSL,1,3m,1y)<br>1x Cost/Time (BSL) | ● (yellow) |
| 2012 Sibbitt[25] | RCT | 25 mL mechanical syringe | 60 mL automatic syringe | knee effusion in rheumatoid arthritis, osteoarthritis | 20/22 | US joint aspiration/ injection (lidocaine, triamcinolone) | knee joint | – | – | 1x Accuracy (BSL)<br>1x Safety (BSL,2w) | ● (yellow) |
| **Multiple joints** | | | | | | | | | | | |
| 2018 Just[64] | Retrospective cohort study | US-NB | US-P&F/ Arthroscopy | Inflammatory arthritis, degenerative disease | US-NB: 402/ US-P&F: 65 Arthroscopy: 57 | Synovial biopsy | wrist, knee, MCP, ankle, elbow, MTP | – | 1x Efficacy (n.a.) | 2x Safety (BSL,7-14d)<br>2x Efficacy (BSL,7-14d) | ● (yellow) |

*These columns indicate the number of outcomes studied and their categories (eg, 6× efficacy indicates that six different outcomes related to the efficacy category were studied), with the respective time point(s) when the outcome was determined (parenthesis). The term 'BSL' refers to differences concerning the outcomes at BSL. A detailed description of studies and outcomes can be found in supplement.
†A green, yellow, red and black circle indicate low, moderate, high and critical risk of bias, respectively. In case multiple circles are depicted, certain outcomes within one study had different risk of bias.
BSL, baseline; MCP, metacarpophalangeal joints; MTP, metatarsophalangeal joints; n.a., not applicable; NB, needle biopsy; P&F, portal and forceps; PICO, Population, Intervention, Comparator, Outcome; RCT, randomised controlled trial; RoB, Risk of Bias; US, ultrasound.;

portal and forceps—and an arthroscopic approach for synovial tissue biopsy at multiple joints. They observed similar safety (pain and adverse events) and efficacy outcomes in all three groups. Slightly more patients in the portal and forceps as well as in the arthroscopic groups reported that they would eventually accept further synovial biopsies.[64] Studies comparing different settings to perform interventional procedures were not found.

### Procedural protocols for imaging-guided interventions (PICO3)

Sixteen studies were found (nine on large, three on small joints and periarticular structures and four on nerves) comparing either different procedures and puncture sites (eg, in-of-plain US and out-of-plain US, injection in different knee recesses),[22 61 67–72 74 78] or different targets (eg, periarticular vs intra-articular) for imaging-guided interventions.[65 66 73 75–77] Table 6 and online supplemental table 9 contain and overview of studies and detailed results, respectively.

#### Large joints and periarticular structures

*Shoulder*

Two studies (one RCT with high[67] and one RCT with low[68] RoB) compared glenohumeral joints with the subacromial/subdeltoid bursa as targets for US-guided GC injections in patients with adhesive capsulitis/frozen shoulder. Patients reported higher pain levels,[67 68] as well as increased symptom severity[68] after injections into the subacromial/subdeltoid bursa. Shoulder extension and external rotation, however, were better in the subacromial/subdeltoid bursa group in one study,[67] whereas in the other study, internal rotation and scores according to the American Shoulder and Elbow Surgeon scale were better when the glenohumeral joint was injected.[68] Another RCT (moderate RoB) focusing on patients with scapular pain and comparing injections either in the subscapular muscle or in the scapulothoracic bursa reported no differences between the groups according to safety and efficacy outcomes.[22]

*Spine and SIJ*

A retrospective cross-sectional study (high RoB) investigated different targets at the spine when using CT to retrieve tissue samples in patients with infectious spondylodiscitis/osteomyelitis. No differences in quality and quantity of samples were observed when either the bone, disc or paravertebral tissue was targeted.[69] Two prospective cohort studies (both high RoB) compared the value of injecting GC intra-articularly or periarticularly at the SIJ via CT[65] or US[66] guidance. The CT study reported higher pain levels at 3 and 6 months in case of periarticular injections, while the US study concluded that there was no difference in pain 4 weeks after the injections.

*Knee*

In-of-plain US and out-of-plain US was compared in patients undergoing knee injections in one RCT with moderate RoB. The study revealed no differences concerning accuracy, safety and duration of the intervention between groups.[71] Furthermore, no differences were found for accuracy and safety when US-guided knee injections were conducted at the mediallateral, midlateral or superolateral recess according to two RCTs with moderate RoB each.[70 72]

#### Small joints and periarticular structures

US-guided periarticular injections of the AC joint resulted in lower pain reduction when performing the crossover arm test as compared with intra-articular injection, according to one RCT with low RoB. Other pain assessments (eg, pain at night or pain after pressure) and the amount of other adverse events were similar between groups.[77] Intra and extra tendon sheath injections at the A1 pulley were compared in two RCTs with high[76] and moderate[75] RoB. No differences concerning safety and efficacy outcomes were found between groups in both studies.

