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REVIEW ARTICLE

Interventional articular and para-articular knee procedures

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ABSTRACT

The knee is a common area of the body to undergo interventional procedures. This article discusses image-guided interventional issues specific to the knee area. The soft tissues in and around the knee are frequently affected by sport-related injuries and often need image-guided intervention. This article details the specific technical issues related to intervention in these soft tissues, including the iliotibial tract, fat pads, patellar tendon and other tendons, bursae and the meniscus. Most often, simple procedures such as injection and aspiration are performed without image guidance. Rarely image-guided diagnostic arthrography and therapeutic joint injections are necessary. The technique, indications and diagnostic considerations for arthrography are discussed in this article. Primary bone and soft-tissue tumours may involve the knee and adjacent soft tissues. Image-guided biopsies are frequently necessary for these lesions; this article details the technical issues related to image-guided biopsy around the knee. A number of newer ablation treatments are now available, including cryoablation, high-frequency ultrasound and microwave ablation. Radiofrequency ablation, however, still remains the most commonly employed ablation technique. The indications, technical and therapeutic considerations related to the application of this technique around the knee are discussed here. Finally, we briefly discuss some newer, but as of yet, unproven image-guided interventions for osteochondral lesions and Brodie's abscess.

INTRODUCTION

The knee is one of the commonest joints affected by osteoarthritis and other internal derangements, such as ligament and meniscal pathology, which may need image-guided and surgical management. The tissues around the knee are also a common site for bone tumours and intervention in the form of biopsy or ablation is often performed around the knee. Interventions such as injections are routinely performed in the knee and, in most instances, are performed in the outpatient setting without any image guidance. In this article, we discuss issues related to image-guided intervention specific to the knee joint. Detailed descriptions of the techniques and the merits of most of the procedures are described elsewhere in this issue. We also discuss newer techniques such as drainage of abscess and retrograde drilling of osteochondral lesions, even though there is sparse literature on these procedures and the evidence is limited currently.

SOFT TISSUES

Iliotibial tract

The main pathology of the iliotibial tract arises distally, around the distal lateral femoral condyle, most commonly seen in runners and cyclists.¹ Aetiological theories include friction secondary to the fascia snapping over the bone

and compression of the fat and connective tissue deep to the fascia.^{2,3} MRI shows areas of oedema deep to the fascia.⁴ Ultrasound may also be used to show the same pathology, with the added benefit of dynamic scanning.⁵ More recently, a proximal iliotibial tract syndrome has been proposed, which manifests as a strain injury at the proximal attachment of the iliotibial tract at the iliac crest.⁶

As with most sports-related overuse pathologies, conservative management with physiotherapy is the first-line treatment. If this fails, then direct interventions may be considered. Localized corticosteroid injections have been shown to have a short-term efficacy in managing the pain from iliotibial tract syndrome⁷ with ultrasound guidance being the mainstay of image-guided intervention.⁸ In our practice, we identify the pathology on the preliminary MRI and then use ultrasound guidance to target the injection, with the pathology often being subtle on ultrasound. Our approach is from medial to lateral, with the tip of the needle being placed at the deep surface of the distal iliotibial tract. We choose to inject a combination of corticosteroid (40 mg depo-medrone) and long-acting local anaesthetic (2 ml 0.5% bupivacaine) (Figure 1).

Figure 1. Proton density with fat suppression images in the coronal (a) and axial (b) planes showing oedema deep to the distal iliotibial tract (arrows). Panoramic longitudinal ultrasound image (c) showing fluid deep to the distal iliotibial tract (arrow), corresponding with the oedema on MRI. This can be targeted for needle placement [as shown in transverse ultrasound image (d)], where the needle is placed deep to the iliotibial tract.

Fat pads

MRI is the optimal modality for assessing the infrapatellar fat pad (Hoffa's fat pad); however, CT or ultrasound may also be used in patients who are unable to have MRI.^{9,10} The fat pad may become inflamed, through altered biomechanics of the extensor apparatus of the knee.¹¹ It is vascularized and richly innervated, making it a potential generator of anterior knee pain.¹² Physiotherapy, specifically with quadriceps conditioning, is one of the first-line treatments for mechanical disorders of the infrapatellar fat pad. If this fails, then steroid and anaesthetic injection may be considered.¹³ Ultrasound-guided ablation with

ethanol is a further potential treatment option for patients who fail conservative management.¹⁴

The injection can be performed with ultrasound guidance, targeting the area of inflammation/impingement as shown on MRI (Figure 2). From a lateral to medial approach, the needle is placed deep into the patellar tendon and into the inflamed fat. The fat pad is an intracapsular, extrasynovial structure, being covered on its posterior surface with a synovial lining.¹⁵ This synovial lining prevents the spread of any injectate in the fat pad from flowing into the synovial compartment of the knee.

