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Early diagnosis of primary/idiopathic adhesive capsulitis: Can imaging contribute?


Abstract

Adhesive capsulitis is a frequently presenting shoulder disorder in musculoskeletal medicine. It is recognized as consisting of three stages, and is often difficult to diagnose in its early stage and differentiate from other shoulder disorders. Treatment of this disorder has been proposed to be dependant on the stage, with early treatment suggested to decrease the overall morbidity. Arguably therefore, recognition in this early stage is desirable. The purpose of this paper is to review the current evidence that may support the role of imaging facilitating a diagnosis of adhesive capsulitis and to discuss this in relation to the contemporary understanding of the pathology of this disorder. The emerging role of Doppler ultrasound in the diagnosis and management of inflammatory arthropathies is discussed, and in particular its potential to contribute to the early diagnosis of adhesive capsulitis. Whilst the diagnosis of adhesive capsulitis is presently largely based on clinical examination, this review outlines the current and future role that radiology may be able to contribute to the clinical presentation.

Key words:
Introduction

Adhesive capsulitis is a disorder of the shoulder which is frequently encountered in the primary health care setting. This disorder is characterized by gradually worsening pain and stiffness of the glenohumeral joint (Neviaser and Neviaser 1987; Hannafin and Chiaia 2000). Traditionally, it has been reported to affect 2-5% of the normal population though, with advancing understanding of the pathology through arthroscopic examination it has been recently suggested that incidence may actually be as low as 0.75% (Bunker 2009). Adhesive capsulitis is generally described as primary or secondary (Reeves 1975; Chambler and Carr 2003). Primary or idiopathic adhesive capsulitis results from an unknown cause whereas secondary adhesive capsulitis is due to a known cause such as trauma or surgery. It is recognized that adhesive capsulitis progresses through three stages and the natural history is towards resolution (Pearsall and Speer 1998; Siegel, Cohen et al. 1999; Chambler and Carr 2003). The three stages have been described as the painful stage (first) lasting between three and nine months, the adhesive stage (second) lasting between four to 12 months, and the resolution stage (third) lasting from five to 26 months (Pearsall and Speer 1998). Whilst various treatment options have been reported with variable results, it has been proposed that treatment implemented in the first or early stage may decrease the overall morbidity of the disorder (Hazleman 1972; Hannafin and Chiaia 2000). Arguably, therefore, diagnosis and treatment in this early stage are most important.
The diagnosis of adhesive capsulitis is clinical and often one of exclusion (Hannafin and Chiaia 2000; Hand, Athanasou et al. 2007; Manske and Prohaska 2008; Kelley, McClure et al. 2009). It is acknowledged that diagnosis of adhesive capsulitis in its early stage can be difficult as the symptoms may be non-specific and easily confused with other pathologies, such as rotator cuff tendinopathy or subacromial bursitis (Manske and Prohaska 2008; Kelley, McClure et al. 2009). Whilst the diagnosis of established adhesive capsulitis is straightforward and essentially clinical, it is likely that confusion with coexisting impingement syndrome is common as features of both conditions may be present. In an attempt to address the lack of clearly defined diagnostic criteria for the early stage of adhesive capsulitis a Delphi study was conducted resulting in eight clinical identifiers being established for this early stage (Walmsley, Rivett et al. 2009). These identifiers remain to be validated and currently there is no definitive test or investigation for the early diagnosis of this disorder. The use of radiology as an adjunct to diagnosis in musculoskeletal medicine is well established, however its role in the recognition of early stage adhesive capsulitis has yet to be determined. The current and potential future contribution of radiology in the diagnosis of adhesive capsulitis will be discussed in the light of the contemporary understanding of the anatomical and pathological evidence for the disorder.

