REHABILITATION OF LUMBAR BONE STRESS INJURIES IN TENNIS PLAYERS

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INTRODUCTION

The lumbar spine is the most commonly injured region in elite adolescent tennis players[1] and it is estimated that 60% of tennis players aged between 11-19 with low back pain have a symptomatic pars interarticularis abnormality[2]. The pars interarticularis is typically at risk in sports such as tennis due to repetitive axial loading, twisting and extension of the trunk in end range positions[3]. A pars interarticularis abnormality of a fracture or cortical defect has been traditionally described as spondylolysis[4], however more recently lumbar bone stress injury (LBSI) has become the preferred term because it encompasses the broader continuum ranging from bone oedema on MRI (bone stress) at the lower end to cortical breach (stress fracture). LBSI also implies that the pars abnormality is symptomatic, a relevant distinction as pars abnormalities have been observed in over one third of asymptomatic adolescent tennis players[2].

Management

When managing a LBSI the clinician has two broad approaches to choose. One is to use a functional approach which is guided by symptoms and recovery of function but where bone healing, although desired, is not a priority[5]. This approach allows a more rapid return to activity (approximately 2-3 months) but the longer term recurrence rates are not clear. The other is to follow a "structural" approach[6] where a healed fracture is a very important criteria for return to sport. The time frames for return to sport using this approach are longer (typically 5-6 months) but experiences from other sports (particularly cricket fast bowling) has suggested that fracture healing following a LBSI correlates well with greater long term resilience in elite sport[6] and is the approach advocated by this author.

Use of imaging

MRI scans are the modality of choice when assessing LBSI as they are sensitive to active bone stress as well as being able to visualise fracture morphology[7]. This provides the clinician with a tool to do the following:

- Diagnose a LBSI and stage the point on the bone stress injury continuum (stress reaction or stress fracture)
- Assess the potential to heal (active stress fracture or chronic united defect)
- Assess bone healing over time.

Staging where the athlete is on the bone stress continuum is key; an early diagnosis without the presence of significant cortical breach is associated with excellent bone healing (taking approximately 2.5 months), whereas when the cortical breach is bigger it takes longer to heal (3-5 months), and

Table 1

Phase 1 (0-6 weeks)					
Lumbo-pelvic control examples	*Mobility*	*Aerobic activity*	*Tennis specific*	*Avoid*	*Criteria to progress*
Modified dead bugs-leg lower/lift variation includng *SLR and hip abduction* *4 point kneel hip extension variations* *Bridging* *DL squat* *Lunge* *DL RDL* *Lateral plank*	*HS stretch* *Hip flexor stretch* *Supported Tx rotation*	*0-2 weeks: Walking alternate days* *2-6 weeks: Stationary bike (lumbar spine neutral)*	*Nil*	*Extension* *Rotation/LF* *Jumping/landing* *Provocative activity* *Swimming*	*Absence of clinical findings (no pain in ADL, no pain on previous positive clinical testing eg: quadrant)* *Performing exercises with good control and technique (clinician's subjective interpretation)* *MRI at 6 weeks showing reduced BMO and a healing fracture*

Table 1: Summary of phase 1 management.

approximately 20% of the cases do not heal[8]. Getting a fracture to heal first time is preferable as recurrent fractures may take 2-3 times longer and be more prone to recurrence[9].

Other factors

It is important to consider other contributing factors in the development of the bone stress injury that may require input from other health professionals. In particular, relative energy deficiency in sport (RED-S) is a syndrome associated with inadequate fuelling for athletic demands and is a risk factor for bone stress injury[10]. Therefore, both sports dieticians and sports physicians play an important role in diagnosis, management, and education of the athlete. Optimal nutrition during the recovery process will also facilitate healing of the fracture.