#### Nerves

Two RCT on US-guided injections in CTS, both with moderate RoB, investigated the performance of drug release above or below the median nerve,[74] or an ulnar versus a midline approach for injection.[61] No differences between groups were found for safety and efficacy outcomes including long-term pain, other adverse events, function and electrophysiological parameters. Another study with moderate RoB reported less long-term pain, better function and less swelling of the median nerve after injection of the carpal tunnel from the radial rather than from the ulnar site of the wrist.[78] Furthermore, one retrospective cohort study (high RoB) assessed whether there were differences in safety or efficacy outcomes when the needle was placed in the intraepineurium as compared with the extraepineurium, when performing US-guided hydrodissection and GC injection of the median nerve in CTS.[73] The results for safety and clinical efficacy outcomes like function and symptom severity were comparable between groups, while patients receiving intraepineural injections yielded a higher reduction of perinerve oedema 2 weeks after the intervention as compared with those who underwent extraepineural interventions.

## DISCUSSION

Overall, we found that imaging (especially US)-guided interventions at joints and periarticular structures were reported to lead to more accurate needle positioning as compared with palpation-guided interventions in the majority of studies. The studies themselves, as well as results for safety and efficacy were heterogeneous, and data on cost-effectiveness were absent. Another observation is that the quality of studies was generally low: 51% had a moderate and 47% a high or critical RoB assessment.

**Table 6** Procedural protocols for imaging-guided interventions (PICO3)

| Year author | Study design | Procedure | Alternative procedure | Disease | No procedure/ ALTERNATIVE PROCEDURE | Intervention (COMPOUND) | SITE | FAVORS procedure* | FAVORS alternative procedure* | No difference between procedures* | RoB† |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Large joints and periarticular structures** | | | | | | | | | | | |
| 2018 Khallaf[67] | RCT | GH approach | SASD approach | adhesive capsulitis | 20/20 | US injection (methylprednisolone, lidocaine) | shoulder | 1x Safety (12w) | 2x Efficacy (12w) | 1x Safety (BSL,12w)<br>3x Efficacy (BSL,12w) | ● (red) |
| 2016 Cho[68] | RCT | Intra-articular | Subacromial Bursa or intra-articular and bursa | Frozen shoulder | 36/37 | US injection (triamcinolone, lidocaine) | GH/ Subacromial bursa/both | 1x Safety (BSL,3,6,12w)<br>2x Efficacy (BSL,3,6,12w) | 1x Safety (BSL,3,6,12w) | 3x Efficacy (BSL,3,6,12w) | ● (green) |
| 2014 Chang[22] | RCT | subscapular muscle | scapulothoracic bursa | patients with scapular pain | 18/18 | Subscapular muscle: US injection<br>Scapulothoracic bursa: palpation guidance injection (lidocaine, triamcinolone) | subscapularis muscle/ scapulothoracic bursa | – | – | 2x Safety (BSL,1,2,3,12w)<br>1x Efficacy (1,12w) | ● (yellow) |
| 2015 Chang[69] | Retrospective cross sectional study | Bone (Endplate) Biopsy | Disk Biopsy/ Paravertebral soft tissue Biopsy | Diskitis osteomyelitis | 102 | CT Biopsy | Spine | – | – | 2x Accuracy (BSL) | ● (red) |
| 2015 Althoff[65] | Prospective cohort study | intra-articular | peri-articular | Sacroiliitis | 23/7 | CT injection (triamcinolone) | SIJ | 1x Safety (3,6m) | – | – | ● (red) |
| 2009 Hartung[66] | Prospective cohort study | Intra-articular | Periarticular | Acute sacroilitis | 8/12 injections | US Injection (triamcinolone, gadolinium) | SIJ | – | – | 1x Safety (BSL,24h,4w) | ● (red) |
| 2013 Jang[71] | RCT | Out of plain US | In plain US | knee OA | 41/44 | Injection (lidocaine, triamcinolone, contrast agent) | knee joint | – | – | 1x Accuracy (BSL)<br>1x Safety (BSL)<br>1x Cost/Time (BSL) | ● (yellow) |
| 2011 Park[72] | RCT | Medial Portal | Midlateral Portal/ Superolateral Portal | Knee OA | 40/43/43 knees | US injection (lidocaine, triamcinolone, contrast agent) | knee joint | – | – | 1x Accuracy (BSL)<br>1x Safety (4w) no difference between any group | ● (yellow) |
| 2013 Park[70] | RCT | Midmedial Portal | Midlateral Portal/ Superolateral Portal | Knee OA | 40/40/40 knees | US injection (contrast medium, lidocaine, triamcinolone) | knee joint | – | – | 1x Accuracy (BSL)<br>1x Safety (n.a.) no difference between any group | ● (yellow) |
| **Small Joints and Periarticular Structures** | | | | | | | | | | | |
| 2013 Sabeti-Aschraf[77] | RCT | Intra-articular injection | Periarticular injection | AC joint arthralgia | 53/53 shoulders | US Injection (lidocaine, betamethasone) | AC joints | 1x Safety (BSL,1h,1,3w) | – | 4x Safety (BSL,1h,1,3w) | ● (green) |
| 2016 Shinomiya[76] | RCT | Intra sheath | Extra sheath | Trigger finger | 27 (29 fingers)/28 (32 fingers) | Injection (triamcinolone, mepivacaine) | A1 pulley middle/ ring fingers | – | – | 2x Safety (BSL,4w)<br>5x Efficacy (BSL,4w) | |
| 2018 Mardani-Kivi[75] | RCT | Intra sheath | Extra sheath | trigger finger | 83/83 | US injections (methylprednisolone, lidocaine) | A1 pulley flexor tendons | – | – | 1x Safety (BSL,3,6,12,24,48w)<br>1x Efficacy (BSL,3,6,12,24,48w) | ● (yellow) |
| **Nerves** | | | | | | | | | | | |
| 2018 Babaei-Ghazani[74] | RCT | Above Median nerve | Below Median nerve | CTS | 22/22 | US injection (triamcinolone) | carpal tunnel | – | – | 3x Safety (BSL,6w,12w)<br>6x Efficacy (BSL,6w,12w) | ● (yellow) |
| 2018 Hsu[73] | Retrospective cohort study | Intraepineurium | Extraepineurium | CTS | 39/62 wrists | US hydrodissection, injection (llidocaine, triamcinolone) | carpal tunnel | 1x Safety (2w)<br>4x Efficacy (BSL,2w) | – | 2x Safety (BSL,2w)<br>3x Efficacy (2w) | ● (red) |
| 2019 Rayegani[61] | RCT | US ulnar in plane | US midline in plane | CTS | 27/27 | injection (triamcinolone, lidocaine) | carpal tunnel | – | – | 3x Safety (BSL,10w)<br>7x Efficacy (BSL, 10w) | ● (yellow) |