**Pathology of adhesive capsulitis**

An appreciation of the pathology of adhesive capsulitis provides a rationale behind the selection and timing of appropriate radiological investigation. Whilst there has been controversy as to whether the disorder primarily represents an inflammatory or
fibrotic process, it is now largely recognized that a mechanism involving capsular inflammation followed by fibrosis is responsible for the symptoms (Hand, Athanasou et al. 2007). Historically both inflammation (Wiley 1991; Rodeo, Hannafin et al. 1997; Hand, Athanasou et al. 2007) and fibrosis (Bunker and Anthony 1995) have been microscopically described in adhesive capsulitis. Although histological examination has not identified inflammatory cells in the glenohumeral joint capsule in some studies, (Bunker and Anthony 1995; Bunker, Reilly et al. 2000) others describe a visual appearance of synovitis consistent with inflammation (Neviaser and Neviaser 1987; Hannafin and Chiaia 2000; Watson, Dalziel et al. 2000).

The surgical examination of patients believed to have adhesive capsulitis has identified the rotator interval area of the glenohumeral joint capsule as the anatomical location predominantly involved in this disorder (Ogilvie-Harris and Myerthall 1977; Ozaki, Nakagawa et al. 1989; Wiley 1991). As seen in Figure 1 the rotator interval is a triangular space bounded superiorly by the anterior aspect of the supraspinatus tendon and inferiorly by the superior aspect of the subscapularis tendon. It is bordered medially by the lateral margin of the coracoid process and laterally by the transverse humeral ligament. Its contents include the coracohumeral and superior glenohumeral ligaments, together with the long head of biceps tendon (Fitzpatrick, Powell et al. 2003).
Both arthroscopic (Wiley 1991; Bunker and Anthony 1995; Watson, Dalziel et al. 2000) and open surgical studies (Ozaki, Nakagawa et al. 1989; Omari and Bunker 2001) assessing the role of the rotator interval in adhesive capsulitis have demonstrated inflammation of the extra-articular tissue in this area, synovitis of the anterosuperior glenohumeral joint capsule and thickening of the coracohumeral ligament. Histologically the rotator interval has also been demonstrated to be an area of pathological significance (Bunker and Anthony 1995). Arthroscopic findings of adhesive capsulitis have also described the presence of red, inflamed synovium in the rotator interval, surrounding and in some instances indistinguishable from the intra-articular portion of the biceps tendon and coracohumeral ligament (Lee, Sykes et al. 2005). Macroscopic appraisal of the tissue in this study suggested the presence of chronic inflammation as demonstrated by high vascularity (Lee, Sykes et al. 2005).
The controversy and confusion regarding the exact pathogenesis of adhesive capsulitis has been proposed by Hand et al (Hand, Athanasou et al. 2007) to stem from the fact that many published studies have examined groups of patients who were resistant to conservative treatment, and thus in the later stages of the disorder. It does, however, also appear from the surgical evidence that the pathology in the early stage of the disorder is inflammatory and this is supported by the clinical observation that intra-articular corticosteroid injections provide short term improvement in symptoms (Bulgen, Binder et al. 1984; van der Windt, Koes et al. 1998; Arslan and Celiker 2001; Carette, Moffet et al. 2003; Diercks and Stevens 2004; Ryans, Montgomery et al. 2005; Lorbach, Anagnostakos et al. 2010). In summary, the pathological evidence suggests that adhesive capsulitis in the early stage involves inflammatory changes of the glenohumeral joint capsule associated with increased vascularity in the synovium initiating at the rotator interval area, which then progresses to thickening and fibrosis of the capsular tissue.

**Current radiology in the diagnosis of adhesive capsulitis**

The radiological investigations most commonly performed for patients presenting with shoulder pain in the primary health care setting are X-ray and ultrasound examinations. These imaging investigations may confirm a diagnosis or be useful to eliminate other various possible pathologies (Kelley, McClure et al. 2009). Whilst the various imaging modalities have described numerous findings in adhesive capsulitis, no one investigation to date is regarded as superior to clinical examination for the
diagnosis of this disorder. Although invasive, conventional arthrography has been suggested as the preferred imaging investigation for adhesive capsulitis as it is able to demonstrate reduced glenohumeral joint volume (Binder, Bulgen et al. 1984; Neviaser and Neviaser 1987). Arthrographic evaluation of glenohumeral joint volume has however been suggested to provide misleading information in the presence of full-thickness rotator cuff tears which allow contrast material to flow into the subacromial space (Hsu, Anakwenze et al. 2011).