Manual therapy

Although a graduated exercise program is the cornerstone of the rehabilitation process, manual therapy is a useful adjunct to address some of the potential underlying factors in the development of a LBSI. Commonly, there may be a loss of thoraco-lumbar rotation, an essential element for tennis ground strokes[11] and serving[3], which may lead to increased load on the lumbar spine[12]. Also, a loss of hip extension range due to a hip flexor restriction may contribute to either an increased lumbar lordotic position, or a compensatory lumbar extension, either of which may overload the pars interarticularis. Similarly hamstring tightness has been linked with an increased risk of LBSI in soccer players[13]. Therefore, manual therapy and exercise interventions to address these deficits may be an important aspect of the conservative management throughout the rehab process.

Phases of rehabilitation

Three main phases of rehabilitation when managing a LBSI have been proposed[14] and are outlined below with approximate time-frames. In an elite sports environment tracking bone healing with MRI forms an important part of the decision-making process with respect to when the athlete is able to progress to higher level activity. There is no strong evidence to support any particular exercise approach, with published reports being based on clinical experience, and the following is based on our clinical experience. It should also be emphasised that the time frames are a guide, and individual cases will vary when clinical, functional, technical, maturational, and radiological variables are taken into consideration. The case study presented later in this article provides an example of this.

Phase 1- Fracture protection (0-6 weeks)

During this early phase (see Table 1) the emphasis is on protecting the fracture to facilitate healing. The use of bracing in this phase is often advocated but to date the evidence does not provide strong support for this approach[15]. In a tennis player where the causative factor is a specific sporting movement (e.g.: serving) which is not replicated in normal activities of daily living then bracing is not usually required. However, bracing may be appropriate if:

1. There is a bilateral acute LBSI
2. There is a near full or full unilateral fracture
3. The pain is of high intensity

Although a brace may not be necessary, instructions to the athlete to avoid lumbar extension, rotation, axial loading (and tennis) need to be adhered to.

During this phase the player is able to do lumbo-pelvic control exercises provided they are able to maintain a neutral lumbar spine when under load. Aerobic activity is initially limited to walking (when pain-free) and progressed to stationary bike (low to moderate intensity remaining seated with a neutral spine). Swimming is best avoided in phase 1 while the clinician is trying to limit lumbar extension and rotation.

Fundamental movements (e.g.: squat, lunge, hip hinge) can be introduced with body weight resistance and emphasis on performing the movement with good technique. Resistance can then be added to these movements at an appropriate time later in the rehabilitation.

Upper body loading, particularly maintaining shoulder and scapular muscle function can be done provided the lumbar spine remains in a neutral position and is

symptom free. Depending on the specific clinical situation, care may be needed with overhead loading, and this is often best left until phase 2 when the clinician is more confident that bone healing is progressing as expected.

Phase 2- Protected reloading (6-12 weeks)

In this phase the rehab approach shifts from a "support and control" focus to gradually increasing resistance load, running with transition to on-court movement, spinal mobility, and shadow hitting. Resistance loading with a high rate and strain magnitude is a potential osteogenic stimulus[16], which may improve fracture healing in the remodelling phase[17].

The time frames in Table 2 are a guide and each case may be slightly different depending on the size of the fracture, the stage of healing, whether the fracture is new or recurrent and the symptomatic status. The return to running program is based on a previously described program for runners[18] initially but after 2-3 weeks can become more tennis specific movement on court.

If there is a technical aspect to the injury (e.g. serve or ground strokes) then this phase of the rehabilitation is an opportunity for the coach to begin some basic technical correction with shadow hitting and for the on-court movement sessions to incorporate any specific factors that may need to be addressed with respect to footwork.