Continued

**Table 6** Continued

| Year author | Study design | Procedure | Alternative procedure | Disease | No procedure/ ALTERNATIVE PROCEDURE | Intervention (COMPOUND) | SITE | FAVORS procedure* | FAVORS alternative procedure* | No difference between procedures* | RoB† |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2020 Babaei-Ghazani[78] | RCT | US radial approach | US ulnar approach | CTS | 30/30 | injection (triamcinolone) | carpal tunnel | 1 x Safety (12 w)<br>5 x Efficacy (2,6,12 w) | 1 x Efficacy (12 w) | 3x Efficacy (BSL, 2,6,12w) | ● |

*These columns indicate the number of outcomes studied and their categories (eg, 6 × efficacy indicates that six different outcomes related to the efficacy category were studied), with the respective time point(s) when the outcome was determined (parenthesis). The term 'BSL' refers to differences concerning the outcomes at BSL. A detailed description of studies and outcomes can be found in supplement.
†A green, yellow, red and black circle indicate low, moderate, high and critical risk of bias, respectively. In case multiple circles are depicted, certain outcomes within one study had different risk of bias.
AC, acromioclavicular; BSL, baseline; CTS, carpal tunnel syndrome; GH, glenohumeral joint; n.a., not applicable; OA, osteoarthritis; RCT, randomised controlled trial; RoB, Risk of Bias; SASD, subacromial-subdeltoid; SIJ, sacroiliac joint(s); US, ultrasound.;

Positioning a needle or another instrument in, rather than outside the target not only reduces the risk of adverse events,[41 44] but may also have positive effects on short-term and long-term pain, as well as on efficacy outcomes.[65 73 77]

Studies comparing different imaging techniques such as US and fluoroscopy were scarce, which is related to the fact that centres usually have expertise with one rather than multiple techniques.[1]

Only a few studies were available on different technical settings/equipment for imaging-guided procedures,[25 63 64] addressing the value of different equipment, but not the role of assistance by healthcare professionals, monitoring of vital signs, the use of contrast agents or different types of aseptic/antiseptic conditions. Similarly, studies considering different levels of experience of the healthcare provider performing the intervention have not been conducted. It would for example be important to know the accuracy of a palpation-guided intervention of an experienced clinician as compared with a imaging-guided procedure of a fellow.