Whilst becoming increasingly more common and potentially providing superior diagnostic capabilities for shoulder pain, magnetic resonance imaging (MRI) continues to remain a less accessible and expensive imaging modality and is therefore used less frequently, though it is regarded by some as the gold standard for shoulder imaging (McNally and Rees 2007). Magnetic resonance arthrography (MRA) has been reported to demonstrate enhancement of the rotator interval and thickening and enhancement of the axillary recess (Song, Kwon et al. 2011). Nuclear medicine bone scans are less frequently used and their contribution to the diagnosis of adhesive capsulitis is not regarded as significant (Binder, Bulgen et al. 1984). Although the early stage of adhesive capsulitis has not received particular attention in most reported radiological investigations, findings later in the course of the disorder may provide valuable information.

**Ultrasound imaging**

Ultrasound investigation of the shoulder has become increasingly utilized over recent years with the introduction of better imaging equipment, more advanced
understanding of ultrasound anatomy and a more defined examination technique
(Beggs 2006). This imaging modality is attractive as it has the advantages of being safe,
non-invasive and using non ionizing radiation, (Backhaus, Burmester et al. 2001) as
well as being fast, inexpensive and well-tolerated by the patient (Read and Perko 1998;
Delle Sedie, Riente et al. 2008).

The use of grey-scale ultrasound imaging in the assessment of rotator cuff tendons is
widely accepted (Read and Perko 1998). Conversely, only a small number of published
studies report its application in assisting the diagnosis of adhesive capsulitis (Ryu, Lee
et al. 1993; Lee, Sykes et al. 2005; Homsi, Bordalo-Rodrigues et al. 2006). Indeed, it has
been suggested that with the use of ultrasound there is no single finding that may be
regarded as diagnostic or consistently present in all cases of adhesive capsulitis
(Anderson and Read 2008). Using arthrography as the gold standard for diagnosis
against which the sonographic findings were compared, Ryu et al (Ryu, Lee et al. 1993)
described limitation of movement of the supraspinatus tendon as a reliable criteria for
diagnosis of this disorder. Whilst the duration of the symptoms of participants in this
study was not reported, it is unlikely that they were in the early stage of adhesive
capsulitis, and probably were at the stage when limitation of range of movement
facilitated clinical diagnosis. As a means of assisting the diagnosis of adhesive
capsulitis, the coracohumeral ligament was assessed by Homsi et al (Homsi, Bordalo-
Rodrigues et al. 2006) with ultrasound to determine if it was thickened in patients with
arthrographic evidence of the disorder. They concluded that a thickened
coracohumeral ligament may be suggestive of adhesive capsulitis, but it was
recognized that further studies are needed to validate these results. However the patients examined were likely at a later stage of the disorder when a clinical diagnosis may be more apparent and arthrography was utilized as the diagnostic reference which, may have lead to an incorrect interpretation in some cases (Hall 2005). A further recent suggestion that may assist in the diagnostic dilemma in early diagnosis has been a proposal that dynamic ultrasound assessment of posterior shoulder capsular compliance and joint synovial proliferation may correlate well with the various stages of adhesive capsulitis (Cairns 2009). The ability of ultrasound to assess dynamically has been highlighted by this author together with the importance of early diagnosis.

Colour Doppler ultrasound has also been sporadically reported to provide valuable information in the diagnosis of adhesive capsulitis (Lee, Sykes et al. 2005). Enhanced vascularity and hypoechoic change in the rotator interval have been correlated with vascular synovial fronds visualized with arthroscopic investigation (Lee, Sykes et al. 2005). Though an unblinded assessment, ultrasound appraisal of the rotator interval compared with arthroscopic findings suggested that colour Doppler ultrasound was able to provide an early and accurate diagnosis of adhesive capsulitis by assessing for hypoechoic vascular soft tissue (Lee, Sykes et al. 2005). In contrast to the previous studies, this study examined a group of patients who had experienced symptoms for less than 12 months, therefore reflecting the earlier stage of the disorder. Colour Doppler ultrasound has also been proposed by other authors to show capsulosynovial hyperaemia at the rotator interval early in the disorder, as well as tenderness to probing over the glenohumeral joint capsule (Anderson and Read 2008).
Magnetic resonance imaging

