The role of interventional radiology in elective orthopaedic practice

Abstract

Interventional radiology is a subspecialty of radiology that provides a range of minimally invasive diagnostic and therapeutic procedures. It continues to expand and evolve, and has had a marked impact on clinical care in many settings, in some cases averting the need for major surgery and hospital admission. While its role in the setting of trauma is relatively well established, with arterial embolisation a valuable option in the management of haemodynamically unstable patients, it is less prominent in the elective setting. This article provides an overview of emerging applications of interventional radiology in the elective treatment of orthopaedic conditions.

Key words: Elective surgery; Embolisation; Interventional radiology; Minimally invasive; Orthopaedics; Radiology

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Introduction

The term 'interventional radiology' may be defined as the use of image-guided, minimally invasive procedures for diagnosis or treatment. This in turn may be broadly divided into vascular and non-vascular interventional radiology. The former comprises endovascular interventions such as embolisation, sclerotherapy and stenting, and the latter encompasses other forms of intervention such as image-guided biopsies, radiofrequency ablation, vertebroplasty and kyphoplasty.

Vascular interventional radiology has a burgeoning application in all medical specialties and this is particularly true within orthopaedic practice. With the predicted increase in life expectancy in western countries, orthopaedic surgeons will have a growing number of patients with a low physiological reserve. Interventional radiology offers minimally invasive management options that may complement or even avert the need for surgery and, as such, will be increasingly valuable in an ageing population.

This review highlights the diverse roles that elective interventional radiology plays in orthopaedic patients, with a focus on endovascular interventions.

Vascular pathology

Vascular complications of orthopaedic surgery

Arterial vascular injuries rarely occur during elective orthopaedic procedures (Table 1) (Calligaro et al, 2003; Parvizi et al, 2008). However, they may be associated with significant morbidity and even mortality; this is most commonly encountered during hip and knee joint procedures (Calligaro et al, 2003; Wilson et al, 2003). Risk factors for vascular injury include revision surgery, pre-existing peripheral vascular disease, metastatic cancer, renal failure and coagulopathy (Calligaro et al, 2003; Wilson et al, 2003).

Early presenting complications

Vascular injuries that present early include arterial occlusion (presenting with signs of acute limb ischaemia, including pain, pallor, pulselessness, paraesthesia and paralysis) and arterial laceration injuries (which may present with intraoperative haemorrhage or haematoma formation postoperatively) (Calligaro et al, 2003; Parvizi et al, 2008).

Diagnosis is based on clinical features and may be confirmed with imaging studies such as Doppler ultrasound, magnetic resonance imaging and computed tomography angiography, with the latter often definitive (Parvizi et al, 2008). Management has traditionally been with

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Table 1. Frequency of postoperative vascular complications following total knee and hip arthroplasty

Nature of injury	Frequency	References*
Arterial occlusion or laceration	0.03–0.5%	Calligaro et al (2003), Wilson et al (2003), Parvizi et al (2008), Troutman et al (2013)
Pseudoaneurysm formation	0.02–0.09%	Calligaro et al (2003), Parvizi et al (2008), Ammori et al (2016)
Haemarthrosis	0.3–1.6%	Oishi et al (1995), Worland et al (1996), Ohdera et al (2004), Yoo et al (2018)
Arteriovenous fistula formation	Case reports only	