Figure 2. Proton density with fat suppression images in the axial (a), coronal (b) and sagittal (c) planes showing focal oedema in Hoffa's fat pad (arrows) which can be targeted for localized injection with ultrasound guidance.

Figure 3. Sagittal proton density with fat suppression (a) and T_1 (b) images showing pre-patellar bursitis which may be targeted for injection with ultrasound guidance.

The posterior synovial lining of the fat pad and the synovial-lined plica mean that the fat pad may also be involved in pathologies that give rise to a generalized synovitis, such as the inflammatory arthropathies. Other synovial proliferative disorders may manifest in the infrapatellar fat pad, for example localized or diffuse tenosynovial giant cell tumour [formerly known as pigmented villonodular synovitis (PVNS)]. This condition may be treated with image-guided ablation.

The two other fat pads in the knee, the quadriceps and pre-femoral fat pads, are less commonly inflamed compared with the infrapatellar fat pad. If imaging studies, namely ultrasound or MRI, show them to be inflamed then targeted steroid and anaesthetic injections can be performed.

Bursae

The bursae around the knee are elegantly shown on MRI, making bursography a redundant technique. Possible interventions include ultrasound-guided steroid injection into an inflamed bursa or aspiration for diagnosis of infection or other synovial pathology. Figure 3 shows an inflamed pre-patellar bursa which may be aspirated for diagnosis, with ultrasound guidance if necessary.

Pes anserinus and hamstring tendons

The pes anserinus and hamstring tendons can be evaluated on ultrasound and, owing to their relatively superficial location, are amenable to ultrasound-guided intervention. The range of treatment options is wide and includes steroid injection into the tendon sheath, dry needling and platelet-rich plasma injection. The current National Institute for Health and Care Excellence guidance and a recent Cochrane review indicate insufficient evidence for platelet-rich plasma injection over current standard treatments.^{16,17} The relative merits of each procedure will be discussed elsewhere in this issue; however, as implied by the range of different treatment options, there is no good evidence for the superiority of one over another. As with all image-guided interventions, correct needle placement is crucial, independent of the chosen injectate/procedure. We use a high-frequency

linear probe and place the needle tip in the tendon sheath along the long axis of the tendon, without piercing the tendon (Figure 4). In the absence of any compelling evidence to the contrary, we continue to use an injectate of a corticosteroid (usually 40 mg depo-medrone) with a long-acting local anaesthetic (1 ml of 0.5% bupivacaine).

Patellar tendon

As with the pes anserinus and hamstring tendons, the patella tendon is superficial and readily visualized with ultrasound. Patellar tendinosis is generally associated with overuse injuries, commonly in sports requiring fast acceleration. Ultrasonic abnormalities include tendon thickening, alteration in echotexture, loss of the normal fibrillary pattern, dystrophic ossification and proliferation of vessels, predominantly from the deep aspect.¹⁸ The patellar tendon is richly innervated and can therefore be a strong pain generator.¹⁹

Physiotherapy and quadriceps strengthening exercises should form the first-line treatment for patellar tendinopathies. If these conservative management strategies fail, then a graded interventional approach may be taken.

The patellar tendon is similar in anatomy to the Achilles tendon, in that it does not have a tendon sheath rather a paratenon applied to the superficial surface. The deep surface is invested with a peritenon which is loosely applied to the infrapatellar fat pad. Steroid injection into the paratenon has not been shown to be beneficial and is not recommended.²⁰ It is accepted amongst musculoskeletal radiologists that injecting steroid into the tendon substance is contraindicated, with examples of tendon rupture following this procedure.²¹ Dry needling is a possible alternative technique whereby the tendon substance is traversed multiple times with a needle without injectate, with the aid of local anaesthetic along the needle tract. Usually, a lateral to medial approach in the transverse plane is used, unless there are any specific contraindications, such as skin infection along the desired route. Evidence for dry needling is weak, as with many other tendon procedures.²² Similar to the Achilles tendon,