Unlike ultrasound, the use of MRI and MRA has received wide attention in the literature in the diagnosis of adhesive capsulitis. A summary of studies using MRI is given in Table 1 and a summary of MRA studies is provided in Table 2. Comparison of these studies demonstrates that inclusion criteria for subjects vary and may not always include subjects in the early stage of adhesive capsulitis, but rather more likely in the later stages when the clinical presentation may be more apparent. Further, individual studies describe differing endpoints and as a result it has been suggested that drawing conclusions on the role of these radiological investigations in the diagnosis of this disorder may be difficult (Petchprapa, Beltran et al. 2010). Despite these limitations however, the reported studies using MRI and MRA provide consistent findings and therefore valuable diagnostic indicators.

### Table 1  Summary of MRI studies on adhesive capsulitis

<table>
<thead>
<tr>
<th>Study</th>
<th>Number of shoulders</th>
<th>Inclusion criteria</th>
<th>Duration of symptoms (mean)</th>
<th>Investigation</th>
<th>Summary of findings</th>
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<tbody>
<tr>
<td>Emig</td>
<td>10 AC 15 asymptomatic</td>
<td>9 subjects diagnosed by arthrography, 1 confirmed at surgery.</td>
<td>Not stated</td>
<td>MRI measuring thickness of capsule, synovium and CHL, volume of articular fluid</td>
<td>Capsule and synovium thickness &gt; 4mm was specific (95%) and sensitive (70%) for AC. No significant difference in volume of fluid or thickness of CHL. RI not useful for assessing AC.</td>
</tr>
<tr>
<td>Tamai</td>
<td>18 AC 8 IS 3 healthy volunteers</td>
<td>&gt; 1 month history of shoulder pain and stiffness, &lt; 135º forward elevation, recognizable limitation of IR and ER. Monitored until pain free and near normal ROM.</td>
<td>1-18 months (7 months)</td>
<td>Dynamic gadolinium enhanced MRI assessment of the synovium in AC subjects.</td>
<td>Obvious enhancement of the GHJ synovium in AC subjects clearly distinguishable from that of normal shoulders.</td>
</tr>
<tr>
<td>Study</td>
<td>Number of shoulders</td>
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<tr>
<td>Carrillon 1999</td>
<td>25 AC, 15 with RCT's</td>
<td>Gradually increasing shoulder pain at least 1 month duration, anterior elevation &lt; 135°, ER &lt; 20°, normal X rays.</td>
<td>2-10 months (6 months)</td>
<td>MRI involving two spin-echo T2 weighted sequences with fat saturation and two spin-echo T1 weighted postgadolinium sequences.</td>
<td>Post gadolinium enhancement of the GHJ capsule and synovium was seen in the RI in all 25 AC subjects (in only 1 of the RCT subjects) and in the AR in 22 out of 25.</td>
</tr>
<tr>
<td>Connell 2002</td>
<td>24 AC, 22 RC pathology</td>
<td>Insidious onset of shoulder pain and dysfunction. Pain and stiffness &gt;15 weeks, increasing in nature, most severe at rest, restriction of PROM &gt; 30° in 2 or more planes.</td>
<td>15 weeks – 26 months (10.2 months)</td>
<td>MRI prior to arthroscopic capsulotomy. Routine intravenous gadolinium.</td>
<td>Presence of enhancing fibrovascular scar tissue in the RI, soft tissue thickening around the biceps anchor and thickening of the axillary pouch on MRI are suggestive signs of AC.</td>
</tr>
<tr>
<td>Lefevre-Colau 2005</td>
<td>26 AC, 14 contralateral pain free, non restricted shoulders</td>
<td>Gradually increasing shoulder pain more severe at rest, for at least one month, limitation of PROM mainly in forward elevation and ER, normal X ray, non responsive to normal Rx.</td>
<td>At MRI 3–26 months (9.5 ± 5.4 months)</td>
<td>MRI with gadolinium enhancement measuring GHJ capsule and synovial thickness in the RI and AR.</td>
<td>Mean thickness of AR and RI greater in AC shoulders compared to controls.</td>
</tr>
<tr>
<td>Sofika 2008</td>
<td>46 AC (47 shoulders)</td>
<td>Presumptive clinical diagnosis or MRI findings suggestive of AC. Pts with MRI’s and detailed clinical information that allowed stage to be determined</td>
<td>Clinical diagnosis of stage 1 (0-3 mths), 8 subjects; stage 2 (3-9 mths), 23 subjects; stage 3 (9-15 mths), 8 subjects; stage 4 (15-24 mths), 8 subjects</td>
<td>MRI measuring capsular and synovial thickness at the AR, scoring in the RI, signal intensity in the capsule.</td>
<td>All subjects demonstrated scoring of the RI; 29 subjects had hyperintensity of the GH capsule; capsular and synovial thickening measured in the AR correlated with clinical stage of AC; hyperintense capsular signal correlated with stage 2.</td>
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</table>