**studies were only included if a specific vascular complication was reported*

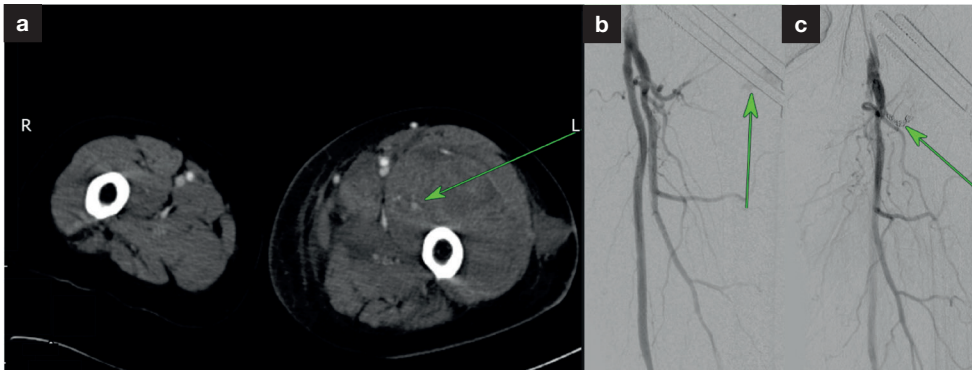

Figure 1. A 90-year-old woman presented with left leg swelling following dynamic hip screw fixation. a. Computed tomography demonstrating a haematoma. b. Angiogram demonstrating active bleeding from the profunda femoris artery. c. Angiogram post embolisation with clinical resolution of swelling.

open surgical repair, open thrombectomy or bypass grafting, and this has produced good outcomes in terms of limb salvage and mortality (Wilson et al, 2003; Parvizi et al, 2008). Nevertheless, the morbidity associated with open surgery is significant (Troutman et al, 2013).

In many cases, endovascular approaches offer a faster approach with a lower risk of morbidity than open surgery (Troutman et al, 2013). Although most cases of active bleeding following laceration injury are managed intraoperatively, some identified postoperatively may be managed using embolisation or covered stents (Figure 1). Arterial occlusion may be managed with pharmacomechanical thrombectomy, catheter-directed pharmacological thrombolysis, or angioplasty with or without stenting.

Complications of endovascular approaches include puncture site-related complications, re-stenosis, and non-targeted embolisation (that may result in skin necrosis or ischaemia of distal structures) (Bilbao et al, 2006). Furthermore, use of such techniques may be limited by the availability of an interventional radiology suite.

Early single centre studies argued that endovascular approaches alone were rarely sufficient, reporting higher rates of re-intervention and reduced limb salvage compared to open surgery (Calligaro et al, 2003). However, more recent studies highlight a move towards endovascular treatment. In a single centre retrospective review, Troutman et al (2013) found equivalent mortality, limb salvage and re-intervention rates in groups treated with endovascular and open approaches, with considerably less morbidity in the former. This group subsequently adopted an 'endovascular first' approach to management of postoperative vascular injury, suggesting that early failures may have reflected limitations in endovascular experience and equipment. An exception to this rule is haemorrhage in a haemodynamically unstable patient, in which case an open repair is favoured.

Late presenting complications

A number of postoperative complications present insidiously with persistent pain and swelling weeks to months after the initial procedure; such presentations may reflect the formation of pseudoaneurysms, traumatic arteriovenous fistulas or a hypertrophic vascular

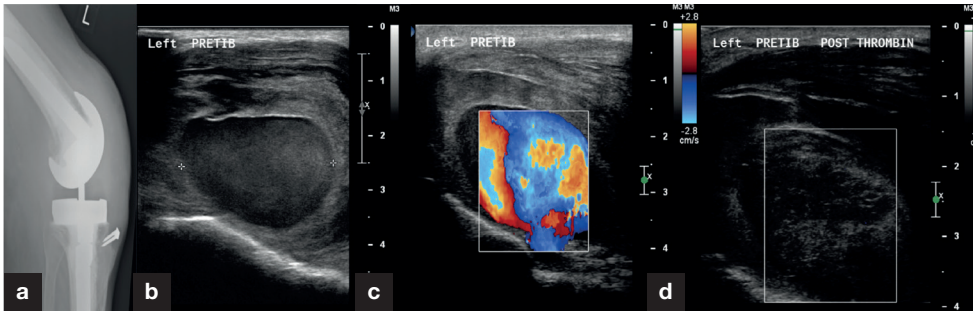

Figure 2. A 77-year-old man presented with pain and swelling over the infero-medial aspect of the knee. A pseudoaneurysm was identified and treated with thrombin injection. a. Radiograph following the operation. b. Ultrasound demonstrated the clinically palpable mass within the left medial pretibial position to correspond to a pseudoaneurysm. c. Doppler ultrasound demonstrates high flow within this pseudoaneurysm. d. Doppler ultrasound demonstrating marked reduction in flow following injection with 3ml human thrombin using a 23-gauge needle.