Table 2

Phase 2 (6-12 weeks)					
Lumbo-pelvic control examples	*Mobility*	*Aerobic activity*	*Tennis specific*	*Avoid*	*Criteria to progress*
Dead bugs-contra-lateral arm and leg together *Prone plank +/- hip extension* *Loaded hip thrust* *Paloff press* *Banded rotation in lunge* *Medicine ball pass and catch into rotation* *Add DB load to DL squat/RDL/Lunge*	*Add Tx rotation in half kneel* *Introduce lumbar rotation stretch (approx week 8)*	*Progressive running program alternate days* *Progressive swimming*	*8-9 weeks:* *Begin on court tennis specific movements* *Shadow FH/BH* *10-11 weeks:* *Shadow serves* *12 weeks: Med ball slams* *Med ball catches into lumbar extension*	*Heavy axial load* *Repetitive end range extension/ rotation*	*Continued absence of clinical findings* *Consistent strength program with quality movement patterns and tolerating progressive resistance* *Demonstrating progressive on court tennis specific movement intensity* *Ideally MRI at 12 weeks shows healed or advanced healing of fracture*

Table 2: Summary of phase 2 management.

Table 3

Return to serving guidelines			
Volume	*Intensity*	*Frequency*	*Periodisation*
Keep volumes around 40-60 serves per day initially while intensity is progressed *Aim for blocks of 10-15 consecutive serves (serving is spread over the session)* *Once player is comfortable serving at good intensity (approx 3-4 weeks) look to add volume* *Aim is to build toward 400-500 serves per week* *Allow 6-8 weeks to reach ths goal* *Serve reload therefore taking approx 3 months*	*Start from service line* *Progress to base line over 3-4 sessions* *Walk through serves initially* *Flat serve before progressing to kick serve* *Monitor intensity with radar or inertial sensors* *Allow 3-4 weeks to build to full intensity*	*Alternate days serving for first 4 weeks* *Gradually add consecutive days over the 2nd 4 weeks*	*When player is serving at normal training intensity begin increasing volume with fluctuating loads over a week* *Low serve day = 40-60 serves* *Moderate serve day = 60-80 serves* *High serve day = 80-120 serves* *Higher volume serving can be spread over two sessions in the day*

Table 3: Return to serving guinelines.

Phase 3-Return to sport (12-24 weeks)

In an ideal situation there is radiologically confirmed healing of the fracture at the beginning of this phase. Therefore, off court, the rehab process can be a more normal training program, which gradually progresses the existing work that has been done during phase 2. Woodchop and med ball throw variations can load the spine into rotation manner which is relevant to building resilience to tennis. In addition, heavier lifts using squat or dead lift variations may be appropriate provided they are done with good technique. As mentioned previously, this type of loading may provide the necessary osteogenic stimulus, as evidence from cricket fast bowlers suggests that lumbar bone mineral density may take up to a year to return to pre-injury levels following a LBSI[19]. This aspect of this approach (the "structural" management approach), is the primary negative aspect as longer time is needed to demonstrate fracture healing, which in turn requires a longer time to reload the bone back to pre-injury levels.

The tennis reload requires close collaboration with the physical performance trainer and coach to gradually increase on-court time. A typical approach would be to limit sessions to inner range movement early (1-2 steps), progressing to mid range (3-4 steps) and outer range (single line to single line) over 3-4 weeks. Also allowing adequate recovery time between sessions is important for bone adaptation, which would typically mean hitting on alternate days for 3-4 weeks.

If the serve is the provocative factor in the development of the LBSI then the serve reload should be well planned with a gradual increase in volume initially and then subsequently in intensity. It is recommended to keep serving to blocks of 10-15 initially and spread over the course of a session to give bone within-session recovery time. Table 3 provides some guidelines for a return to serve program.

In an elite environment, the use of GPS trackers with inertial sensors (e.g. Catapult units) is recommended as an easy way to track actual volumes of serving and ground strokes during training, as well as giving an indication of movement intensity.