Legend: AC, adhesive capsulitis; ADL, activities of daily living; AR, axillary recess; CHL, coracohumeral ligament; ER, external rotation; FE, forward elevation; GHJ, glenohumeral joint; h/o, history of; IR, internal rotation; IS, impingement syndrome; MRA, magnetic resonance arthrography; MRI, magnetic resonance imaging; mths, months; PROM, passive range of movement; RC, rotator cuff; RCT, rotator cuff tear; RI, rotator interval; ROM, range of movement; Rx, treatment; VAS, visual analogue scale.

Table 2 Summary of MRA studies on adhesive capsulitis

<table>
<thead>
<tr>
<th>Study</th>
<th>Number of shoulders</th>
<th>Inclusion criteria</th>
<th>Duration of symptoms (mean)</th>
<th>Investigation</th>
<th>Summary of findings</th>
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<tr>
<td>Manton</td>
<td>9 AC</td>
<td>Retrospective</td>
<td>Not stated</td>
<td>MRA</td>
<td>Concluded no useful MRA signs of AC.</td>
</tr>
<tr>
<td>Study</td>
<td>Number of shoulders</td>
<td>Inclusion criteria</td>
<td>Duration of symptoms (mean)</td>
<td>Investigation</td>
<td>Summary of findings</td>
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<tr>
<td>2001 (47)</td>
<td>19 without signs of AC</td>
<td>arthrographic diagnosis based on having 2 or more of the following: joint volume &lt;10ml, poor or absent filling of the AR of the joint or biceps tendon sheath, irregularity of the capsule insertion, pain after injection of &lt;10ml of contrast, or extravasation of contrast prior to injection ≥10ml</td>
<td>assessing relative amount of fluid in the biceps tendon sheath and AR, corrugation at the margin of the capsule, capsule synovium thickness, abnormalities of the RI, and the presence of RCT's</td>
<td>Capsule/synovium thickness, static fluid, and the presence of corrugation are inconclusive signs distinguishing shoulders with AC from those without.</td>
<td></td>
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<tr>
<td>Lee 2003 (46)</td>
<td>16 AC 11 controls</td>
<td>Arthroscopically proven AC with at least two of the following: vascular synovitis, capsular contracture, tightness of the humeral head against the glenoid, difficult penetration of the GHJ capsule with the arthroscope. Excluded AC diagnosed clinically.</td>
<td>Not stated</td>
<td>MRA measuring thickness of GHJ capsule and synovium, filling ratio of AR to determine relative volume, width of the RI.</td>
<td>Thickening of the GHJ capsule and synovium and diminished filling ratio of the AR to posterior joint cavity appeared to be useful diagnostic criteria for AC.</td>
</tr>
<tr>
<td>Menciardi 2004 (51)</td>
<td>22 Rx arthroscopic capsulotomy for AC 22 age and sex matched controls</td>
<td>Surgical confirmation of AC (thickened GHJ capsule and synovitis in the area of the RI) and treatment with arthroscopic capsulotomy &lt; 3 months after MRA.</td>
<td>3-24 months (11 months)</td>
<td>Pre operative MRA compared with age and sex matched control subjects without AC.</td>
<td>Thickening of the CHL and joint capsule in the RI. Synovitis-like abnormalities at the superior border of the subscapularis tendon significantly more common in AC subjects than in controls.</td>
</tr>
<tr>
<td>Jung 2006 (45)</td>
<td>14 AC 14 controls</td>
<td>Injected GHJ volume &lt; with pain. Pain and stiffness &gt;15 weeks, restriction of PROM of &gt;30° in 2 or more planes, normal X ray.</td>
<td>Not stated</td>
<td>MRA measuring mean thickness of GHJ capsule and synovium, width of the AR and RI.</td>