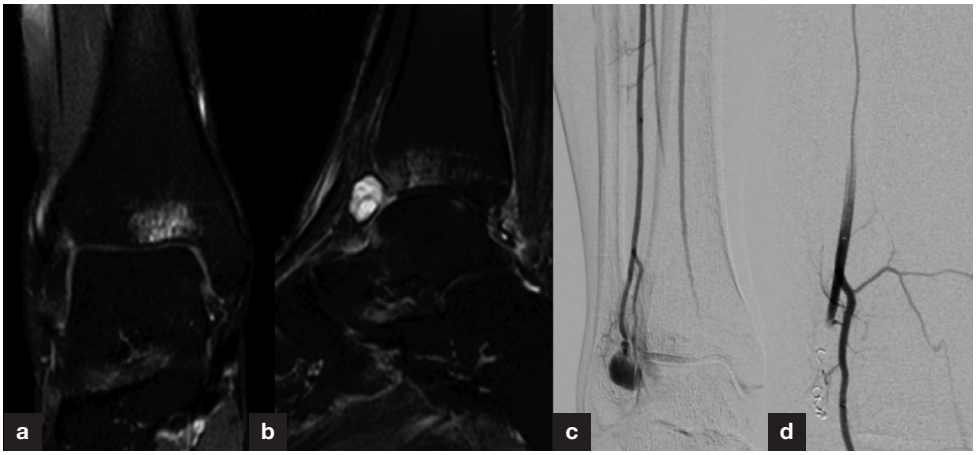

Figure 3. A 32-year-old woman presented with pain following arthroscopic debridement of a traumatic osteochondral defect. Pseudoaneurysm was identified and treated with embolisation with good clinical outcome. a. Coronal T2 image before arthroscopic debridement of traumatic osetochondral defect. b. Sagittal STIR (short TI inversion recovery) image demonstrating a cystic lesion with pulsation artefact, consistent with a pseudoaneurysm (confirmed on ultrasound). c. Angiography before embolisation. d. Angiography following superselective microcoil embolisation.

synovium (Kindsfater and Scott, 1995; Ohdera et al, 2004; Ammori et al, 2016). As for arterial laceration and thrombo-occlusive disease, the diagnosis of these complications is based largely on clinical features and may be confirmed with Doppler ultrasound, magnetic resonance imaging and computed tomography angiography.

Pseudoaneurysm

Pseudoaneurysms may form following total knee arthroplasty and may be palpable as a pulsatile mass in the popliteal fossa with the involvement of the profunda femoris and its branches reported following hip arthroplasty. Endovascular techniques that may be used include coil embolisation, thrombin injection or stent graft exclusion (Figures 2 and 3) (Troutman et al, 2013; Ammori et al, 2016).

Haemarthrosis

Recurrent haemarthrosis is an uncommon complication of total knee arthroplasty (Table 1). In the absence of a bleeding disorder, this has commonly been attributed to impingement of proliferative synovium between articulating components (Kindsfater and Scott, 1995; Oishi et al, 1995; Worland and Jessup, 1996). However, several reports support other pathologies such as aneurysm, pseudoaneurysm and arteriovenous fistula formation in perigenicular vessels (Saksena et al, 2010). This in turn may account for the highly variable interval

between total knee replacement and first haemarthrosis, anywhere between 2 weeks and 12 months (Kindsfater and Scott, 1995; Ohdera et al, 2004; Yoo et al, 2018).