Case study

Presentation: An elite 18-year-old tennis player presents with R side low back pain

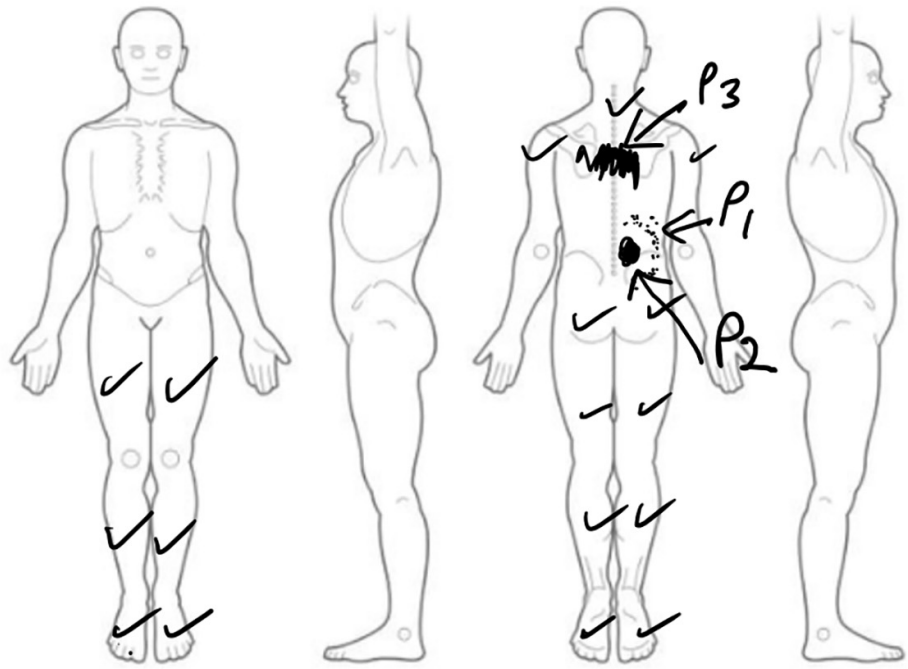


Figure 1: Body Chart of player's pain pattern.

(see Figure 1)

- P1= constant low-grade ache (1/10 Visual analogue scale (VAS)) on court with small warm up effect
- P2= sharp pain with closed stance backhand (BH) and kick serve. The quality of his kick serve and BH is becoming more limited by P2
- P3= thoracic spine stiffness

History:

- Pain has gradually increased over the past month but was pain free prior to this.
- In the past month, training has changed from predominantly hard to clay courts. There is a higher bounce on the clay surface and has had to rotate his trunk more to the right to control his BH because of this. Has also been hitting his kick serve more to take advantage of the higher bounce.
- Has been training with a top 100 male professional (including practice matches) at a higher intensity than normal with less rest and harder ball striking.

Past History:

- Stress fracture low back aged 13-no past scans available, thinks it was right side
- He rested from tennis for 6 months and has not had any issues since then
- Pain in the sternocostal joints approximately 6 months ago which was helped with thoracic spine mobility treatment.

Growth and Maturation: 3 years post peak height velocity, height and weight stable for the past 9 months

Patient Goals: Tournament in 7 weeks' time (junior grand slam).

Physical Examination:

Key outcome measures	
1. Thoracic rotation range of movement in sitting	Right lumbar pain reproduced at end of range to right (Limited range (40° bilaterally))
2. Lumbar quadrant	To the right side reproduces right side lumbar pain
3. Lumbar palpation	Reactive to unilateral pressure right side at L4-5 and L5-S1
4. Hip extension range of movement	10° deficit on left and right modified Thomas test

Imaging (see Figure 2): MRI showed LBSI right L4 pars interarticularis: bone marrow oedema with a ratio of signal intensity from the pars relative to vertebral body of 3.6[20]. Possible cortical anomaly (minor) at L4 pars but no obvious fracture.