Figure 4. Proton density with fat suppression images in the sagittal (a) and axial (b) planes showing fluid in the semitendinosus tendon sheath and adjacent pes anserine bursitis (arrows). Longitudinal ultrasound image (c) in the same patient shows fluid around the semitendinosus tendon (arrow) which can be targeted with ultrasound for needle placement. Longitudinal ultrasound image (d) shows needle placement in the fluid pocket prior to aspiration and steroid injection (arrow).

another potential procedure is “paratenon stripping”. The rationale for this procedure is based on the observation on imaging that tendinopathy is accompanied by increased vascularity and reducing the vascularity may halt the process. Local anaesthetic may be used along the needle tract and the needle placed in the superficial paratenon (transverse approach) and also the deep tendon surface. Injection of solution here may allow free spread of injectate into Hoffa’s fat through the loosely applied peritenon. The majority of the neovascularity arises from the deep tendon surface, making the term “paratenon stripping” a misnomer. Either a high-volume solution containing anaesthetic and/or saline may be injected or, alternatively, a sclerosant such as alcohol.²³ The evidence for this procedure is also relatively weak and compares unfavourably with eccentric exercise training.²⁴

Other tendon therapies, such as extracorporeal shock wave therapy, have shown some potential for treating patellar tendinopathy; however, the evidence remains insufficient to recommend this instead of the other treatments.²⁵ Figure 5 shows a severe proximal patellar tendinosis with neovascularity, which is amenable to ultrasound-guided intervention.

Meniscus

The preferred modality for imaging the meniscus is MRI; however, outside of a few centres, MRI-guided procedures are limited. The deep location of the meniscus means ultrasound assessment is only possible at the most superficial aspect, and therefore, the role of ultrasound is mainly to target a procedure once pathology has already been identified on MRI. The main application of interventional musculoskeletal radiology is in aspiration and injection of parameniscal cysts. If the cyst is peripheral in location, it can be visualized on ultrasound and a needle placed within it. If the cyst is fluid like, it may be aspirated, similar to a ganglion cyst. Steroid may also then be injected for symptom relief.²⁶ Treating the cyst does not address the underlying cause, usually a meniscal tear, and we therefore reserve this procedure for those patients who are unable (or unwilling) to undergo a more definitive surgical treatment (Figure 6).

Soft-tissue masses

Soft-tissue lesions around the knee are commonly ganglia or bursae.²⁷ Lesions which are not clearly cystic are often not fully characterized on imaging alone and require biopsy for histological diagnosis. Most soft-tissue lesions around the knee are

Figure 5. Sagittal (a) proton density with fat suppression images showing proximal patellar tendinosis and oedema in the subjacent Hoffa's fat pad. The corresponding longitudinal ultrasound image (b) demonstrates neovascularity in the proximal patellar tendon and hypoechogenicity consistent with severe tendinosis. During the procedure, the needle tip is seen deep to the paratenon (arrow) in this longitudinal image (c), immediately superficial to the patellar tendon. The needle is placed both superficial and deep to the patellar tendon and following the procedure, fluid can be seen encircling the patellar tendon (arrows) in this axial (d) ultrasound image.

superficial enough to be adequately visualized with ultrasound guidance and are amenable to percutaneous ultrasound-guided biopsy (Figure 7). Common to biopsy of all musculoskeletal tumours, a compartmental approach should be taken following discussion with the sarcoma surgeon. Ideally, the biopsy route should not enter the adjacent compartments to the lesion, with consideration of the need to excise the biopsy tract if the lesion is found to be malignant. Usually, this means taking a longitudinal needle approach to the lesion. It is our routine practice to capture an ultrasound image of the needle within the lesion for documentation of the approach and the site of biopsy. As with most ultrasound-guided interventional procedures around the knee, generally a linear high-frequency transducer is used to visualize the needle and lesion. If the lesion is deep, CT may also be used to guide biopsy, as shown in Figure 8. With deep lesions, it may not be possible to only cross the lesional compartment with the biopsy needle. In these cases, it is especially important to plan the biopsy route with the sarcoma surgeon.

Benign cystic lesions around the knee may also be aspirated with ultrasound guidance, followed by steroid injection (Figure 9).

