OLYMPIC SPECIAL FEATURE

Radiological interventions for soft tissue injuries in sport

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ABSTRACT. Injection therapy has played an integral role in the rehabilitation of sports injuries for many years. The athlete's primary goal is a rapid return to sporting activity. This may be achieved by a combination of either a temporary or permanent reduction in pain, and by a pharmacological or physiological effect that promotes or accelerates a healing response. A wide variety of pharmacological agents are used. However, there is often a lack of good evidence that quantifiable effects can be achieved. There are restrictions on the use of some pharmaceutical agents. This article reviews the various pharmacological agents and bioactive substrates that are available, and discusses the current evidence base of their use in common sports injuries.

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Injection therapy has played an integral role in the rehabilitation of sports injuries for many years. The athlete's primary goal is a rapid return to sporting activity. This may be achieved by a combination of either a temporary or permanent reduction in pain, and by a pharmacological or physiological effect that promotes or accelerates a healing response. A wide variety of pharmacological agents are used. However, there is often a lack of good evidence that quantifiable effects can be achieved.

There are restrictions on the use of some pharmaceutical agents. The World Anti-Doping Agency (WADA) provides specific information on the use of all "therapeutic" drugs [1]. Substance prohibition may apply at all times, "in competition" or by sport. This also applies to method of administration. For example, corticosteroids are banned for intramuscular use but approved for intra-articular and peritendinous use. Radiologists and sports physicians should be aware of the requirement for temporary use exemption (TUE) forms, when restrictions apply.

This article reviews the various pharmacological agents and bioactive substrates that are available, and discusses the current evidence base of their use in common sports injuries.

Image guidance

The widespread use of diagnostic ultrasound in musculoskeletal (MSK) disease has led to an increased use of ultrasound guidance for many soft tissue injection procedures. Ultrasound is often used as an alternative to fluoroscopy for joint injections.

This practice has developed from a desire to ensure accurate placement of the injectate, and the need to avoid introducing potentially harmful substances into other structures that are susceptible to injury. There is good

evidence that ultrasound enables a more accurate delivery of the pharmacological agent at the correct anatomical site. Blind subacromial injections are intrabursal in only 7–29% of cases [2–5]. However, the impact on therapeutic effect is controversial. A randomised double-blind trial demonstrated evidence that intramuscular steroid is as effective as intrabursal steroid in patients with subacromial impingement [6]. However, both groups in this study received intrabursal lignocaine, which itself may have a therapeutic effect.

Ultrasound guidance is best performed by direct needle visualisation. The needle should ideally be parallel to the probe face. This can be achieved for most injections by careful consideration of technique. The operator should be aware of image artefacts such as oblique cross-cut and beam averaging that may limit accurate visualisation of either the needle or the target point [7]. It is important that the tip of the needle should be clearly visible at all times during needle placement and during the early phase of injection.

Timing of intervention

The timing of therapeutic intervention following an injury is dependent on a number of factors. These include the nature of the injury, the impact on performance and whether the athlete is 'in competition'. Chronic tendonopathy is usually treated initially by a regime of eccentric loading physiotherapy. Conversely, it may be preferable to treat tenosynovitis or paratendonitis by injection early after the onset of symptoms. Athletes in competition may only require pain relief to enable them to compete, but out of competition may require a definitive therapeutic procedure.

It is important to consider all aspects of the rehabilitation programme. Physiotherapy may be re-introduced immediately or delayed for a period following therapeutic injection. It is imperative that there is dialogue between the radiologist and the physician/

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Figure 1. Coronal T_2 fat-suppressed MR images of the adductor origins of a professional rugby player with left-sided groin pain. (a) There is a secondary cleft in the adductor longus origin due to chronic tendinopathy. This was treated with an injection of cortico-steroid in pubis symphysis. (b) The player had a second injury within 5 weeks of the injection and re-presented with a complete tendon avulsion.

therapist, and that diagnostic imaging is reviewed prior to treatment.

Pharmacological agents and bio-active substrates

There is a wide variety of injectates available for a range of MSK conditions. Treatment decisions are often based on personal experience or preference rather than on reliable scientific evidence. In some procedures such as dry needling or tendon stripping (brisement) the only pharmacological agent that may be required is local anaesthetic.