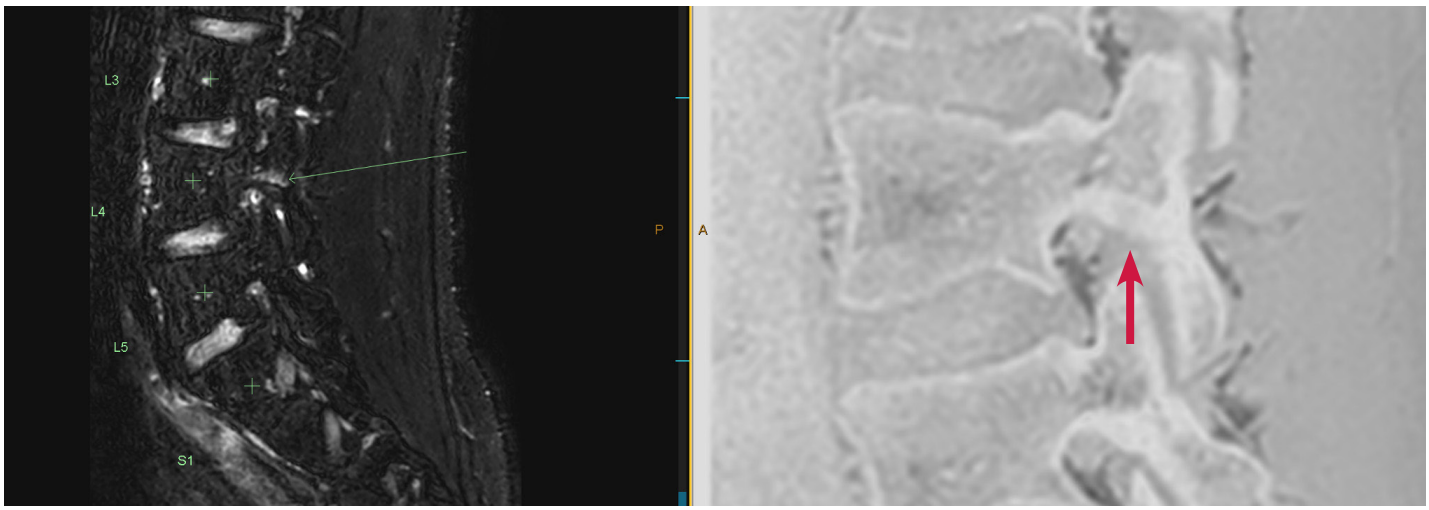
Interpretation

Pars interarticularis lesions are common in adolescent tennis players[2] and likely contributors to this injury were:

- Younger age
- Higher intensity of practice/play
- Higher volume of kick serves (self-reported)-kick serve puts higher forces on lumbar spine[21]
- Change in loading on closed stance backhand due to higher bounce on clay-lumbar rotation loads the contralateral (and ipsilateral) pars[22]
- Reduced thoracic rotation range = lumbar spine closer to end range during backhand
- Past history of lumbar spine stress fracture

Management

This situation required careful consultation, management and planning to accommodate the players desire to play in two junior grand slams. Returning to play at week 7 represented a risk as LBSI injuries may take up to 16 weeks to heal[9]. However, in favour of a possible early return was the lack of cortical breach and the BMO although intense (ratio of 3.6) was quite localised. A plan was agreed between sports science and sports medicine staff, player, and coach, giving the maximum amount of deload



Bone marrow oedema (BMO) ratio = 3.6
Ratio = pars interarticularis signal/vertebral body signal

No fracture but slight cortical anomaly

Figure 2: MRI at diagnosis.