ARTICULAR INTERVENTION

Arthrography

Indications

With the routine use of high-quality MRI including metal artefact reduction techniques, the use of arthrography of the knee has declined significantly. Nevertheless, there are still some indications for arthrography in the knee such as evaluation of post-operative meniscus, characterization of chondral and

osteochondral injuries and delineation of intra-articular loose bodies. Arthrography can also be used to assess the status after autologous chondrocyte implantation and sometimes for assessment of anterior cruciate ligament grafts.²⁸

Risks and contraindications

Arthrography is a safe procedure with few risks. There are no absolute contraindications for arthrography itself. Patients may, however, have contraindications for MRI scanning such as a pacemaker, and in these situations, CT arthrography can be employed.

Figure 6. Longitudinal ultrasound image showing a degenerate meniscus with associated parameniscal cyst (arrow), which can be targeted for ultrasound-guided aspiration and steroid injection.

Figure 7. Sagittal proton density with fat suppression MR image (a) and ultrasound image (b) in the transverse plane demonstrating a highly vascular soft-tissue tumour in the popliteal fossa. Ultrasound image in the longitudinal plane during biopsy (c) showing satisfactory needle position in the tumour which turned out to be a high-grade leiomyosarcoma. In most cases, the biopsies should be performed in the longitudinal plane or the plane of eventual resection. Usually, sarcoma surgery is performed with a longitudinal incision rather than a transverse incision.

As it is an invasive technique, there is a small risk of infection. This risk is, however, very low with good aseptic technique. In a study of >125,000 arthrographic procedures, the authors only demonstrated 3 cases of infection.²⁹ In addition to using a strict aseptic technique, we avoid arthrography in the presence of an active infection elsewhere in the body and reschedule the test once the infection has settled.

The other risk is bleeding; however, in experienced hands, this risk is negligible. There are different locally applicable policies in various radiology departments regarding the cessation of anti-coagulation and in patients with bleeding disorders. The risk of a cardiovascular event from stopping anticoagulation should be weighed against the risk of bleeding. In addition, there is no firm evidence that performing arthrography in patients on anti-coagulation is detrimental.

All patients should be made aware of the feeling of fullness and tightness after the injection, which is to be expected after joint distension. Some patients may experience minor exacerbation of

pain in the days following the injection, but any symptoms should settle within a week after arthrography.³⁰

Only a small dose of radiation is required to perform the procedure, especially with good fluoroscopic technique and shielding. Usual radiation protection measures should be applied to arthrography as per local guidelines.

Technique

Knee arthrography can be guided by fluoroscopy, ultrasound or MRI or can be performed without image guidance. Usually, arthrography of the knee is performed under fluoroscopic guidance. The most commonly used approach is the lateral patella–femoral approach but a medial patella–femoral or direct anterior approach (medial or lateral to the patellar tendon) may also be used.^{28,31,32}

The patient is positioned supine with the knee slightly flexed to enable the quadriceps to be relaxed. After obtaining informed consent, a sterile technique is used to infiltrate the skin and subcutaneous tissues with a small amount of appropriate local

Figure 8. Axial proton density with fat suppression image (a) showing an indeterminate soft-tissue lesion in the posterior aspect of the knee (arrow). The lesion was biopsied with CT guidance (b), as was too deep for accurate ultrasound visualization. Histology indicated a ganglion cyst.

Figure 9. Axial proton density with fat suppression image (a) showing a fluid signal lesion in vastus intermedius (arrow). A longitudinal approach was taken during ultrasound-guided aspiration (arrow) (b), yielding gelatinous fluid consistent with a ganglion.

anaesthetic solution. The same 22-gauge needle can then be advanced into the knee joint. A small volume of iodinated contrast medium (1–3 ml) is used to check for satisfactory articular position of the needle, and subsequently, 35–50 ml of the arthrographic solution is injected into the joint until resistance is felt or the patient complains of fullness/pain. Satisfactory needle position is confirmed if the injected iodinated contrast medium flows freely away from the needle tip (Figure 10). If iodinated contrast does not flow freely or is loculated at the needle tip, the needle should be repositioned before injecting the rest of the arthrographic solution. Any pre-existing joint effusion should be aspirated and samples sent for analysis if there is a clinical need to do so.

When a lateral or medial patellofemoral technique is used, needle placement can be helped by pressing on the contralateral aspect of the patella downwards whilst displacing the patella towards the needle, which will open up the ipsilateral aspect of the patello-femoral joint. For example, if using a lateral approach, we can press down on the medial aspect of the patella with the fingers at the same time lifting the lateral aspect of the patella upwards and outwards whilst directing the needle such that the needle tip ends at the deeper aspect of the midpoint of the apex of the patella (Figure 10). In the direct anterior approach, the needle is passed either immediately medial or lateral to the patellar tendon towards the femoral trochlea.

