Original Article

Surgical repair of lumbar stress fractures in professional cricketers

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Background: Professional cricket fast bowlers sustain high rates of lumbar stress fractures (spondylolysis). Limited research exists around the success of surgical repair when these injuries fail conservative treatment. We present an ambispective cohort study of spondylolysis surgical repair in a consecutive group of multi-national professional cricket fast bowler using a technique not previously reported in this unique sporting group.

Methods: Between 2004 and 2019, a consecutive series of male professional fast bowlers with lumbar spondylolysis who had repeatedly failed conservative treatment and subsequently received surgical repair using a cable-screw construct were reviewed. Analysis comprised of ambispective outcome and radiological data collection and a survey at final follow-up.

Results: The cohort included 13 elite (7 state and 6 international) cricket fast bowlers from 3 countries (New Zealand, Australian and India) with an average age of 26 years (range, 20.3–29.5 years). All returned to play professional cricket at a median time of 8 months (IQR, 7–11 months) post surgery. All ten players surveyed at final follow-up [median, 38 (IQR, 31–103) months, range, 15–197 months] rated their bowling performance as the 'same or better' compared with prior to surgery. At final follow-up, 10 players continue to play cricket professionally ranging from 15 to 107 months post-surgery [median 35 (IQR, 24–43) months].

Conclusions: Our cohort demonstrated favorable return to play rates and career longevity following surgical repair of spondylolysis. To our knowledge it is the largest published surgical series of spondylolysis repair in cricketers, and the first to document the success of a cable-screw surgical technique in this sporting group.

Keywords: Spondylolysis; cricket; lumbar; stress fracture; pars repair

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Introduction

The physical demands on fast bowlers in cricket are well recognized to result in high rates of lumbar stress injuries, particularly in professionals of which many are training and competing nearly year-round (1-4). The repetitive lumbar extension, coupled with axial rotation and lateral flexion during the delivery action, can produce mechanical loads that exceed the structural capacity of the posterior bony elements of the lumbar vertebra. If the microdamage created accumulates, it can ultimately result in a fracture (spondylolysis). These injuries typically manifest in the pars interarticularis and pedicle regions of the vertebra's neural arch. They most frequently affect the lower lumbar levels and they overwhelmingly occur on the side opposite to the bowling arm (1-5). A literature review reporting the

incidence of pars defects in athletes across a wide range of sports, identified fast bowling cricketers to have one of the highest incidences (32%) of all and markedly higher that the general population (6%) (6).

Spondylolysis can exist in both acute and chronic forms. For an acute fracture, the universally recommended treatment strategy involves a period of rest, bowling technique analysis and rehabilitation, typically extended over a 4- to 6-month period. However, in some cases injuries can reoccur in the same location if return to play precedes the recovery of full bone strength properties. Players then face the prospect of a successive rehabilitation period, further time on the sideline and ongoing uncertainty over how resilient the area will be. Ultimately another repeated cycle of conservative treatment presents a threat to their professional careers.

Chronic established pars defects can be asymptomatic in many cricketers allowing optimal performance with few limitations (4). For some though, pain can be a limiting feature, possibly due to the hypermobility of the posterior elements (7). For this cohort, bony union is unlikely to occur with conservative treatment (8). These players are typically managed symptomatically commonly involving a short period of rest until symptoms subside and then gradual progression back to play. Occasionally however, pain persists.

Whether these recurrent acute or symptomatic chronic spondylolysis scenarios are an indication for surgical intervention in order to achieve more robust and durable healing is often considered, but limited research exists detailing the outcomes of surgery in this specific patient cohort (2,3,9). If surgery is ultimately selected, the most appropriate motion preserving technique is debated with few published case series available (2,3,9).

We present the outcomes of lumbar stress fracture repair in a consecutive cohort of multi-national professional cricket fast bowlers with spondylolysis, using a surgical technique previously unreported in this unique sporting group.

We present the following article in accordance with the STROBE reporting checklist (available at https://dx.doi.org/10.21037/jss-21-18).

Methods

A consecutive cohort of male professional fast bowlers undergoing surgical repair of lumbar stress fractures, between 2004 and 2019, were analysed. All procedures were performed by two surgeons (GI and/or RS) based in Christchurch, New Zealand.