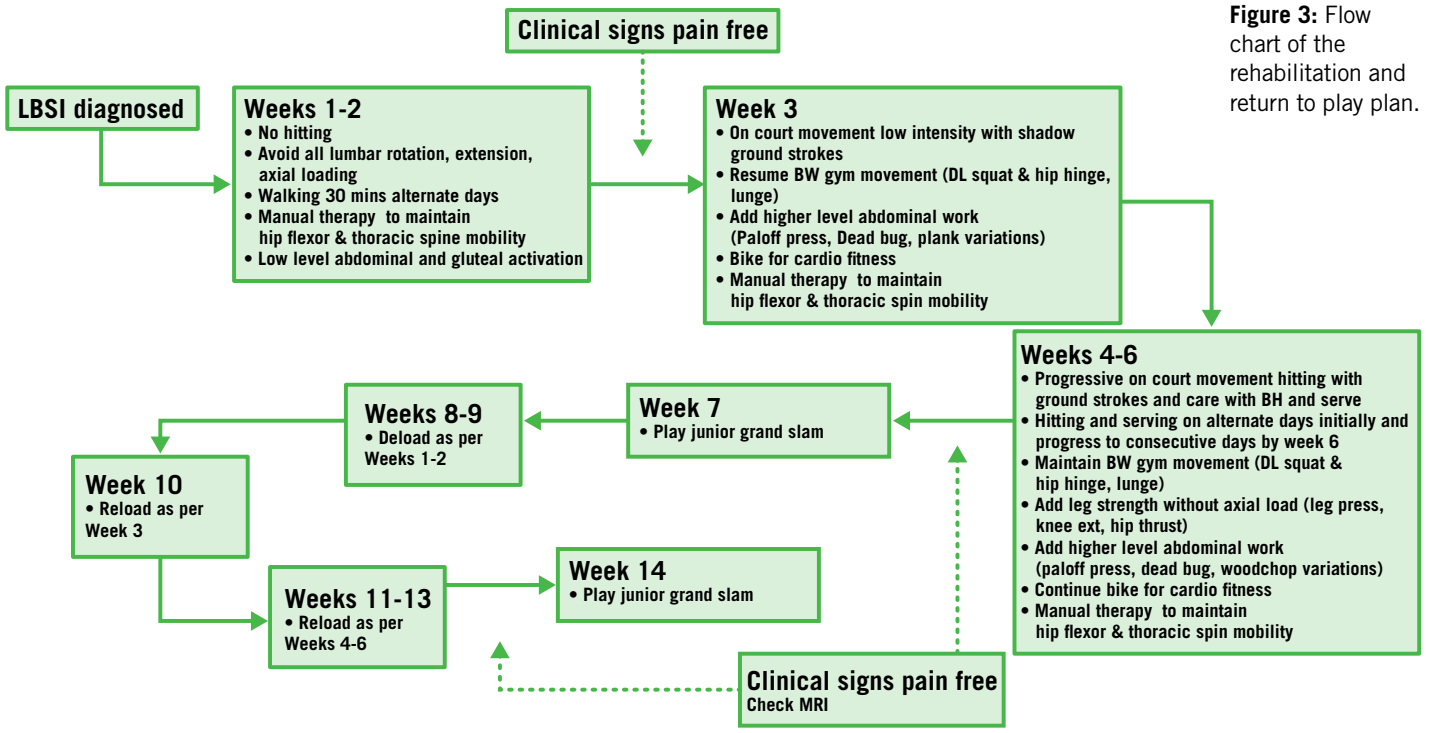


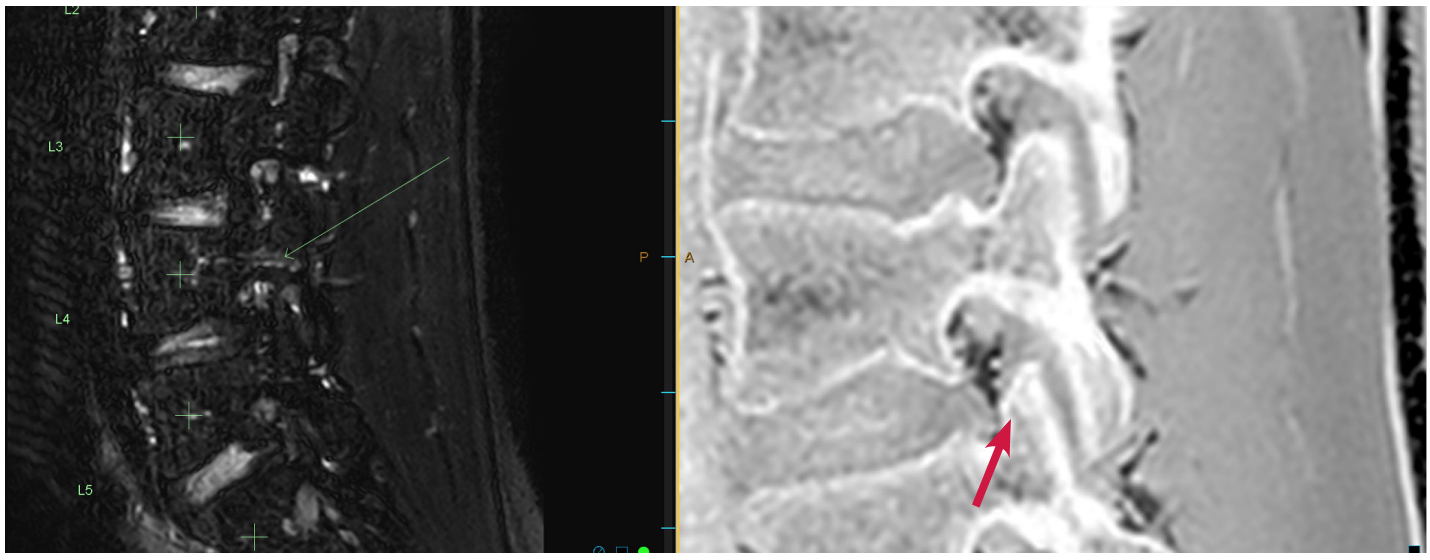
Figure 3: Flow chart of the rehabilitation and return to play plan.

possible (2 weeks) to allow some healing but still have sufficient time to prepare for a tournament. The potential risks of pushing to play were clearly outlined to all parties before a final decision was made. The player's consistent tennis load over the previous year provided some confidence that he could return to play on a limited preparation.

Figure 3 summarises the rehabilitation and return to play plan. Weeks 1-2 consisted of manual therapy including mobilisation of the thoracic spine with posterior-to-anterior glides over the zygapophyseal and costotransverse joints, and a therapist assisted thoracic rotation movement in controlled range to avoid lumbar rotation (see Figure 4). The hip flexors were treated with soft tissue massage and controlled stretching (avoiding lumbar extension). The rationale for both was to improve movement in the adjacent regions to potentially reduce load on the lumbar spine. At the end of the second week the goal was for the clinical outcome measures to be pain-free, and this was achieved.

Week 3-6 involved a tennis reload starting with tennis specific movements on court but with shadow hitting only. Over the next 4 weeks tennis work including hitting was reintroduced on alternate days initially, as bone responds well to bouts of loading and recovery time[23]. In the final week before competition consecutive days of hitting were reintroduced.