For MR arthrography, dilute gadolinium (2 mmol l^{-1} concentration) is used. This solution can either be obtained in pre-filled syringes (e.g. Magnevist®; Bayer, Berkshire, UK) or can be prepared individually. At the Robert Jones and Agnes Hunt Orthopaedic Hospital, we use manufacturer-supplied pre-filled syringes. Occasionally, in potentially claustrophobic patients, we prepare the solution ourselves to combine gadolinium and iodinated contrast medium so that we can also perform CT arthrography if necessary. When iodinated contrast medium is used, we dilute the iodinated contrast to achieve iodine strength of 100–150 mg of iodine ml^{-1} . Sometimes, a short- or long-acting local anaesthetic can be included in the arthrographic solution as a diagnostic test (so if the patient experiences pain relief in the hours following the injection, the knee can be confirmed as a source of the patient's pain), but there is some recent interest in the risk of chondrotoxicity associated with intra-articular local anaesthetic injections.^{33,34} The chondrotoxic effect of local anaesthetic agents is time, concentration and drug dependant.³⁵ At the concentrations and volumes injected during

arthrography or therapeutic joint injection, the risk of chondrotoxicity is probably very low. In our department, we use ropivacaine which has been demonstrated to be of lower toxicity than bupivacaine to the chondrocytes.

Inadvertent injection of gas bubbles can complicate assessment of loose bodies. To avoid this, a “wet to wet” connection is recommended between the needle, syringe or connecting tube. Gentle mobilization of the joint through the normal range of motion helps to redistribute the contrast throughout the joint to “coat” the articular surfaces adequately and facilitate insinuation of the contrast material into meniscal tears. The subsequent MRI or CT scan should be performed soon after the arthrogram, usually within an hour, as the gadolinium and iodine are gradually resorbed by the synovium into the blood stream and further dilution takes place.

Indirect MR arthrography (after injection of intravenous gadolinium and following exercise) can also be performed, but this does not achieve the same degree of distension of the joint and is not routinely used in the knee. Further discussion on indirect MR arthrography is beyond the scope of this chapter.

Diagnostic considerations of arthrography

In the post-operative repaired meniscus, conventional MRI depends on the demonstration of a high T_2 signal extending to the articular surface to diagnose a meniscal tear. However, this criterion depends on the presence of an effusion in the knee itself, and in addition, it is sometimes difficult to differentiate the high T_2 signal of a re-tear from post-operative granulation tissue. Arthrography therefore is advantageous because the instillation of fluid under pressure has a higher chance of extending into the meniscal tear and is specific for diagnosing a meniscal re-tear (Figure 10b). In addition, gadolinium has a lower viscosity than synovial fluid and therefore has a higher likelihood of extending into the tear. At the Robert Jones and Agnes Hunt Orthopaedic Hospital, we initially perform a non-arthrographic MRI scan and reserve MR arthrography for cases where conventional MRI scan is not diagnostic.

In the case of osteochondral lesions, MR or CT arthrography is superior not only at diagnosing the lesions but also in staging and characterizing, particularly in reference to the stability of the osteochondral lesions (Figure 10c–f). Following microfracture or cartilage transplantation for the treatment of osteochondral

Figure 10. Fluoroscopic image (a) during knee arthrography shows needle placement by a lateral approach. The needle tip is on the deep aspect of the patellar midpoint. Iodinated contrast is seen to flow freely in the joint confirming satisfactory needle placement. Sagittal T_1 weighted fat saturated (T1FS) post-arthrographic MR image (b) shows extension of contrast material into a recurrent vertical tear (arrow) in the periphery of the posterior horn of the medial meniscus. Axial T1FS post-arthrographic MR image (c) shows a deep punched-out osteochondral defect in the patella (arrow). Sagittal reconstruction image from a CT arthrogram in a second patient (d) shows a stable osteochondral lesion in the medial femoral condyle with an intact articular surface. These lesions do not need intervention and are followed up conservatively. Sagittal reconstruction images (e, f) from a CT arthrogram of a third patient show a detached osteochondral lesion (arrow) and a separate loose body (arrow) behind the lateral femoral condyle.

lesions, arthrography gives a better depiction of the state of the repair tissue (Figure 11a–c).

