Shoulder pain is a common problem in competitive swimmers. Up to 80% of swimmers report having had shoulder pain at some point in their career. Although various etiologic factors for shoulder pain in swimming have been proposed, it is likely that the final common pathway causing pain in swimming is subacromial impingement in the setting of repetitive overuse. The particular motions of the swimming stroke with forward flexion, adduction and internal rotation cause a typical impingement position. Alterations in shoulder kinematics due to rotator cuff overuse and muscle fatigue also likely contributes to impingement. Furthermore, swimmers often have some degree of underlying shoulder laxity, suggesting that shoulder instability may also play a role in the production of pain. The repetitive overhead activities in swimming may lead to acquired capsular laxity similar to other overhead activities, such as throwing. Shoulder laxity may lead to pathologic instability and eventually secondary rotator cuff impingement. A broader differential diagnosis should be considered in the masters (older) athlete, including osteoarthritis, rotator cuff pathology, degenerative labral pathology, adhesive capsulitis, as well as referred pain from the cervical spine.

The diagnosis of typical ‘swimmer’s shoulder’ in younger competitive swimmers is largely based on clinical parameters, including history and physical examination. However, the physical examination will often be normal, with full range of motion, normal strength, no focal areas of tenderness and variable presence of positive impingement signs. There may be shoulder laxity on examination, but there is often a similar degree of laxity in the contralateral asymptomatic shoulder. Imaging studies are important for further evaluation.

The imaging modalities that are used for evaluation of shoulder pain in swimmers include plain radiographs, MRI, ultrasound and occasionally CT scan. The particular imaging modalities used will depend on the clinical scenario, patient age, history and physical examination findings. This review will discuss the role of each of these imaging modalities.

**PLAIN RADIOGRAPHS**

A comprehensive evaluation of the shoulder typically begins with plain
radiographs. In young competitive athletes these are often normal. Radiographs are useful to evaluate the status of the physis in the skeletally immature athlete. Rarely, pain may come from a stress reaction at an unfused acromial apophysis (os acromiale) (Figure 1). In the older athlete, arthrosis of the glenohumeral or acromioclavicular joint may be present. Plain radiographs should be obtained if an athlete has persistent pain that does not respond to initial management or if there is night pain or atypical pain, as pathologic bone lesions may also be noted on plain radiographs.

MRI SCAN

The primary modality for imaging the athlete’s shoulder is MRI. MRI permits evaluation of the glenohumeral ligaments, labrum, rotator cuff tendons and articular surfaces. High-resolution MRI with appropriate pulse sequences will show adaptive changes consistent with repetitive overhead activity. The glenohumeral capsule is often thickened, which is thought to be due to remodelling from repetitive plastic deformation caused by underlying

Figure 1: A 17-year-old female swimmer with an unfused acromial apophysis (os acromiale) that remained symptomatic and was treated with bone grafting and internal fixation.

Figure 2: MRI scan demonstrating increased thickness of the glenohumeral capsule in a 16-year-old male swimmer (arrow).
capsular laxity (Figure 2). Labral tears may be present in the setting of instability, although patients with multidirectional instability often have a normal labrum.

Changes in signal and morphology of the rotator cuff tendons and biceps consistent with tendonosis is often seen in high-level athletes (Figure 3). These intrinsic tendon changes are due to repetitive overhead activity and overuse and may contribute to symptoms. Partial thickness rotator cuff tears may be seen in older, experienced swimmers who have been training for many years (Figure 4). Frank rotator cuff tendon tears are uncommon in high school and college-age swimmers, but as athletes now stay in the sport well into their late twenties, rotator cuff tendon pathology is being seen more frequently. MRI is also the most sensitive imaging modality to detect early changes in articular cartilage, which may be pertinent in the older athlete (Figure 5).

ULTRASOUND
Ultrasound has become increasingly popular for evaluation of the shoulder in the overhead athlete. Ultrasound allows evaluation of the rotator cuff tendons and subacromial bursa (Figure 6). The advantage of ultrasound is the ease of use, reduced cost compared to MRI and the ability to image at the point of care (i.e. in the clinic or even the training environment). Importantly, ultrasound allows dynamic evaluation of impingement. The shoulder can be placed into the provocative positions that cause either subacromial or subcoracoid impingement. Doppler ultrasound may also be used to evaluate venous and arterial blood flow around the shoulder, which may be useful in the evaluation of suspected thoracic outlet syndrome.

Disadvantages of ultrasound include the difficulty of evaluating the deeper structures such as the capsule and labrum. Also, ultrasound image quality depends on the experience of the ultrasonographer.

A further use of ultrasound is for performing ultrasound-guided injections. The ability to obtain real-time images at the point of care allows ultrasound to be used for accurate localisation of the needle during injection. This is especially helpful for injection into the bicipital tendon sheath, allowing precise placement of the injection as well as avoidance of direct intra-tendinous injection (Figure 7). Ultrasound-guided injections are useful for precise anatomic localisation when injection is being done as a diagnostic test.

COMPUTERISED TOMOGRAPHY SCAN
Computerised tomography (CT) scan is used less commonly in the evaluation of shoulder pain in swimmers. The primary use of CT scan is for careful evaluation of bone structure. This modality is helpful to evaluate pain that may be due to os acromiale. CT may also be used to evaluate glenoid version in the setting of shoulder instability. A relative disadvantage of CT scan is the radiation exposure.

CERVICAL SPINE IMAGING
Evaluation of shoulder pain often requires examination of the cervical spine. Spinal pathology, such as nerve root impingement, degenerative disc disease and cervical spondylosis may present as shoulder pain. Thus, the practitioner needs to carry out a thorough history and physical examination of the cervical spine. Cervical spine imaging starts with plain radiographs, including AP, lateral and oblique views. Flexion and extension lateral views are used to evaluate for spinal instability. Further imaging is carried out using MRI scan to evaluate the intervertebral discs and nerve roots at each level.
CONCLUSION

Evaluation of shoulder pain in the swimmer starts with a careful history and physical examination. The most sensitive imaging modality is clearly MRI to further evaluate the capsule, labrum and rotator cuff in swimmers with shoulder pain. A number of different conditions beyond the typical ‘rotator cuff tendinitis’ can cause shoulder pain in swimmers and careful imaging is important to evaluate these differential diagnoses. The practitioner should also consider cervical spine pathology as a cause of shoulder pain.

Figure 6: Ultrasound images of the supraspinatus tendon: (a) normal tendon, (b) coronal view of hypoechoic, heterogeneous and thickened supraspinatus tendon (*) with loss of fibrillar appearance, consistent with tendinosis. Enthesopathic osseous irregularity is seen at the footprint (arrows). GT=greater tuberosity.

Figure 7: Ultrasound-guided injection into the biceps tendon sheath. The arrow shows the needle in the tendon sheath, adjacent to the biceps tendon (*).