<td>In the absence of a full thickness RCT, thickness of the GHJ capsule and synovium &gt;3mm at the level of the AR is a practical MR criterion for the diagnosis of AC on oblique coronal T2 weighted MRA without fat suppression.</td>
</tr>
<tr>
<td>Kim 2009 (44)</td>
<td>26 AC 47 controls</td>
<td>Painful stiff shoulder for at least 4 weeks, severe pain interfering with ADL, night pain, painful restriction of active and passive elevation to &lt; 100°, 50% restriction of ER. AC confirmed arthroscopically in 11 shoulders.</td>
<td>Not stated</td>
<td>Retrospective review of patients undergoing MRA. Estimated the height, base RI area, width, RI index and RI ratio.</td>
<td>Shoulders with AC differed significantly in height, base, RI area, RI index and RI ratio from those without AC.</td>
</tr>
</tbody>
</table>
Consistent with the surgical and histological findings, the area of most interest in both MRI and MRA investigations has been the rotator interval (Wiley 1991; Bunker and Anthony 1995). Some studies report a difference in rotator interval dimensions visualized with MRA, (Jung, Jee et al. 2006; Kim, Rhee et al. 2009) whilst others author were unable to demonstrate statistically significant differences (Manton, Schweitzer et al. 2001; Lee, Ahn et al. 2003). Enhancement of tissue in this area has also been reported in both MRI and MRA investigations, indicating the presence of inflammation Figure 2 (Carrillon, Noel et al. 1999; Connell, Padmanabhan et al. 2002; Lefevre-Colau, Drape et al. 2005; Jung, Jee et al. 2006; Song, Kwon et al. 2011).
Figure 2. Magnetic resonance image of a 61 year old woman with clinical evidence of right adhesive capsulitis and a contralateral healthy shoulder. Sagittal fat-suppressed T1-weighted spin-echo sequence after IV Gd-chelate enhancement (TR/TE=600 ms/15 ms). Note the marked enhancement of the joint capsule and synovial membrane in the rotator cuff interval (black opposed arrow) in the right AC shoulder (a) and the lack of enhancement in the contralateral healthy shoulder (white double arrow) (b). Biceps tendon (arrowhead) and coracoid process (asterisk) are shown. (Image reproduced with permission from: Lefevre-Colau M, Drape J, Fayad F et al. Magnetic resonance imaging of shoulders with idiopathic adhesive capsulitis: reliability of measures. *European Radiology* 2005; 15: 2415-2422).

Interestingly, Connell et al (Connell, Padmanabhan et al. 2002) surgically correlated rotator interval and synovial inflammation using MRI with respect to the various stages of adhesive capsulitis. Thickening of the joint capsule and the coracohumeral ligament in the rotator interval area have also been reported Figure 3 (Carrillion, Noel et al. 1999; Mengiardi, Pfirrmann et al. 2004). Obliteration of the subcoracoid fat between the coracoid process and the coracohumeral ligament has further been described as a useful MRA finding. (Mengiardi, Pfirrmann et al. 2004) Using a variety of methods including both enhanced and unenhanced MRI and direct (intra-articular) and indirect (intravenous) MRA, capsular thickening of the axillary recess has been suggested by several authors as a useful sign of adhesive capsulitis (Emig, Schweitzer et al. 1995; Lee, Ahn et al. 2003; Lefevre-Colau, Drape et al. 2005; Jung, Jee et al. 2006;
However, conflicting results have however also been reported (Carrillion, Noel et al. 1999; Manton, Schweitzer et al. 2001; Mengiardi, Pfirrmann et al. 2004).