MRI/CT arthrography can also be used for assessment of anterior cruciate ligament graft integrity (Figure 12a) and plicae (Figure 12b). Although a bipartite patella is usually considered a congenital variation with no clinical significance, we have seen patients who have an unstable bipartite patellar fragment. Double-contrast CT arthrography, after injecting 6–8 ml of iodinated contrast and 30–40 ml of air, is useful in these cases to demonstrate that the fragment is separate from the patella and also that the cartilage surface is discontinuous (Figure 12c,d).

CT arthrography is excellent at defining the status of the surface of the articular cartilage, sometimes better than MRI, and is also useful when there are contraindications to MRI scanning. CT arthrography is also useful when there is metalwork

related to the previous surgeries which can cause artefact on MRI scans.

MRI and CT arthrography are also more accurate at detecting osseous and cartilaginous loose bodies compared with conventional MRI and CT imaging³⁶ (Figures 10f and 11b).

Therapeutic joint injections

Knee joint injections may also be performed for therapeutic pain management. The drugs that are most frequently used are corticosteroids, anaesthetic agents, hyaluronic acid and platelet-rich plasma. Corticosteroids reduce the inflammatory reaction in the joint by restricting the accumulation of leucocytes and macrophages, and the release of vasoactive kinins. Corticosteroids also reduce the formation of prostaglandins, thereby also reducing the inflammatory process. Local anaesthetics are injected into joints to provide short-term pain-relief and sometimes for

Figure 11. Sagittal proton density with fat suppression MR image (a) a few years following microfracture shows heterogenous signal in the medial femoral articular cartilage. CT arthrographic sagittal reconstruction image (b) in the same patient shows that the cartilage has reconstituted satisfactorily albeit with minor hypertrophy. Also note the loose body along the posterior margin of the Hoffa's fat pad surrounded by contrast (arrow). Sagittal T_1 weighted MR arthrographic image (c) in a different patient following autologous chondrocyte transplantation (ACI) shows hypertrophic cartilage (arrow), a recognized complication after ACI.

diagnostic purposes. If a knee joint injected with local anaesthetic demonstrates complete pain relief for the duration of the action of the anaesthetic, this suggests the knee is the source of

the patient's symptoms. This can be a useful test prior to performing major surgeries such as arthroplasty or arthrodesis, especially when clinical examination is equivocal regarding the

Figure 12. Sagittal T_1 MR arthrographic image (a) shows normal appearances of an intact anterior cruciate ligament graft. Axial T_1 weighted fat saturated MR arthrographic image (b) shows a markedly hypertrophic medial plica (arrow). Axial CT supine (c) and prone (d) images following double-contrast arthrography shows an unstable bipartite fragment of the patella (arrows). In the supine position, air can be seen to extend between the bipartite fragment and the patella whilst in the prone position, iodinated contrast extends into the defect.

Figure 13. Axial CT images (a, b) from a knee examination. The arrows depict the ideal route for biopsy of bone lesions around the knee to enable satisfactory resection of the biopsy tract during definitive surgery. Axial CT images showing needle positions during biopsies of distal femoral (c) and proximal tibial lesions (d) in two different patients. Histology showed the femoral lesion to be a cyst secondary to calcium pyrophosphate deposition and the tibial lesion to be a giant-cell tumour of the bone.

source of symptoms. As described in the previous section, there is controversy regarding the chondrotoxicity of local anaesthetics and this should be considered.

Joint aspiration may also be needed therapeutically when there is a large effusion affecting the movement of the joint and to provide symptomatic relief. Aspiration is also useful for analysis of the fluid, especially when infection or crystal deposition diseases are considered.

The evidence for efficacy from injection of hyaluronic acid and platelet-rich plasma in osteoarthritis of the knee is limited and inadequate currently.^{37–39}

The technique for performing all these knee injections/aspirations is similar to arthrography.

Other interventional procedures for knee arthritis
There are some more recent interventional procedures described for treatment of knee osteoarthritis refractory to conservative management such as pulse-dose radiofrequency (PRF) treatment.^{40,41} In their study, Masala *et al*⁴⁰ performed PRF treatment on 40 patients and reported significant benefit in pain and improved quality of life without any complications. PRF has been shown to cause ultrastructural changes in the nociceptive fibres⁴² and some reduction in the immune response. However,

these are small studies and the results cannot be extrapolated to larger populations. There are no data to show long-term effectiveness.