Local anaesthetic

Local anaesthetic agents are often used as both therapeutic and diagnostic agents for a variety of bursal, peritendinous and impingement disorders. Long-acting agents such as bupivacaine (Marcaine; CareStream Dental, Stevenage, UK) or levobupivacaine (Chirocaine; Abbott Laboratories, Chicago, IL) may be used alone or in combination with cortico-steroids. Anaesthetic effects last from 180 to 360 min [8]. The risk of chondrolysis for intra-articular injections is not a concern for soft tissue procedures [9].

Cortico-steroid

Synthetic cortico-steroids are used widely in soft tissue disease for their anti-inflammatory effects. Common preparations are prednisolone-based and include methyl prednisolone (Depo-medrone; Pfizer, New York, NY), triamcinolone acetonide (Kenalog, Squibb, UK) and hydrocortisone. Steroids are often combined with a local anaesthetic agent for both intra-articular and soft tissue injections. Reports of aggregation of corticosteroid crystals in this situation have not been substantiated [10]. Steroid injections can be considered to act as a long-acting anaesthetic to control pain in self-limiting disorders [7].

The major side effects of concern are tendon rupture and skin and fat atrophy. Cortico-steroids have anti-fibroblastic effects. Although reports of tendon rupture

following steroid injection are largely anecdotal, it is generally regarded that intratendinous injection of steroids are contraindicated (Figure 1). Although, peritendinous injections are considered safe with a very low risk of tendon rupture (0.1%) [11], the use of steroids should be considered carefully if there is pre-existing severe tendinopathy or partial tear. Informed consent with the patient is recommended. It is generally good practice to inject deep rather than superficial to the target tendon or fascia to avoid the complication of skin and fat atrophy.

Hyaluronic acid

Hyaluronic acid (HA) occurs naturally in synovial fluid. HA injections are used as a form of visco-supplementation for the treatment of osteoarthritis (OA) [12]. However, recent studies have shown better outcomes for platelet-rich plasma (PRP) than HA with early stages of OA [13]. Commonly used preparations include Durolane (Smith & Nephew, London, UK), Orthovisc (De Puy, UK) and Ostenil [TRB Chemedica (UK) Ltd, UK].

There has been recent interest in the use of HA for treatment of soft tissue pathology such as tendinopathy, subacromial bursitis and partial rotator cuff tears, particularly in the younger athletic population. The proposed mechanism of action of HA in the soft tissues is poorly understood, but there is *in vitro* evidence that HA reduces the rate of degeneration of tendon matrix components and stimulates proteoglycan synthesis [14].

Platelet-rich plasma

Autologous blood and PRP have been used to promote healing of tendons, muscles and ligaments by the introduction of blood products [15]. The theoretical advantage of PRP over autologous blood is that the concentration of platelets is 4–5 times higher. The active substrates include:

- platelet-derived growth factor
 - chemotaxis, cellular proliferation

- transforming growth factor-beta
 - promotes matrix synthesis
- epidermal growth factor
 - cellular proliferation
- vascular endothelial growth factor
- endothelial cell growth factor
 - endothelial cell proliferation, angiogenesis
- fibroblast growth factor
 - angiogenesis, fibroblast proliferation
- insulin growth factor (IGF 1,2)
 - cellular proliferation and maturation, bone matrix synthesis.

PRP constituents have both anti-inflammatory and pro-inflammatory effects that depend on the degree of platelet activation [16]. There are different proprietary systems available, but all require the use of a centrifuge to obtain the PRP from an autologous blood sample. Potential complications include an excessive fibroblastic response within the soft tissues, which may occur if non-steroidal anti-inflammatory agents are taken following injection [17].

Sclerosants

Sclerotherapy with phenol or alcohol is used for treatment of Morton's neuromas and stump neuromata by inducing a chemical neurolysis [18]. Polidocanol is a local anaesthetic agent that has been used to obliterate neovascularisation associated with tendonopathy. Tendon neovascularisation is thought to be associated with abnormal nerve growth and pain, although the significance of new vessel formation remains unclear. Sclerotherapy has been used for chronic Achilles and patellar tendonopathy, targeting injections around the feeding vessels on the deep surface of the tendon [19, 20].

Prolotherapy

Proliferative therapy (or regenerative injection therapy) is a technique that uses locally irritant substances to stimulate growth factor production and fibroblast proliferation. The fibroblasts promote extracellular matrix production, and thus healing of disrupted collagen fibres [21]. The most commonly used agent is hyperosmolar dextrose usually in a concentration of 25% mixed with saline. Alternative injectates include P2G (phenol 2%, glycerol 25% and phenol 25%) and sodium morrhuate [22].