Figure 3 Sagittal oblique T1-weighted (700/12) image shows thickened CHL (arrows) in a 57-year-old patient with adhesive capsulitis. C = coracoid process (Image reproduced with permission from: Mengiardi B, Pfirrmann C WA, Gerber C et al. Frozen shoulder: MR arthrographic findings. *Radiology* 2004; 233: 486-492).

Despite the findings reported in the literature, Petchprapa et al (Petchprapa, Beltran et al. 2010) have recently suggested that the clinical role of MRI may be limited due to the variability of methodology in the studies reported to date. Whilst some authors may draw certain conclusions from their studies, they are not always supported by others using differing methodologies. Further, as adhesive capsulitis is a disorder that progresses through a series of stages, reported results should be considered within the context of the duration of symptoms of the subjects. Some authors acknowledge the various stages of adhesive capsulitis in their studies, (Tamai and Yamato 1997; Connell, Padmanabhan et al. 2002; Sofka, Ciavarra et al. 2008) however it should be noted that generalized conclusions where the stage of the disorder has not been identified may need to be drawn with caution. Although findings have been described that may be useful indicators of adhesive capsulitis, plain MRI and MRA are not investigations
routinely utilized in the primary health care setting and therefore their practical application to this disorder may be limited (Hsu, Anakwenze et al. 2011). Nonetheless the diagnosis of adhesive capsulitis is essentially clinical, and whilst not routinely performed in the early stage of adhesive capsulitis, MRI may facilitate a diagnosis at that stage which may be subsequently confirmed clinically (Petchprapa, Beltran et al. 2010).

**The future of ultrasound in the diagnosis of adhesive capsulitis**

As discussed earlier there is evidence that various radiological investigations have identified several features that may assist in the diagnosis of adhesive capsulitis. Other imaging modalities, notably power Doppler ultrasound, with the potential to assist diagnosis, have received little attention. Two of these will be discussed in light of the current pathological understanding and existing radiological evidence.

**Power Doppler ultrasound**

The radiological assessment of vascularity has been made possible with technological improvements and, in particular, with both colour and power Doppler ultrasound. In contrast to colour Doppler ultrasonography, which is better suited to evaluate high velocity flow in large blood vessels, power Doppler ultrasound is better suited to detect low velocity blood flow in small vessels as in the synovium (Wakefield, Brown et al. 2003). Although power Doppler ultrasound has its origins in cardiac investigations, it has since been applied to other diagnostic situations including musculoskeletal medicine (Newman, Adler et al. 1994; Wamser, Bohndorf et al. 2003).
In musculoskeletal inflammatory disease, power Doppler ultrasound has the potential to detect soft tissue hyperemia (Newman, Adler et al. 1994). Power Doppler has also been described as an efficient tool to measure and monitor disease activity and progression (Agrawal and Dasgupta 2008).