In all cases the surgical indication was persistent lumbar back pain associated with lumbar pars/pedicle stress fractures that limited the ability to consistently bowl at a professional level of performance. All players had radiographic evidence [on computed tomography (CT) and/or magnetic resonance imaging (MRI)] of either recurrent lumbar stress injuries occurring at the same level or chronic pars defects. All patients were required to have fully completed a least one course of appropriate conservative management supervised by sports physicians/physiotherapists experienced in this field. Surgery was not considered in players in which the index level was associated with severe disc disease or spondylolisthesis.

The surgical technique involved a cable-screw construct customized by the senior author (GI) (*Figure 1*). Through a 5–7 cm midline incision and following para-spinal dissection, two 4.5 mm ×32 mm titanium screws (Depuy Synthes) were inserted into both pedicles of the affected level under image intensifier or intra-operative CT (O-ARM/Medtronic) guidance. The inferior 2–3 mm edge of the supra-adjacent inferior facet is removed with an osteotome. If the pars fracture was complete and accessible, the fracture site was then delineated, decorticated and any intervening fibrous tissue removed. The area surrounding the pars was 'petalled' with an osteotome and, if accessible, the fracture packed with autogenous bone graft harvested from the posterior superior iliac crest. A 1mm titanium cable (Atlas Cable System, Medtronic) was then passed around both screw heads and under the spinous process of the involved vertebra in a 'figure-of-eight' pattern before being tensioned to 27 kg (60 lb). The screws were then advanced to secure the cable under the screw heads. Fluoroscopic or intraoperative CT images were taken to confirm metal-ware position prior to closure.

For all procedures the technique used by both surgeons, either operating alone or together, was performed consistently as described except for one specific case. For this player a longer (50 mm × 4.5 mm) titanium screw (Depuy Synthes), placed under O-ARM (Medtronic) guidance, was used unilaterally to lag a recurrent stress fracture localized at the base of the L2 pedicle at the posterior vertebral body wall junction. The remainder of the surgery was completed as described.

Post operatively no bracing was prescribed. Patients were advised to walk frequently and underwent routine plain radiograph imaging day 1- and 6-week post op. Simple