Angiography is useful for identifying the underlying cause of haemarthrosis; direct visualisation of pseudoaneurysms and arteriovenous fistulae is often possible whereas a hypervascular synovium may be indicated by the presence of a vascular blush. Conservative management options include rest, ice, cast immobilisation and joint aspiration, and this may be effective in up to a third of patients (Kindsfater and Scott, 1995; Ohdera et al, 2004). Open or arthroscopic synovectomy has been favoured in cases that do not respond to conservative measures with high success rates reported; Kindsfater and Scott (1995) reported resolution in 14 out of 15 patients following open synovectomy.

Embolisation is a minimally invasive alternative to open synovectomy without its associated morbidity. It has largely been used in cases where underlying arteriovenous fistulae or pseudoaneurysms have been identified, but it may be an alternative to open synovectomy in cases where bleeding originates from a hypertrophic vascular synovium (van Baardewijk et al, 2018). Geniculate artery embolisation has been reported clinically successful in up to 86% of patients and although up to 50% of patients may require re-intervention, there is a low incidence of morbidity associated with this (van Baardewijk et al, 2018). In their case series of 14 patients van Baardewijk et al (2018) reported small haematomas in two patients without any ischaemic complications.

Pulmonary embolism

Pulmonary embolism is a common perioperative complication in orthopaedics. The conundrum of managing patients who are in a hypercoaguable state with blood-thinning medications in the perioperative period is significant (as anticoagulation is relatively contraindicated in surgery and trauma). Placing temporary inferior vena cava filters as an alternative to anticoagulation is common in this population with the rationale that it simultaneously mitigates the risk of pulmonary embolism in patients with lower limb deep vein thrombosis, and reduces the risk of intraoperative or perioperative bleeding by removing the requirement for anticoagulation (Kaufman et al, 2006).

Inferior vena cava filters can be placed under fluoroscopic guidance with access through the common femoral vein or internal jugular vein and they may be permanent or retrievable with removal via internal jugular access (**Figure 4**).

Early complications of inferior vena cava filter insertion include bleeding, haematoma formation at the venous puncture site and malposition of the filter. Late complications include increased incidence of deep vein thrombosis and filter migration (to another part of the inferior vena cava or heart) which may require surgery. Although minor penetration of the inferior vena cava wall is typically clinically insignificant, further intervention may be required if surrounding structures are involved (Van Ha, 2006).

Although the use of inferior vena cava filters is widespread, the evidence base supporting this use (for temporary filters in particular) is lacking; this may be in part a result of the rapid evolution of the devices (Bikdeli et al, 2017). Current guidelines for use are based largely on a number of small case series, with only two large randomised control trials evaluating permanent inferior vena cava filters having been undertaken (Fullen et al, 1973; PREPIC Study Group, 2005). Although there is no level 1 evidence for the use of temporary inferior vena cava filters in any context, early prospective trials have suggested that use is associated with reduced incidence of pulmonary embolism and increased incidence of deep vein thrombosis with little effect on mortality (Muriel et al, 2014; Bikdeli et al, 2017). However, these studies cover a wide variety of specific indications and patient populations and therefore results are not easily generalisable.

Indications for inferior vena cava filters may be classified as absolute, relative or prophylactic. Patients fulfilling absolute criteria have confirmed venous thromboembolism, risk of significant pulmonary embolism and contraindication to, complication or failure of pharmacological therapy. This includes patients with venous thromboembolism who need to stop anticoagulation before surgery. Most published guidelines support use in this context (Baglin et al, 2006; Kaufman et al, 2006). Relative or extended indications for inferior vena cava filters have been introduced with the development of newer generations of inferior vena cava filters that are easier to place and remove. Relative indications