Whilst most musculoskeletal ultrasound is performed using grey-scale ultrasound alone, the detection of hyperemia with both colour and power Doppler is reported to be becoming increasingly common (Boesen, Boesen et al. 2010). Power Doppler ultrasound has been demonstrated to provide a reliable and accurate method for visualizing blood flow in the synovial tissue of patients with osteoarthritis and rheumatoid arthritis of the knee joint (Walther, Harms et al. 2001). With respect to the shoulder, several studies that assessed biceps tendon pathology give evidence that this modality provides important diagnostic information (Strunk, Lange et al. 2003; Wamser, Bohndorf et al. 2003; Chang, Wu et al. 2010). Notably power Doppler ultrasound has been able to distinguish between inflammatory and non-inflammatory shoulder pain through assessment of the biceps tendon sheath in patients with rheumatoid arthritis, compared with patients with degenerative diseases of the shoulder (Strunk, Lange et al. 2003). However, Wamser et al (Wamser, Bohndorf et al. 2003) conclude that while power Doppler ultrasonography is able to detect active inflammatory changes in the soft tissues of the shoulder, it is less capable than MRI in determining the degree of synovitis and distinguishing synovitis from fluid. The suggestions that a negative Doppler signal does not exclude the possibility of synovitis, but rather a positive signal is an indication of active synovitis has also been proposed.
(Koski, Saarakkala et al. 2006). Histopathologically, a minor colour signal in the synovium has been shown to be an important marker for synovitis, though the amount of colour may not correlate strongly with the severity of the histopathological synovitis (Koski, Saarakkala et al. 2006).

Both the current pathological and surgical evidence, together with findings on ultrasound and MRI imply the rotator interval is the area of initial synovial hyperaemia in adhesive capsulitis. It has been proposed that increased signal intensity of the joint capsule and synovium in the early stage is likely to reflect the active synovial and capsular response at this stage of the disorder (Sofka, Ciavarra et al. 2008). It would appear logical therefore that an imaging modality with the ability to detect synovitis may have potential to identify the early stage of adhesive capsulitis. Figure 4 illustrates a power Doppler examination of a patient with clinically diagnosed adhesive capsulitis showing an area of increased vascularity in the rotator interval area. Evidence of enhanced vascularity in the rotator interval using colour Doppler ultrasound (Lee, Sykes et al. 2005) has been demonstrated, however the role of power Doppler ultrasound in the diagnosis of adhesive capsulitis remains to be investigated.
Figure 4 Power Doppler ultrasound of 54 year old female with a 6 month history of adhesive capsulitis demonstrating increased vascularity at the rotator cuff interval.

Although the use of Doppler ultrasound is promising in musculoskeletal medicine, a number of limitations require consideration. Application of Doppler ultrasound is influenced by the skill of the examiner, sensitivity of the machine, as well as technical artifacts (Walther, Harms et al. 2001). The technique is highly motion sensitive and even minimal soft tissue motion can make differentiation of blood flow from motion difficult to discern (Rubin 1999). Further, excessive pressure from the transducer may also result in vessel occlusion, although a stand-off gel pad may minimize this issue (Wakefield, Brown et al. 2003). It has also been demonstrated that the selection of the ultrasound machine used for investigation is important as an inability to detect a signal at the capillary flow level may be due to flow in synovium being under the detection threshold of some machines (Koski, Saarakkala et al. 2006).

As ultrasound is safe, inexpensive, non-invasive and relatively accessible it may contribute in the future in diagnostically combining clinical signs and symptoms with
objective radiological findings (Walther, Harms et al. 2001). Power Doppler is an emerging technology that may, by measurement of vascularity of the musculoskeletal system provide an indication of disease processes and progression (Joshua, Edmonds et al. 2006). Arguably therefore, there is merit in assessing the shoulders of patients with acute pain with respect to vascularity of the capsule and particularly the rotator interval to determine whether an increase in vascularity may be present, potentially assisting in the early diagnosis of adhesive capsulitis.

**Conclusion**

Ultrasound and MRI findings in adhesive capsulitis have been described and may be useful diagnostically, most notably demonstrating increased vascularity in the rotator interval (Lee, Sykes et al. 2005; Lefevre-Colau, Drape et al. 2005). Despite reports of radiological examinations potentially being of some value in the diagnosis of adhesive capsulitis, it has also been argued that to date these investigations do not provide any real contribution over that of standard clinical assessment (Beggs 2006). Notably however, most studies have involved severe cases or those at a later stage of the disorder. With this imaging modality becoming increasingly popular in the clinical setting (Wakefield, Brown et al. 2003) power Doppler ultrasound may enable the clinician to combine imaging with the history and examination findings to facilitate early diagnosis of adhesive capsulitis. Future studies are required to explore these potential benefits.

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