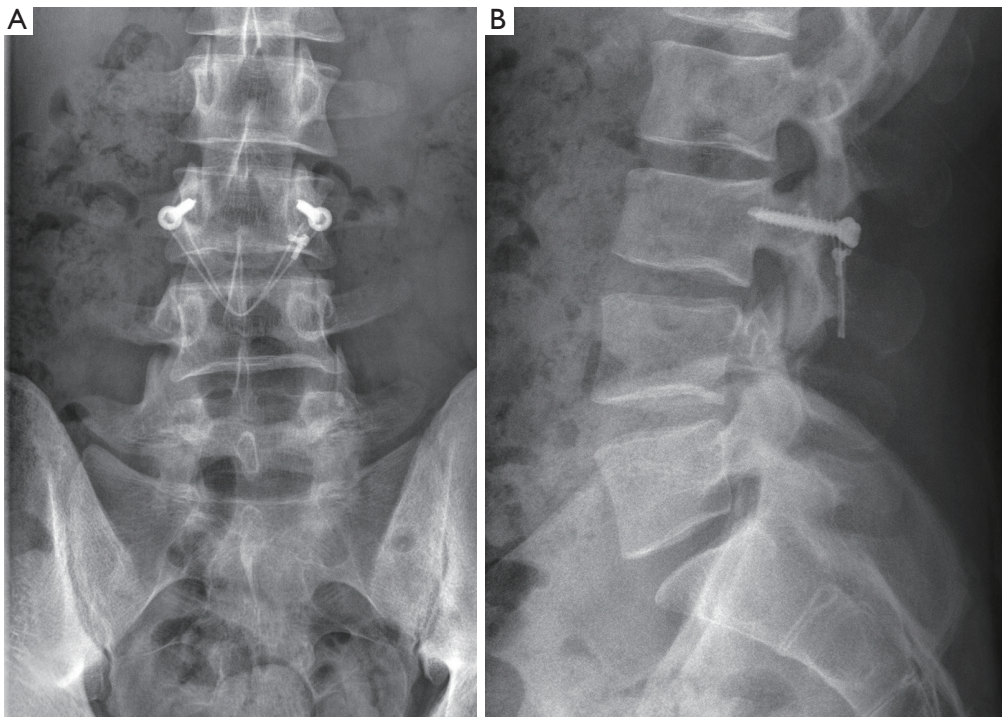

Figure 1 Anteroposterior and Lateral radiographs of a L3 pars repair demonstrating our preferred surgical technique. (A) Anteroposterior (AP) radiograph. (B) Lateral radiograph.

analgesia (avoiding opioids) was utilized with NSAIDs used sparingly.

A multi-stage standardized rehabilitation program (supervised by DS) was prescribed for all with the objective to recondition the athlete by progressively increasing load without jeopardizing the healing/integrity of the surgical site. The rehabilitation protocol was broken down into several distinct phases covering the areas of acute wound care, strength loading, running, bowling and then playing. For each stage, clear clinical and functional objectives were set, that prepared the athlete for transition to the next rehabilitation phase (*Table 1*).

Bowling loads and technique were also assessed and optimised during this phase.

Load management consisted of reviewing the historic workloads including bowling volume and intensity to inform bowling workload progressions during rehabilitation. Bowing actions were assessed by the athletes preferred bowling advisor. Generally this process consisted of video analysis of the biomechanics of the action at various points (back foot landing, front foot landing, ball release) with emphasis on the amount of lumbar spine extension, side flexion range and shoulder/hip counter rotation angle.

In all cases demographic and injury characteristics were recorded. Return to play data was also collected including the timelines required and the level (state/international) of cricket achieved. For those players with operations performed prior to 2016 these outcomes were recorded retrospectively from the case notes. For the group post 2017, return to play data was collected prospectively. Also recorded prospectively in the post 2017 group was peri-operative adverse events, union rates on CT scanning 6–12 months post-surgery and Visual Analogue Scale (VAS, 1–10) pain scores at 1-year post-op reflecting the level of back pain typically experienced during both normal activities and when playing cricket.

At final follow-up all players were surveyed by telephone or email on a range of aspects of their post-operative rehabilitation and their status post-surgery. This included a specific question on 'how you rate your bowling ability post-surgery, compared to your abilities prior' with the following categories provided: same or better, loss of 10% performance, loss of 10–20% performance, loss of >20% performance.

Table 1 Post-operative rehabilitation protocol

Phase	Functional objective	Weeks	Activities	Avoid/precautions
Wound care/pain management	Prepare to move	0–2	Regain functional ROM and ADL's	Wound infection; over exertion (range of movement, ADL's i.e., lifting)
Muscle and bone healing	Prepare to load	2–6	Lower abdominal activation; mobility patterns (neutral spine); non axial leg strength; fitness (non-weight bearing)	End range extension; increased ground reaction forces (i.e., running)
Trunk and leg strength	Prepare to run	6–10	Lower limb strengthening; multi-joint strength; anti-rotation strength; off feet conditioning (e.g., Alter-G, X-Trainer)	End range extension; lumbar spine rotation; increased ground reaction forces (i.e., running)
Running	Preparation for bowling	10–16	Trunk rotation strength; plyometrics; interval running (focus on progression of intensity)	Combined rotation and ground reaction forces i.e., bowling
Bowling	Preparation for play	16+	Gradual progression of bowling load, frequency and intensity	Accelerated loading program
Playing	Preparation to perform	TBC	Progression of playing intensities back to original level of competition	Accelerated playing program i.e., multi-day games as first game time

The active phases [2–6] involve progression of loads which are thought to be safe based on accepted healing timeframes of the tissue affected during the surgical process. ROM, range of motion; ADL, activities of daily living.

Statistical analysis

Statistical analysis, involving calculations of median +/– interquartile range (IQR), was performed on EXCEL (Microsoft).

Ethical statement

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Given its status as an observational audit of standard clinical practise this study was considered exempt from requiring New Zealand Health and Disability Ethics Committee approval, however all patients gave informed consent to the collection of relevant data.