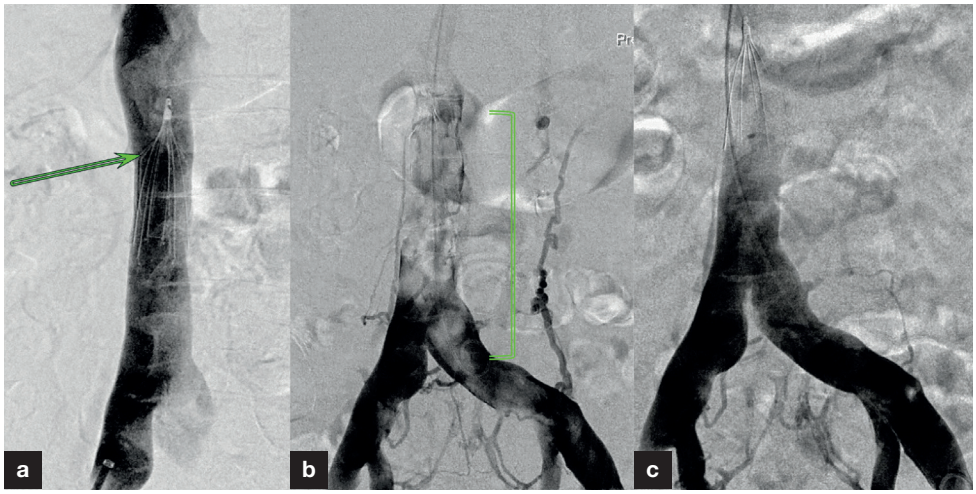

Figure 4. A 78-year-old woman presented with shortness of breath 4 days following a left total knee replacement. Computed tomography pulmonary angiography confirmed the presence of a pulmonary embolism. She subsequently developed skin necrosis at her surgical wound which required debridement and flap reconstruction. An inferior vena cava filter was inserted to prevent pulmonary embolism in the perioperative period in which pharmacotherapy was contraindicated. When she returned 4 weeks after the surgery for filter removal, extensive occlusive thrombus was identified in the left common iliac vein and distal inferior vena cava. The thrombus was cleared using an AngioJet mechanical thrombectomy device, and the filter was retrieved successfully. a. Inferior vena cava filter inserted before surgery. b. At 4 weeks post insertion, extensive occlusive thrombus identified in the left common iliac vein extending into the inferior vena cava filter. c. Venography after thrombectomy demonstrates complete clearance of thrombus in the left common iliac vein and inferior vena cava.

include free-floating iliofemoral or inferior vena cava thrombus and massive pulmonary embolism treated with thrombolysis or thrombectomy. The evidence in support of this is weaker and there is no real consensus on this, with some groups recommending use (Kaufman et al, 2006), and others not (Baglin et al, 2006). Use in the prophylactic setting for patients without documented venous thromboembolism is also contentious, with some groups against use (Baglin et al, 2006) and others for use in very high-risk trauma patients (Kaufman et al, 2006).

The use of inferior vena cava filters may be an important therapeutic alternative in selected patients with venous thromboembolism but more high quality evidence is required to support their expanding use.

Non-vascular pathology

Malignancy

Embolisation has assumed a prominent role in the management of both malignant and benign bone tumours. The aims of embolisation are to devascularise the tumour with the intent of reducing intraoperative bleeding, acting as a sole curative therapy or as a palliative procedure to alleviate symptoms.

Preoperative embolisation

Surgical resection is the main treatment modality for many musculoskeletal tumours, but heavy intraoperative blood loss is a major problem in highly vascularised tumours such as renal cell carcinoma metastases. Embolisation is widely considered to be a safe and effective means to reduce intraoperative blood loss and facilitate more complete resection (Figure 5) (Pazionis et al, 2014).

Renal and thyroid metastases are hypervascular in many cases and as such they form a large proportion of tumours for which preoperative embolisation is indicated (Pazionis et al, 2014). Embolisation may be contraindicated in the setting of renal failure, disorders of coagulation and complications include non-target embolisation and post-embolisation syndrome (Bilbao et al, 2006).