Synovial biopsy is covered elsewhere in this issue.

OSTEOCHONDRAL LESIONS—IMAGE-GUIDED TREATMENT

Osteochondral lesions are a common problem in the knee. Various methods of treatment are advocated for symptomatic and unstable lesions, including microfracture, mosaicplasty and cartilage transplantation. Most of these techniques involve arthroscopy or open surgery as well as drilling. Drilling through the joint requires traversing the hyaline cartilage surface. To avoid this, some surgeons have advocated retrograde drilling using fluoroscopic guidance.⁴³ Seebauer *et al*⁴⁴ have recently described the high degree of accuracy and feasibility of MRI-guided retrograde drilling and bone grafting of osteochondral lesions of the knee in cadavers. The same authors have previously performed a similar study on cadaveric ankles and showed the feasibility of this procedure.⁴⁵ The authors used MRI guidance which is three dimensional and therefore more reliable than fluoroscopy. This also obviates the need for constant checking of the needle position by altering the angle of the X-ray tube during the procedure. This technique may also be of benefit in cases where the osteochondral lesions are in inaccessible

Figure 14. Axial (a) CT image demonstrates an osteoid osteoma nidus in the subchondral bone of the medial tibia (arrow). CT image during radiofrequency ablation (b) showing the active probe tip in the lesion. Sagittal reconstruction CT image (c) from a different patient showing a chondroblastoma in the posterior aspect of the proximal tibia (arrow). CT image during radiofrequency ablation (d) shows satisfactory deployment of a multitine umbrella probe in the lesion.

locations and also when the overlying hyaline cartilage remains intact and needs preservation.

OSSEOUS LESIONS

Bone biopsy

In this section, we discuss the specific issues related to bone biopsies around the knee. Bone biopsies are usually performed in cases of suspected infection and tumours when the diagnosis is not certain or when tissue is needed for planning final treatment. In the case of infection, biopsy is needed to establish the diagnosis, identify the organism and administer appropriate antibiotic therapy. All bone biopsies should be discussed at a multidisciplinary tumour meeting prior to the biopsy procedure, so that the surgeon and the radiologist can discuss the path taken for the biopsy. This is to ensure that the biopsy tract can be included in the subsequent tumour resection and that there is no contamination of other compartments, especially when limb sparing is being considered. There have been reports of tumour recurrence in needle tracts following bone biopsies.⁴⁶ It is for this reason that all patients needing biopsies for primary bone tumours are ideally referred to a sarcoma treatment centre.

Image-guided biopsy is nearly as accurate as open biopsy for the diagnosis of sarcomas, with fewer complications.⁴⁷ A review of 430 CT-guided biopsies performed at our institution showed 91.9% accuracy with no significant complications.

Particular attention should be taken when assessing the primary tumour for knee joint involvement. If the tumour is intra-articular, surgery would include arthroplasty of the affected joint. However, if the tumour is extra-articular, radical surgery may be possible with joint preservation. It is important therefore that the biopsy tract does not extend through joints and, where possible, an extra-articular biopsy approach should be considered. Patient outcome can be affected by a poorly planned biopsy approach either because (a) a much wider area needs to be resected (including unnecessary amputations), (b) a larger area of the patient needs to be subjected to radiotherapy to include the biopsy tract or (c) the biopsy tract is not excised and the patient may develop a recurrence in the biopsy tract and suffer significant reduction in survival.^{48,49}

For bone lesions in the distal femur, two different approaches can be taken. If the lesion is located laterally, a direct lateral approach through the vastus lateralis anterior to the lateral intermuscular septum is recommended. For medial lesions, a direct medial approach through the vastus medialis/adductor tubercle is suggested (Figure 13). In the proximal tibia, an anteromedial approach is recommended (Figure 13). For the proximal fibula, a direct lateral approach immediately anterior to the posterior intermuscular septum is ideal. In all these approaches, avoid traversing the knee joint articular space. These approaches are guidelines and a discussion with an orthopaedic oncological surgeon is necessary before the biopsy, regarding the route.⁵⁰

Figure 15. Sagittal (a) and axial (b) proton density with fat suppression (PDFS) images show biopsy-proven pigmented villonodular synovitis (PVNS) in the posterior intercondylar region of the knee (arrows). This lesion would be difficult to approach through standard arthroscopic procedure. CT image during RF ablation (c) showing a multitine needle deployed in the lesion. MRI PDFS image (d) 18 months following radiofrequency ablation shows satisfactory resolution of the PVNS lesion.