Results

A total of 13 professional fast bowling cricketers from 3 countries (New Zealand 9, Australia 3, India 1) were included in the case series. Five players had demographic, injury and return to play data collected retrospectively, while 8 were followed prospectively. Ten players completed the survey on post-operative rehabilitation aspects and bowling performance at final follow-up [median 38 months (IQR 31–103), range, 15–197].

The baseline demographics of the cohort and injury characteristics are summarised in *Table 2*. At the time of surgery, the youngest player was aged 20 years and 4 months while the oldest was 29 years and 6 months old. No player had a history of previous lumbar surgery.

Prior to surgery all players experienced significant disruption to their professional career as a result of their lumbar stress fractures. Eleven players experienced recurrent fractures, reoccurring at the same anatomical site. The median time between a players first confirmed diagnosis of spondylolysis and surgery was 31 months (IQR 25–54; range, 13–107). The median number of 'cycles', comprising of a fracture or re-fracture followed by a further course of conservative rehab was 3 (IQR 2.75–3.25; range, 1–4). Players were repeatedly sidelined during these periods of conservative treatment. While no universal strategy was followed, conservative care generally comprised of 2–6 months of rest, then rehabilitation coupled with advice about bowling technique and loads. Compliance with these protocols' pre-surgery was not documented. One player with a unilateral fracture (confirmed radiologically 4 years prior) had developed a hypertrophic non-union that resulted in radiculopathy of the traversing nerve, 7 months prior to surgery. One player with bilateral established defects had experienced episodic lumbar pain for 5 years, was first diagnosed radiologically 15 months prior to surgery, and remained symptomatic despite 2 periods of conservative care prior to surgery.

In nine players the lumbar stress fracture was unilateral.

Table 2 Baseline patient demographics and stress injury features

Variable	Outcome
Mean age (at surgery)	26 years (range, 20.3–29.5 years)
Nationality	New Zealand 9, Australia 3, India 1
Delivery arm	Right 8, left 5
Grade of cricket (prior)	State 7, international 6
Level:	L2 1; L3 2; L4 5; L5 5
Unilateral/bilateral	Unilateral 9: 8 recurrent acute, 1 chronic. Bilateral 4: 3 chronic (one side)/acute (opposite), 1 chronic both sides
Spondylolisthesis	At index level 0/13; other level (one) 2/13 (both L5/S1)

Table 3 Survey results at final follow-up

Variable	Outcome
No. of players interviewed	10 (77%)
Duration post surgery	Median 38 months (IQR, 31–103 months), range, 15–197 months
Rating of bowling performance post surgery	Same or better (100%)
Further spinal injury (>4 weeks sidelined)	0/10
Required further spinal Intervention	0/10
Concomitant injuries during rehab	5/10
Back Pain (VAS 0–10) playing cricket median [IQR]	1 [0–3]
Back Pain (VAS 0–10) normal activities median [IQR]	1 [0–2]

All were located on the side opposite the bowling arm. Four players had bilateral injuries. Three players had a chronic fracture on one side (opposite to the bowling arm) and recurrent acute injuries on the other side (all on the same side of the delivery arm). One player had chronic established radiographic features on both sides.

No player had spondylolisthesis at the index level. Two players had chronic established pars defects at another single level, both involving L5. One player had chronic bilateral pars defects at two other levels, involving the adjacent vertebra above (L3) and below (L5) his surgical level (L4), including a grade 1 L5/S1 spondylolisthesis.

The surgeries were performed by GI (5 cases), GI and RS combined (5 cases) or RS (3 cases). In 11 cases intraoperative imaging was provided by image intensifiers while in 2 cases intra-operative CT guidance (OARM, Medtronic) was employed.

All 13 players have returned to play professional cricket, 12 performing at the same level or better than prior to surgery. The median time to return to play state cricket or better was 8 months (IQR, 7–11 months). Of the 7 cricketers playing state level cricket prior to surgery, all returned to play state cricket again with 2 players progressing to play international cricket post-surgery. Of the 6 international players, 5 have returned to play international cricket. One of these players did not bowl again at international level due to a subsequent shoulder injury. One prior international player, with 6 ODI and 6 T20 caps, has not returned to international cricket to date but continues to bowl in state level cricket.