A Delphi-based consensus paper series on clinical indications for imaging-guided interventional procedures in the musculoskeletal system has recently been published by the European Society of Musculoskeletal Radiology.[5–7] While this series presented important general statements on the use and the value of imaging (eg, 'US guidance is a safe and effective method for brachial plexus block'),[6] the present work focused on direct comparisons between methods, settings and procedures when performing imaging-guided interventions (eg, US vs fluoroscopy, or intra-articular vs periarticular injections). Certain studies only assessing one imaging method, setting or procedure are therefore not covered in this review.[79–87]

One of the major limitations of the available studies was their low scientific quality. Missing information on the randomisation process (for RCTs), outcome assessment (RCTs and non-randomised studies) and the population of interest (cross-sectional studies) were the main reasons for moderate/high RoB of the studies retrieved. Potential confounders were also observed in a small number of non-randomised studies, which was mainly due to their retrospective design. Prospective study design as well as adequate statistical models accounting for confounding factors such as the baseline values of certain outcomes may in future lead to more robust results.

Another limitation was the heterogeneity of study designs and outcomes which prevented us to meta-analyse the available data. We nevertheless tried to categorise outcomes according to overarching groups (accuracy, efficacy, safety and cost-effectiveness) in order to facilitate comparison between studies and to enable overall conclusions. Some outcomes could have been assigned to several of these categories (eg, pain was reported under 'safety', even though it could also be considered an efficacy outcome), and we tried to be as consistent as possible when categorising the outcomes into these broader groups in order to provide the best information available to the EULAR task force and the scientific community.

In conclusion, the majority of studies indicated a higher accuracy of needle positioning at joints and periarticular structures when using imaging (especially US) guidance as compared with palpation-guided interventions with the limitation of heterogeneity of data and considerable RoB. Heterogeneity was also observed among studies on safety and efficacy, whereas data on cost-effectiveness were virtually absent.

**Author affiliations**
[1]Department of Rheumatology and Immunology, Medical University of Graz, Graz, Austria
[2]Internal Medicine and Nephrology Unit, Department of Life, Health and Environmental Sciences, University of L'Aquila, L'Aquila, Italy
[3]Department of Medicine, ASL 1 Avezzano-Sulmona-L'Aquila, San Salvatore Hospital, L'Aquila, Italy
[4]University of Ferrara, Ferrara, Italy
[5]Rheumazentrum Ruhrgebiet Herne, Ruhr University Bochum, Bochum, Germany
[6]Northwell Health, New York, New York, USA
[7]Rheumatology Service, Hospital of Bruneck, Bruneck, Italy
[8]Centre for Rheumatology, University College London, London, UK
[9]National Institute for Health Research (NIHR) University College London Hospitals Biomedical Research Centre, University College London Hospitals NHS Foundation Trust, London, UK
[10]Department of Rheumatology, Northwick Park Hospital, London North West University Healthcare NHS Trust, London, UK

**Twitter** Pedro M Machado @pedrommcmachado

**Contributors** PB and FC drafted the first version of the manuscript. LF designed the search terms for the literature search. All authors contributed, revised critically and finally approved the final version of the manuscript. PB acted as guarantor.

**Funding** This work was funded by the European Alliance of Associations for Rheumatology (IMG016). PMM is supported by the National Institute for Health Research (NIHR), University College London Hospitals (UCLH), Biomedical Research Centre (BRC).

**Competing interests** PMM has received consulting/speaker's fees from Abbvie, BMS, Celgene, Eli Lilly, Galapagos, Janssen, MSD, Novartis, Orphazyme, Pfizer, Roche and UCB, all unrelated to this manuscript. FC has received consulting/speaker's fees from Abbvie and Celgene, all unrelated to this manuscript. XB has received consulting/speaker's fees from Abbvie, BMS, Celgene, Galapagos, Gilead, Eli Lilly, Janssen, MSD, Novartis, Pfizer and UCB, all unrelated to this manuscript. CD has received consulting/speaker's fees from Abbvie, Eli Lilly, Janssen, Novartis, Pfizer, Roche and Sanofi, all unrelated to this manuscript.

**Patient consent for publication** Not applicable.

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data availability statement** All data relevant to the study are included in the article or uploaded as online supplemental information. Not applicable.



**ORCID iDs**
Philipp Bosch http://orcid.org/0000-0002-6783-6422
Francesco Carubbi http://orcid.org/0000-0003-1958-5136
Carlo Alberto Scirè http://orcid.org/0000-0001-7451-0271
Xenofon Baraliakos http://orcid.org/0000-0002-9475-9362
Christian Dejaco http://orcid.org/0000-0002-0173-0668
Pedro M Machado http://orcid.org/0000-0002-8411-7972

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