Common applications include periligamentous injection for treatment of lower back pain. Intratendinous dextrose injections have also been described for the treatment of Achilles tendonopathy [23].

Traumeel S

Traumeel is a homeopathic preparation of botanical and mineral ingredients that is used to treat muscle injuries. The pharmacology is not understood but it is

thought to suppress inflammatory mediators and stimulate the release of anti-inflammatory cytokines [24]. It is used both topically and by local injection. Despite the lack of good scientific evidence, it remains in popular use for acute and recurrent muscle strains, and other inflammatory MSK disorders [25].

Actovegin

Actovegin is deproteinised calf blood serum that is reputed to enhance aerobic oxidation. Used intravenously it is regarded as performance enhancing and is prohibited by WADA. However, its use is permitted for local injection in muscle injury. The physiological mix of amino acids is thought to accelerate muscle fibre synthesis [26].

Aprotinin

Matrix metalloproteinases (MMPs) are enzymes that break down collagen. They are found in excess amounts in chronic tendonopathies [27]. MMP inhibitors such as aprotinin may control the cycle of degradation and repair. There are conflicting reports of the efficacy of peritendinous injection of aprotinin in treatment of patellar and Achilles tendonopathy [28]. A randomised controlled trial (RCT) of Achilles tendonopathy did not show any significant improvement in outcome for patients treated with aprotinin *vs* placebo [29].

Therapeutic applications

Tendonopathy

Tendonosis is a disorganised healing response that occurs when the breakdown of collagen fibres exceeds the rate of repair. Histologically there is non-inflammatory collagen degeneration, with fibre disorientation and thinning. There is hypercellularity, scattered vascular and neural ingrowth, with increased intratendinous glycosaminoglycans [30]. The angiogenesis often fails to penetrate the most severely affected areas [31]. Tendonosis may occur in isolation or in association with paratendonopathy, where an inflammatory process can affect the synovial tendon sheath or adventitial paratendon.

Tendon repair is a slow process, which may delay return to competition. The resolution of symptoms precedes regression of angiogenesis and reduction of tendon thickness [32]. Early return to full activity can lead to a repetitive cycle of progressive tendonosis. Therapeutic regimes aim to modify contributing extrinsic aetiological factors. Eccentric-loading physical therapy is widely employed, although there is little high-quality research to support the clinical effectiveness of physiotherapy over other treatment regimes for tendonopathy [33]. A wide variety of interventions have been proposed that aim to reduce the time period of rehabilitation.

Tenosynovitis

Tenosynovitis is common around the wrist joint in racquet sports and golf, and in the peroneal tendons and flexor hallucis longus tendon of track and field athletes and ballet dancers. Intrasheath injection of low-dose cortico-steroid may be beneficial. However, treatment may be unsuccessful if there is a failure to diagnose other soft tissue injury on diagnostic imaging. For example, extensor carpi ulnaris (ECU) tenosynovitis in the wrist may be associated with an ECU subsheath tear or triangular fibrocartilage disruption.

Paratendonitis

Inflammatory paratendonitis leads to effusions, adhesions, thickening and scarring. Achilles paratendonitis is common in a wide range of sporting activities. It may be exquisitely painful. Injection of the paratendon with low-dose cortico-steroids is usually performed in the acute stage. In the more chronic situation, and especially when there is concurrent tendonosis, a tendon sheath stripping procedure may be performed (also termed tendon brisement and hydrostatic decompression; Figure 2). This is performed with a combination of local anaesthetic and saline, which may include a cortico-steroid [34]. High volume injections of up to 50 ml have been advocated in an attempt to break down adhesions [35]. Repeat injections may be required [18]. This technique has been used in the Achilles and patellar tendons with reduction in pain, although there are no RCT studies.

Tendonosis

Many injection therapies have been advocated for resistant tendonosis. These include high-volume tendon stripping, dry needling, autologous blood injection, PRP, HA, sclerosant therapy and prolotherapy.