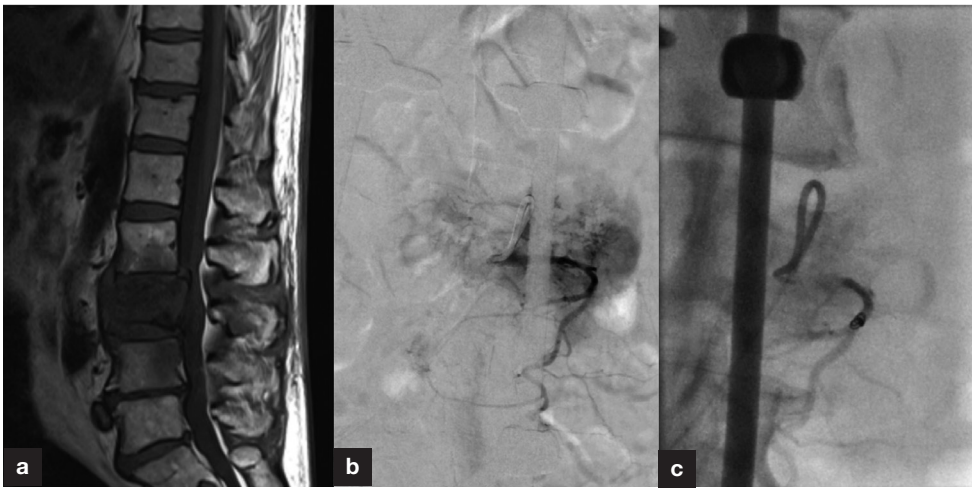

Figure 5. A 72-year-old man presented with pain on a background of renal cell carcinoma and L3 metastasis. Embolisation was performed before an L3 vertebrectomy and cage fusion. Both procedures were successful and the patient was walking pain free at 6 weeks. a. Sagittal T1-weighted magnetic resonance imaging demonstrating tumour within L3 vertebral body with spinal cord impingement. b. Pre-procedural angiogram demonstrating supply to the metastasis from the L2 and L3 lumbar arteries. c. Angiogram following selective catheterisation and embolisation with particles was performed, with prior coil embolisation of the distal left L3 lumbar artery to minimise non-target embolisation. This demonstrates devascularisation of the tumour.

Pre-procedural catheter angiography is invaluable in identifying the arterial supply to the tumour which may then be cannulated and embolised. The choice of embolic agents used is largely operator dependent with sparse availability of comparative results in the literature.

Much of the evidence in support of preoperative embolisation derives from retrospective case-control studies. Pazionis et al (2014) attempted to address limitations in previous studies by matching patients who had embolisation with those who did not with respect to age, tumour size and surgery type. They found reduced intraoperative blood loss (0.90 litres vs 1.77 litres), shorter operation time (3.13 hours vs 3.91 hours) with preoperative embolization, and that the interval time (up to 2 days) between embolisation and surgery did not influence intraoperative blood loss.

Curative and palliative embolisation

In populations with limited surgical or oncological options, embolisation can serve as an important curative or palliative intervention.

Although much of the literature focuses on the efficacy of embolisation of tumours in the preoperative setting, there is a growing consensus that embolisation alone may be an effective option in select groups. Giant cell tumours are benign neoplasms that most frequently arise at epiphyses, with surgical resection the standard of care (Balke et al, 2012). The sacrum is a common site for giant cell tumours, but surgical resection may be problematic as a result of limited accessibility and proximity of sacral nerve roots (Balke et al, 2012). Lin et al (2002) first described serial arterial embolisation for sacral giant cell tumours with 9 of 18 patients showing a durable radiographic response at long-term follow up. Further small case series have built on these findings to demonstrate robust long-term results and support the role of embolisation alone in cases where surgical resection presents an unacceptably high risk of morbidity (Balke et al, 2012).