Of the 8 players monitored prospectively 2 developed superficial wound erythema treated successfully with oral antibiotics and dressings. CT scans taken 6 to 12 months post operatively confirmed union had occurred in seven (88%) players. The only player monitored prospectively who demonstrated bony non-union had established bilateral chronic appearing pars defects on presentation. Despite these radiographic findings they returned to play competitive state cricket 8 months post-surgery and continue to play as an allrounder 42 months post-surgery. The median VAS (0–10) level of back pain reported while bowling by the prospective cohort at 12 months post-surgery was 1 (IQR, 1–1.25) and in normal everyday activity was 1.5 (IQR 1–2).

At final follow-up 10 players completed the survey (*Table 3*). All players rated their bowling performance as either the 'same or better' compared to their abilities prior to their pre-surgery injury. No player reported a reduction in their bowling performance post-surgery. No player post recovery from surgery, reported having suffered a further

Table 4 Published series of spondylolysis repair in cricketers

Author	Number	Mean age (years, range)	Mean follow up (months, range)	Union rate	Return to competitive cricket
Hardcastle (2) [1993]	10	21 [15–235]	18 [6–47]	100%	9/10 (90%)
Ranawat *et al.* (3) [2003]	9	22	68 [22–120]	Not specified	9/9 (100%)
Debnath *et al.* (9) [2003]	4	Not specified†	Not specified†	Not specified†	4/4 (100%)

†, subgroup of a larger cohort.

spinal injury requiring being sidelined for >4 weeks or has received further spinal surgery or interventions (e.g., injections) for any spine related pathology, including the index level of surgery. At final follow-up median VAS (0–10) level of back pain while bowling was 1 (IQR, 0–3) and in normal everyday activity was 1 (IQR, 0–2).

All players reported the post-surgical rehabilitation program was more thorough and extensive compared to those experienced when the prior injuries were managed non-operatively. Seven of the 10 surveyed players reported changes to their bowling action were initiated during the post-surgery rehabilitation period. Eight players reported more conservative management of their bowling loads post-surgery.

Concomitant injuries occurred in 5 players during the rehabilitation process especially in the transition to higher intensity parts of the program i.e., running, bowling and having returned to play. These injuries occurred in the groin (3), hamstring, quadriceps, and shoulder. At final follow-up, 10 players continue to play cricket professionally ranging from 15 to 107 months post-surgery [median 35 months (IQR, 24–43)]. Three players have since retired at 32, 69 and 119 months post-surgery including one player who retired at 34 years and 11 months of age having played an additional 57 months of international cricket after surgery.

Discussion

Our consecutive case series of 13 multi-national male professional cricket fast bowlers whose careers has been repeatedly interrupted with lumbar stress fractures, demonstrated favorable return to play rates and career longevity following surgical repair. All players successfully returned to play professional cricket. All ten players surveyed at final follow-up rated their bowling performance post-surgery as the same or better than prior and reported durability post-surgery with no subsequent periods sidelined by significant spinal injuries or further surgical intervention necessary. To our knowledge it is the largest published surgical series of spondylolysis repair in cricketers, and the first to document the success of a cable-screw surgical technique.

The efficacy of surgical repair of lumbar stress injuries in a wide range of athletes has been proven. Return to sports following surgery is typically reported to occur at rates greater than 80% and at intervals from 5 to 12 months (9-13). Of the many surgical techniques available that preserve the motion segment, the most common reported in elite athletes involves a direct repair with inter-fragmentary screw fixation directly across the defect and cancellous bone grafting as described by Buck (14). Repair via compression across the defect achieved with cable-screw system has been less commonly utilised (7,15-18) despite a lack of strong evidence favoring any of the described surgical techniques in use (11,13,19).