Dry needling, which involves repeated lancing of a tendon, is based on the same principle as autologous blood and PRP injections (Figure 3). Haemorrhage releases growth factors that initiate a healing response [36]. Dry needling is performed prior to autologous blood or PRP injection, and requires an initial peritendinous injection of local anaesthetic. Autologous blood injections for epicondylitis and patellar tendonosis have shown good symptomatic responses in studies without control groups [36]. Repeat injections at 2–4 weeks may add therapeutic value. A recent RCT study of 33 patients showed only small short-term symptomatic improvement of Achilles tendonopathy for autologous blood injection and physiotherapy *vs* physiotherapy alone [37]. However, the injections were peritendinous rather than intratendinous.

A recent meta-analysis of PRP studies reviewed 32 papers, of which 13 met the criteria, but only 3 were RCTs. It concluded that PRP use in tendon and ligament injuries has several potential advantages, including faster recovery and, possibly, a reduction in recurrence, with no adverse reactions described [15]. One RCT study showed no difference between PRP and placebo for Achilles tendonopathy, but the injections were performed blind, which is a potential source of error [38].

Dry needling, autologous blood and PRP are now being used for a wide range of tendonopathies including hip adductors and hamstring origins [39].

Figure 2. (a, b) Longitudinal ultrasound images of an athlete with chronic Achilles tendonosis. The tendon is thickened with areas of low reflectivity and there is marked neovascularisation which was treated successfully with (c) a tendon stripping procedure. The needle is positioned on the deep surface of the tendon in the transverse plane and the injectate infiltrated into the paratendon.

A prospective RCT of HA *vs* placebo injection of chronic lateral epicondylitis was performed in a population of 331 racquet sports athletes. A significantly better response was observed in the HA group for reduction in pain, improved grip strength and pain-free return to sport at 30, 90 and 365 days [40]. Polidocanol sclerotherapy has shown good short- and mid-term response in chronic Achilles tendonopathy. Pain reduction and improvement in ultrasound appearance at 2-year follow-up has been recorded, but there are no RTC studies [41].

Prolotherapy for chronic mid-Achilles and insertional tendonopathy with intratendinous injection of lignocaine and dextrose has shown improved pain scores at 12–48 months [23]. However, this study had no control group and involved multiple repeat injections (range

Figure 3. Transverse ultrasound image of a patient receiving dry needling therapy to the Achilles tendon. The needle is repeatedly advanced under ultrasound guidance into the areas of tendonopathy, following infiltration of the paratendon with local anaesthetic.

1–13; median 5). A more recent randomised study compared blind peritendinous injections of hyperosmolar glucose combined with eccentric loading exercises against eccentric loading exercise alone. There was an enhanced response at 1 year for the combination group as opposed to the single-treatment groups [42].

The wide range of interventional techniques makes it difficult to identify any single “best” therapy for treatment of tendonosis. Although the evidence suggests that improvement in rehabilitation times can be achieved, there are very few RCT studies that compare more than one interventional technique against a control group.

Two recent meta-analyses of different injection therapies for tendonopathy both concluded that all treatments had promising effects, with the exception of steroids, which often showed relapse of symptoms in the long term [11, 43]. However, another conclusion might be that the other techniques are not necessarily beneficial, but that steroids are detrimental to tendons. There is no good evidence base to support the use of cortico-steroids in chronic tendon lesions [44].

Plantar fasciitis

Pain at the origin of the medial bundle of the plantar fascia is a common occurrence and may be resistant to conservative therapy. Injection with steroid therapy has long been a popular treatment, but with variable long-term results [45, 46]. A normal heel pad distributes load and protects against heel pain [47]. It is the authors’ preference not to inject steroids superficial to the plantar fascia, to avoid the risk of fat atrophy.

A variety of other injection techniques, including dry needling [48], autologous blood and PRP [49, 50], and prolotherapy [51], are employed with varying results. Botulinum toxin type A have also been used in treatment of plantar fasciitis. Improved pain outcomes for botulinum *vs* saline injection have been shown in a randomised study of patients with bilateral plantar fasciitis [52].

Bursitis and impingement syndromes

The anti-inflammatory effect of steroids on soft tissues reduces the effect of mechanical impingement. It has been established practice for many years to use steroid injection for bursopathy, including subacromial and retrocalcaneal bursitis. Steroids are commonly used for other impingement phenomena.

External impingement of the shoulder associated with subacromial bursitis may be effectively treated by intrabursal injection of steroid and anaesthetic [2]. It is common practice to use volumes of at least 10 ml to fill the bursa in an attempt to break down bursal adhesions. Some practitioners advocate larger-volume injections. Early rehabilitation with physiotherapy is recommended to encourage shoulder movement through the entire range of motion.