In the palliative setting, embolisation has analgesic effects for patients with malignancies ranging from primary malignancy to metastatic renal cell and thyroid carcinoma, and hepatocellular carcinoma (Facchini et al, 2016). Facchini et al (2016) reported a marked, albeit temporary, reduction in pain scores of 50% in 97% of patients with mean duration of 9 months.

Inflammatory and degenerative conditions

Inflammatory and degenerative musculoskeletal conditions are one of the newest fields of application for embolisation therapy. Early studies suggest embolisation therapy may be

effective not only in the treatment of osteoarthritis but a range of other conditions including tendinopathies and frozen shoulder.

Symptoms of knee osteoarthritis are among the most disabling with current management options including analgesic medications for minor pain and joint replacement for severe, end-stage osteoarthritis. In cases refractory to conservative management yet not thought to qualify for joint replacement, pilot studies have suggested a role for vascular interventional radiology.

In one case series, Okuno et al (2015) demonstrated that transcatheter arterial embolisation of abnormal neovessels can be used to relieve pain and improve functional scores. They used the embolic agents imipenem/cilastatin sodium and 75 µm Embosphere particles to ablate neovessels arising from a number of genicular arteries in soft tissue areas surrounding the knee associated with pain. They did not report significant adverse outcomes and reported significant and durable pain reduction with increased function. In their single centre, single arm study they evaluated outcomes at 1, 4 and 6 months and thereafter every 6 months for 4 years. They found significant clinical reduction in pain as evaluated using WOMAC (Western Ontario and McMaster Universities Osteoarthritis Index) scores as well as radiographic improvement as evaluated using the WORMS (Whole Organ Magnetic Resonance Imaging Score). The efficacy of this technique is in keeping with the hypothesis that neovessels and their accompanying nerves are a key source of pain in osteoarthritis (Okuno et al, 2015).

This technique has also been piloted at the shoulder for adhesive capsulitis and at the elbow in cases of lateral epicondylitis, as well as for iliotibial band syndrome, Achilles tendinopathy and plantar fasciitis (Okuno et al, 2014; Iwamoto et al, 2017). Despite promising early results, it is important to note that they are all relatively small, single-armed studies and more rigorous trials are needed to substantiate these findings.

Infection

Osteomyelitis is a major challenge in orthopaedic surgery. Although the rate of primary infection following elective orthopaedic surgery is low, failure rates of management with revision surgery are often high. Although the optimal management of prosthetic joint infection is debated, surgical intervention is almost always necessary alongside prolonged courses of oral or intravenous antibiotics. In some cases, patients may be unsuitable for revision surgery as a result of multiple comorbidities, and long-term antibiotic therapy (up to 6 months) may be used with palliative intent (Osmon et al, 2013).

In cases requiring prolonged courses of antibiotics, interventional radiology may offer a number of options to enable prolonged outpatient intravenous therapy. These options include peripherally inserted central catheters, tunnelled central lines (Hickman lines) and implantable ports.

Peripherally inserted central catheters are passed into a peripheral vein to terminate in the superior vena cava or right atrium and can be used for venous access for a number of months as long as the line remains viable. Hickman lines are tunnelled centrally inserted catheters that may also be used for a number of months to provide central access. Implantable ports differ from the external lines in that they obviate the need for an external catheter, with some suggestion that this increases patient acceptability and reduces the rate of complications (Polderman and Girbes, 2002).

Insertion of such lines and ports may be complicated by damage to surrounding structures with resultant nerve damage, pneumothorax, arterial puncture, arrhythmias and stroke. Furthermore, their use may be complicated by infection, thrombosis and thrombophlebitis (Polderman and Girbes, 2002).