The repair of spondylolysis using compression obtained with wire and cables has various iterations. Nicol and Scott (20) in their original description of repair by wiring placed stainless steel wire around the transverse process and beneath the spinous process. Subsequently surgeons, concerned about the fragility of the transverse process added pedicle screws to achieve a more robust anchor and directed two wires or cables in various patterns sublaminarly or around the spinous process (15-17). The surgical technique preferred by the senior author (GI) largely follows these later versions albeit using a single cable passed in same trajectory as originally employed by Nicol and Scott.

Outcomes from surgical repair of pars injuries in highly selected professional cricketers has been previously reported, however the published literature is limited to small cases series (2-4) (*Table 4*). Of a combined 23 players included in these reports, 22 returned to play competitive cricket. Exclusively the surgical technique used involved the 'Bucks' direct screw repair prompting many authors to conclude that this technique should be considered the 'operation of choice' for professional cricketers (3).

However, the results of this case series suggest that a further proven option also exists. While excellent outcomes using a Bucks screw technique in athletes are undeniable, proponents of cable-screw systems favour their use because of equivalent clinical success and its simplicity (7,15-19). Rather than the success of the surgery being dependent on accurate screw placement at a trajectory specific to each fracture morphology, the screw-cable system can be consistently applied to a wide variety of injuries. It also avoids a large proportion of the pars' footprint being occupied by a screw, leaving the area free to participate in bony union. We recognise that a greater degree of erector spinae dissection is necessary, particularly compared to minimally invasive and percutaneous screw fixation techniques (21,22), but there have been no obvious adverse outcomes related to muscle dissection.

While non-surgical management remains the mainstay of treatment for an initial acute lumbar stress injury, in our experience, players presenting with recurrent unilateral fractures at the same site (with or without contralateral chronic defects) are the most appropriate surgical candidates. Successful outcomes were achieved in players with additional established bilateral defects at other levels when the players symptomatic profile could be accurately correlated with the development of acute refractures at the chosen surgical level. In these scenarios' radiological features such as bone marrow oedema was regarded as a reliable marker. We do not typically use injections to localise symptomatic levels.

It is widely acknowledged that asymptomatic spondylolysis is common in many athletes (15). It remains clinically challenging to confirm that these isolated established defects are the primary pain generator, a key prerequisite in assessing surgical suitability. While clinical success was achieved in this player, he was the only player not to develop bony union. Examples of clinical success despite radiological pseudarthrosis have been previously reported in case series of repair of spondylolytic defects (7). The success of surgery in these cases is postulated to result from stabilisation of the hypermobile posterior arch (7,13).

All surveyed players commented on the essential role rehabilitation protocols played in their recovery. In addition, players also committed to addressing key recognizable risk factors including bowling loads and technique. Players reported, and were observed to, being more focused and compliant with graduated rehabilitation protocols post-surgery compared with prior conservative management protocols, possibly reflecting the appreciation that this was a potentially career defining event. We therefore acknowledge that the keys to success in this specific cohort are multifactorial and it is impossible to accurately apportion how much of the clinical success in our cohort was related to surgical factors versus post-surgery rehabilitation versus changes in bowling loads and technique. The management of these players is therefore best addressed by an experienced collective of physiotherapists, sports physicians, radiologists and surgeons with a special interest in lumbar stress injuries. This creates a consistency and familiarity with surgical selection, clinical pathways, surgery strategies and post-operative rehabilitation protocols.

Other limitations of the study include the ambispective and subjective reporting of outcomes, with five players in this series having their clinical outcomes assessed retrospectively. A wide range in the time periods between surgery and the final follow-up survey, mixes short- and long-term results. Some players currently relatively early post-op may in time experience delayed surgically related complications. It is also acknowledged that sporting performance post-surgery lacks a standardized metric, is difficult to define and near impossible to quantify (10), however, we considered return to professional play rates, pain levels and career durability as the most relevant surrogate measures.

Conclusions

In our experience, for elite cricketers repeatedly sidelined by lumbar spondylolysis, surgical repair using the described technique followed by compliance with a thorough rehabilitation protocol promotes durable healing in a manner compatible with high rates of return to bowling at a professional performance level.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). Given its status as an observational audit of standard clinical practise this study was considered exempt from requiring New Zealand Health and Disability Ethics Committee approval, however all patients gave informed consent to the collection of relevant data.

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