Viscosupplementation with HA injected in the subacromial bursa has been used as a treatment for patients with partial thickness rotator cuff tears. A randomised, double-blinded placebo-controlled study compared five consecutive weekly injections of HA with a control group with saline injections. No significant difference in outcome measures was seen during the treatment period, but there was a significant improvement in outcomes for pain and disability at 6 weeks and long-term follow-up (mean 3 years) [53].

Steroids have been used effectively in a small case study of posterior ankle impingement with early return to sports activity [54]. Steroid injection and dry needling may also be useful in posteromedial impingement [55]. Unresponsive cases of ankle impingement may require arthroscopic resection of the focal areas of nodular synovitis. Iliotibial band friction syndrome may be treated successfully by cortico-steroid injection in cases refractory to oral non-steroidal anti-inflammatory medication [56].

Muscle tear

Muscle tears are usually treated conservatively with rest, ice, compression and elevation, followed by rehabilitation. Intervention is most often performed for lower limb injuries.

Large intramuscular haematomas can be aspirated. This reduces symptoms of pain, and may improve healing time. It is most frequently performed for contusional injuries of the vasti muscles of the thigh, but has been used anecdotally at other sites, including the hamstrings [57]. Aspiration is ideally performed at about 10 days post injury, when the haematoma is in a stage of liquefaction and can be monitored by serial ultrasound imaging [7]. A strict sterile technique is essential to avoid infection.

Injection of Actovegin and Traumeel (often combined) into areas of muscle injury is becoming an increasingly common practice. Injections are performed on the day of injury, and on days 2 and 4 post injury. The evidence base is weak, but a recent study on the use of Actovegin for treating muscle injury showed that players were able to return to sport 8 days earlier than a control group treated by physiotherapy alone [58].

PRP is no longer restricted by WADA for intramuscular use [1]. However, there is limited evidence that PRP accelerates muscle healing [59], and a recent review article concluded that PRP has not yet displayed proven evidence for the stimulation of healing after sports muscle injury [60].

Recurrent hamstring strains have been treated by a different approach using L5 nerve root block and epidural injection of cortico-steroid [61]. The basis of this treatment hypothesises that neural compromise may impair co-ordinated muscle firing.

Ligament injury

Prolotherapy has commonly been utilised for treatment of lower back pain with injection around the ilio-lumbar, supraspinous and interspinous ligaments, with conflicting evidence of efficacy [62]. This treatment is intended to strengthen ligaments in patients with lumbar instability pain.

Other potential indications include peri-articular injections to encourage ligament healing. Prolotherapy has been utilised for hypermobile joints. Recent animal studies have shown an increase in cross-sectional area of stretch-injured medial collateral ligaments (MCL) treated by dextrose injection [63]. Prolotherapy has been described for treatment of sprains of the anterior talofibular ligament, with growth and repair documented by MRI and ultrasound [64]. However, there are no published outcome data to support its efficacy.

There is also anecdotal evidence for the use of PRP in acute MCL injuries [18].

Other techniques

Other interventional techniques that do not involve the use of injection of bioactive substrates, but which may require image guidance, include electrocoagulation and cryotherapy. These techniques have been used to treat tendonopathy and neural induced pain syndromes [18, 34]. An RCT study of shockwave therapy showed improved outcomes *vs* eccentric loading physiotherapy for chronic Achilles tendonopathy [65].

Future developments are likely to see an increased use of growth factors, mesenchymal stem cells and other derived tenocyte-like cells for treatment of tendon and muscle injury [17, 66, 67].

Conclusion

There is a huge amount of literature on the subject of intervention for soft tissue sports injury, but a large proportion is level II evidence or below, with few RCT studies. Meta-analyses suffer the problem that it is often difficult to compare studies because of differences in methodology. Furthermore, many studies have been performed with blind injections. Ultrasound guidance should now be regarded as the gold standard for any proposed research study. This makes it hard to assess the true impact of intervention on rehabilitation time.

It is worthwhile remembering the principle of “first do no harm”. Intratendonous injection of cortico-steroid should generally be avoided, although peritendonous steroid injection is considered to be safe. The use of other intratendonous injections should be viewed with caution where there is pre-existing severe tendonopathy, particularly in the lower limb.

Consideration should also be given to the timing of re-introduction of physiotherapy programmes after injection therapy. Early aggressive rehabilitation programmes may negate any healing effects of injection therapy.

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