Direct surgical repair of spondylolysis in athletes: indications, techniques, and outcomes

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Object. Athletes present with back pain as a common symptom. Various sports involve repetitive hyperextension of the spine along with axial loading and appear to predispose athletes to the spinal pathology spondylolysis. Many athletes with acute back pain require nonsurgical treatment methods; however, persistent recurrent back pain may indicate degenerative disc disease or spondylolysis. Young athletes have a greater incidence of spondylolysis. Surgical solutions are many, and yet there are relatively few data in the literature on both the techniques and outcomes of spondylolytic repair in athletes.5

Methods. A systematic review of the MEDLINE and PubMed databases was performed using the following key words to identify articles published between 1950 and 2011: “spondylolysis,” “pars fracture,” “repair,” “athlete,” and/or “sport.” Papers on both athletes and nonathletes were included in the review. Articles were read for data on methodology (retrospective vs prospective), type of treatment, number of patients, mean patient age, and mean follow-up.

Results. Eighteen articles were included in the review. Eighty-four athletes and 279 nonathletes with a mean age of 20 and 21 years, respectively, composed the population under review. Most of the fractures occurred at L-5 in both patient groups, specifically 96% and 92%, respectively. The average follow-up period was 26 months for athletes and 86 months for nonathletes. According to the modified Henderson criteria, 84% (71 of 84) of the athletes returned to their sports activities. The time intervals until their return ranged from 5 to 12 months.

Conclusions. For a young athlete with a symptomatic pars defect, any of the described techniques of repair would probably produce acceptable results. An appropriate preoperative workup is important. The ideal candidate is younger than 20 years with minimal or no listhesis and no degenerative changes of the disc. Limited participation in sports can be expected from 5 to 12 months postoperatively. (DOI: 10.3171/2011.9.FOCUS11180)

Key Words • pars interarticularis repair • lumbar spondylolysis • pedicular screw • surgery • outcome • technique • athlete • sports

Spondylolysis is usually an asymptomatic pars interarticularis defect caused by a stress fracture in one or both sides of the neural ring. These fractures can lead to stimulation of the free nerve endings and cause significant back pain, mostly in young athletes ages 12–16 years.1,6 The goals of treatment are the alleviation of pain and the restoration of stability. Conservative management with activity restriction for pain control followed by 3–6 months of lordotic bracing is recommended.10 Despite changes in their daily activities and secession from all strenuous sports, some patients will continue to experience low-back pain. Although the incidence of unmanageable back pain in these competitive athletes is low, some individuals experience debilitating symptoms that could prevent them from pursuing their passion for sports.5,22 Direct surgical repair of spondylolysis is well documented as an effective treatment in young patients in whom nonoperative treatment fails.1,6,7,28,39

Surgical Repair of Spondylolysis

Indications for Surgical Repair

Surgical repair of spondylolysis is indicated in cases in which low-back pain has not resolved after at least 6 months of activity modification and other nonoperative treatment modalities. Increasing pain, worsening neurological problems, and progressive listhesis also are indications for surgical consideration.10,17 Historically, patients with high-grade spondylolisthesis are considered for multilevel fusions whereas lower grade slips or spondylolysis

Abbreviation used in this paper: rhBMP-2 = recombinant human bone morphogenetic protein–2.
without any slips is suited for direct repair.\textsuperscript{32,34} Athletes younger than 20 years are treated with direct repair of the pars defect. Once their pain is controlled, these athletes can start muscle strengthening and range of motion exercises that, with aggressive rehabilitation programs, will have the best chance of returning them to their desired sports.

Preoperative Management

Preoperative studies should illustrate a lytic defect, minimal spondylothesis, healthy disc, and negligible movement of the vertebra. Plain anteroposterior and lateral flexion and extension radiographs can clearly demonstrate any degree of slippage or any motion abnormality in the vertebrae.\textsuperscript{35} These studies should be supplemented with CT scans to define the bony anatomy of the pars.\textsuperscript{6,10} The addition of SPECT scanning allows the detection of an occult and acute stress fracture that would otherwise be missed on plain radiographs.\textsuperscript{36} Moreover, it would ensure the presence of metabolic activity in the lysis as the cause of pain, a factor that would increase the surgical chances of osseous union.\textsuperscript{6} Finally, proper evaluation of cause of pain, a factor that would increase the surgical chances of osseous union.\textsuperscript{6} Finally, proper evaluation of cause of pain, a factor that would increase the surgical chances of osseous union.