Soft tissue injury

Degloving soft tissue injuries occur when skin and soft tissue detach from the underlying deep fascia and muscle. These are associated with shearing or crushing forces (**Figure 6**). 'Morel-Lavallée lesion' is a term used to describe a closed degloving injury typically involving the greater trochanter region, the flank and the knee. These lesions may evolve to become chronic serous subcutaneous collections that are refractory to conservative management or aspiration. Sclerotherapy may be performed in conjunction with aspiration to fully resolve the lesions and prevent open debridement (**Figure 7**) (Dawre et al, 2012).

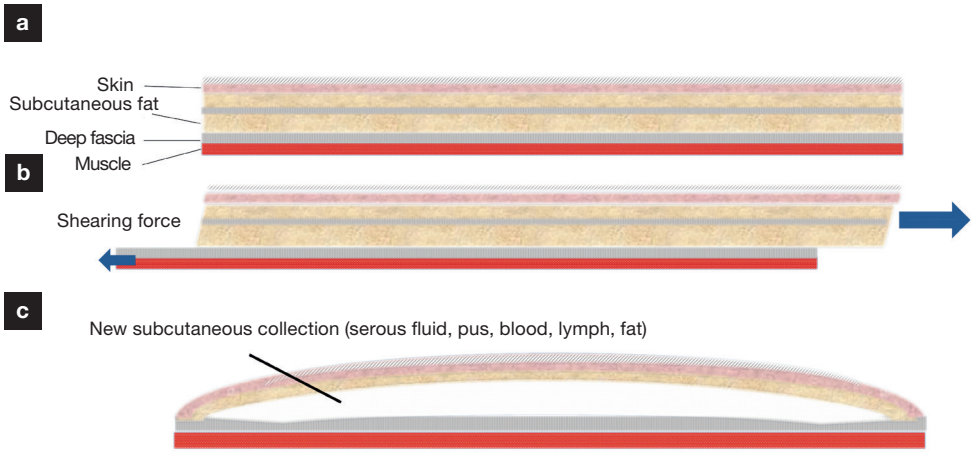

Figure 6. Formation of a Morel-Lavalée lesion. a. Anatomy. b. A shearing force separates the subcutaneous tissue from the deep fascial layer. c. A collection of fluid forms in the intervening space that may be blood, pus, serous, fat or lymph.

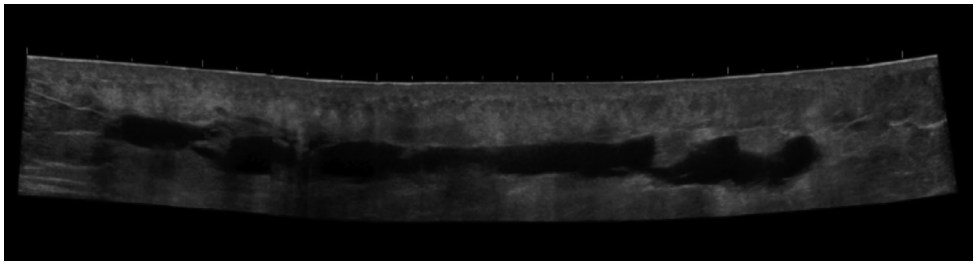

Figure 7. A 58-year-old man presented with swelling over his left hip following a fall while cycling. The lesion was aspirated repeatedly but recurred. The chronic serous lesion shown was successfully treated with two sessions of alcohol sclerotherapy.

Conclusions

The field of interventional radiology continues to evolve and expand. While its application in emergency settings is relatively prominent, there remain numerous viable yet unrecognised treatment options. This review highlights some of the most recent developments in the application of elective interventional radiology to treat orthopaedic patients.

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Conflicts of interest

The authors declare no conflicts of interest.

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Key points

- Interventional radiology is able to provide many treatment options for elective orthopaedic patients.
- Minimally invasive management strategies may facilitate orthopaedic procedures as well as manage their complications.
- Interventional radiology procedures are especially important in the management of patients who may not be fit for surgery.

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