As the pathological diagnosis of bone tumours is dependent on the architecture of the lesion as well as the cellular content, core biopsies are preferred to fine needle aspirations. The largest possible biopsy needle should be used. At our institution, we use 11- to 14-gauge biopsy needles. The biopsy should be obtained from multiple sites in the tumour. Ideally, samples should be sent both for histological and microbiological assessment as it is sometimes difficult to differentiate infection and tumour on imaging grounds alone.

Tumour ablation

Since the first description of radiofrequency thermoablation (RFA) for the treatment of osteoid osteomas by Rosenthal *et al*⁵¹ in 1992, ablation has been used to treat a number of different types of bone and soft-tissue musculoskeletal tumours.⁵² Currently, there are a number of ablation techniques available including RFA, laser ablation, cryoablation, microwave ablation and high-intensity focused ultrasound treatment. Usually, these percutaneous ablation techniques are performed under imaging guidance in the form of ultrasound, CT or MRI. The merits and indications of these various modalities are discussed elsewhere in this issue. CT is the most commonly used guidance owing to its ease of availability and ease of localization of bone lesions. For lesions such as osteoid osteomas, CT is also superior to other imaging techniques for lesion depiction. The nidus of an osteoid osteoma may not be seen and can easily be obscured amongst the oedema on a MRI scan. MRI guidance also needs specialist

equipment both for anaesthesia and the ablation and is currently only used in a few institutions.

Despite all the new ablation techniques, RFA is still the most frequently used technique as the equipment and disposables are cheaper. RFA and other ablation techniques have been used to treat a variety of bone and soft tissue lesions such as osteoid osteomas, chondroblastomas, metastases, phosphaturic mesenchymal tumour, chondromyxoid fibroma, intracortical chondromas, enchondromas, eosinophilic granuloma, epithelioid haemangioma and extra-abdominal desmoid/fibromatosis^{53–60} (Figure 14). Any type of normal or abnormal tissue can be destroyed by an increase of temperature $>60^{\circ}\text{C}$. Therefore, any small, well-defined lesion can be potentially treated with RFA or other ablation techniques. We have also used RFA to successfully treat PVNS in the posterior aspect of the knee. PVNS is best treated by open or arthroscopic resection/synovectomy. However, we have treated patients with lesions in the posterior intercondylar regions with RFA, as these lesions are difficult to access through the standard arthroscopic portals, and surgery through a posterior knee approach has a higher morbidity (Figure 15).

Malignant primary bone and soft-tissue sarcomas are best treated by surgery, as these lesions are generally larger in size and a wide surgical margin confers the best long-term outcome for these patients. However, ablation techniques can be used to treat

recurrent sarcomas, if surgical resection is not an option. Multidisciplinary discussions are essential before embarking on ablation of these lesions. RFA has been used to treat chordomas in these situations.⁶¹ We have used RFA to treat one patient with recurrent proximal tibial giant-cell tumour where, after three previous curettages, the only remaining surgical option was a proximal tibial replacement with a high complication rate.

Osteomyelitis—percutaneous drainage of Brodie's abscess

Osteomyelitis complicated by abscess formation is conventionally treated with intravenous antibiotics and surgical drainage. Hoffer and Emans⁶² first described the successful use of ultrasound and fluoroscopic guidance for the drainage of subperiosteal abscesses in children. They used a Seldinger technique and left an 8-French catheter in the abscess for drainage. The catheter was removed once the pus stopped draining. Ultrasound would be suitable for subperiosteal locations but cannot

access deeper lesions. More recently, Tan et al⁶³ reported successful percutaneous drainage of a deeper Brodie's abscess in the distal femoral metaphysis in a 17-year-old patient using CT guidance. During the same CT procedure performed under general anaesthetic, they drained pus for confirmation of the diagnosis and, using two Bonopty bone biopsy needles, simultaneously irrigated the abscess cavity with normal saline. Using a percutaneous method, the authors suggest, would reduce morbidity, lead to earlier healing and return to pre-morbid function.

SUMMARY

In this article, we describe the various interventional techniques employed in the diagnosis and treatment of disorders in and around the knee. A thorough knowledge of the anatomy, risks and contraindications is necessary before embarking on these procedures. Appropriate training is also required, particularly to perform more complex procedures such as ablation and biopsy, in order to achieve satisfactory patient outcomes.

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