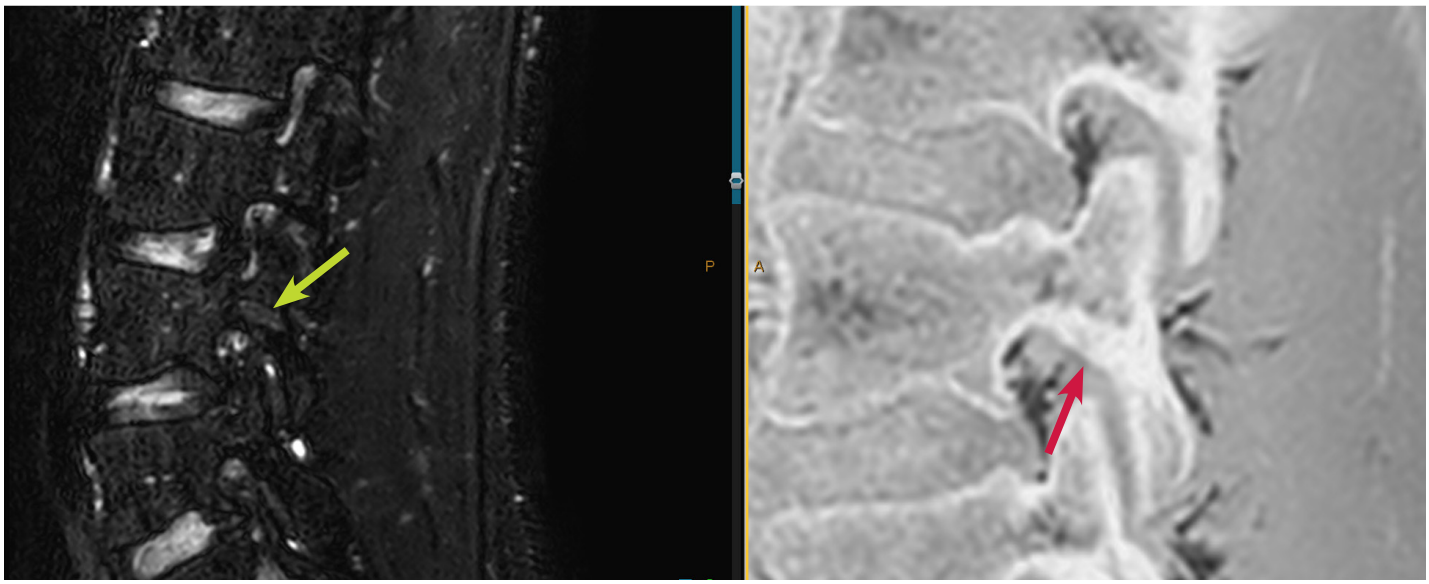
Figure 4: Therapist assisted thoracic rotation in controlled range avoiding lumbar rotation.



Bone marrow oedema (BMO) ratio = 1.6

No fracture but cortical anomaly more apparent

Figure 5: MRI at 6 weeks



Bone marrow oedema (BMO) ratio = 1.1

No fracture, cortical anomaly much improved

Figure 6: MRI at 12 weeks.

An MRI was performed prior to leaving for the tournament which showed a marked reduction in BMO but the cortical bone anomaly at L4 was a little more obvious (Figure 5). The radiologist did not think it represented a fracture but there was some concern about potential resorption of bone at that site (known to occur as part of fracture healing)[24].

The player was able to play the first junior grand slam with no issue and clinical outcome measures remained negative. The loading strategy was then repeated to prepare for the next grand slam. Clinical outcome measures remained negative, and a repeat MRI (at 12 weeks post diagnosis) showed resolution of bone marrow oedema and an improvement in the cortical anomaly (Figure 6). He was able to play the second grand slam and has since made a full recovery.

Considerations

This case study shows the value of an early diagnosis, the ability to be flexible on time frames provided clinical and radiological factors are considered and the importance of a well communicated return to play plan with buy in from all stakeholders. A concern was a possible cortical defect developing on the week 6 scan but the resolution of bone marrow oedema, the absence of clinical signs and the radiologist's interpretation gave confidence to continue as planned.

Other factors that contributed to a good outcome included regular treatment and carefully controlled gym work which improved the range of thoracic rotation and hip extension, which both potentially reduced load on the lumbar spine. The coach and player were also comfortable with the plan to train on alternate days initially, which was a shift in their normal training philosophy, but likely a very important factor in the successful return to play.

SUMMARY

A successful recovery from a LBSI in a tennis player requires an understanding of the underlying healing process of bone. The time frames to achieve bone healing are long and must be respected to get a good long-term outcome. During the healing process rehabilitation can be undertaken to improve muscle support and flexibility initially, and to drive bony adaptation later in the process. There is however some flexibility in the process depending on each individual case, with factors such as the nature of the LBSI, the maturation status of the player, the technical efficiency (or inefficiency) and the athletic development all contributing to the decision-making process. A good starting point is to allow 6 months from the point of stopping tennis to returning to play.

References
Available at www.aspetar.com/journal

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