Overview of Surgical Techniques

In 1968, Kimura\textsuperscript{23} reported on bone grafting without internal fixation for spondylolytic defects. Although in 1968 Scott began using a wiring technique to augment bone grafting of the lytic defect, his results were not published until 1986.\textsuperscript{28,56} Many authors use the Scott wiring method, whereas others have modified the technique to include pedicle screws or cable instead of wire.\textsuperscript{39} In 1970, Buck\textsuperscript{7} documented the use of a lag screw across the lysis, and many authors have described their outcomes following this technique. In 1984, Morscher et al.\textsuperscript{27} reported that the Buck technique of using a 3.5-mm lag screw did not work well with a thin or dysplastic lamina, and they advocated using laminar fixation with a hook screw device specially made for this purpose. That device, a modified Harrington hook that accepts a bone screw, is no longer available from the original manufacturer.\textsuperscript{6} Other authors have reported using pedicle screws to secure the lamina with either a rod-hook construct or a V-shaped rod under the spinous process.\textsuperscript{1,12,29,39}

Basic Surgical Technique. A standard midline approach to the lumbar spine is performed with care taken to preserve the multifidi attachment to the lateral capsules of the L4–5 and L5–S1 facet joints (unless pedicle screws will be used) and to keep the supraspinous and interspinous ligaments intact. The pars defect is exposed and fibrous tissue is removed. Direct exposure of the pars defect is unnecessary if the lytic defect is in the coronal plane. Internal fixation is applied next. Through a 3-cm window over the posterior inferior iliac spine, a small amount of cancellous bone can be harvested from the iliac crest. Some have reported harvesting cancellous bone from the ala of the sacrum, whereas others use cancellous allograft or off-label rhBMP-2 (Medtronic Sofamor Danek).\textsuperscript{9,27} The graft is placed as an onlay at the pars defect with care taken not to place the graft ventral to the defect, a location which could compromise the exiting nerve root. Resection of the caudal 3–5 mm of the inferior facet joints of the cephalad vertebra is recommended no matter what internal fixation is selected. Theoretically, this resection reduces the possibility of the inferior facets impinging into the pars region when the patient stands or loads the spine, particularly during hyperextension.

Single Lag Screw Fixation (Buck). After exposing the pars defect and lamina bilaterally, the inferior edge of the lamina is squared off using a bur.\textsuperscript{7} A drill is introduced at this edge and is directed upward, forward, and slightly outward to pass through the pars and across the pars defect. Direct visualization should confirm the passing of the drill through the pars defect, and the drill trajectory should remain wholly within bone. A screw of appropriate length is placed through this path, and again the screw must be seen to pass through the pars defect. The screws are partially withdrawn, and an autologous bone graft from the iliac crest is placed in the pars defect. The screws are readvanced forward through the pars defect, securing the bone graft in place and stabilizing the construct (Fig. 1). A less invasive modification of the Buck method involves stereotactic navigation using the O-arm (Medtronic, Inc.).\textsuperscript{5} After exposing the spinous process, a trajectory across the pars defect is determined via navigation. A Kirschner wire is passed through this trajectory, and a cannulated screw is placed over the wire across the defect.

Hook Screw Fixation (Morscher). Autologous cancellous bone grafts from the iliac crest are first placed into the pars defects.\textsuperscript{27} Then, 2.5-mm holes are drilled at

![Fig. 1. Drawing showing single lag screw fixation as described by Buck, 1970.](image)
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the bases of the superior articular processes bilaterally. Special screws whose tips consist of a cancellous thread and whose bases consist of a machine thread are used. The screw head is designed to allow attachment to a hook that hooks over the lamina. The screws are inclined so that they form a 40° angle with the superior vertebral endplate. The screws are also placed approximately 20° divergent from each other. The hooks are attached to the screw heads and fastened via a lock nut. The distal end of the hook is hooked underneath the lamina. The lock nut is tightened to achieve appropriate compression over the defect (Fig. 2).

Cerclage Wire Fixation (Scott). The pars defects, laminae, and transverse processes are exposed. The soft tissues on the anterior edge of the transverse processes are freed from the transverse processes. The sclerotic margins of the pars defects are drilled down to expose healthy bone, and the transverse process, superior facet, and lamina are decorticated. A 2-mm hole is drilled in the base of each transverse process, and a 4-mm hole is drilled in the base of the spinous process. A wire is passed through the hole in the transverse process and draped superiorly over the top of the transverse process. The other end of the wire is passed through the hole of the spinous process and draped inferiorly around the bottom of the spinous process. The same procedure is performed on the contralateral side. Autologous cancellous bone from the iliac crest is used to fill the pars defect, and strips of corticocancellous bone from the iliac crest are laid over the pars defect beneath the wires, extending from the base of the transverse process to the lamina. The wires are tightened, providing compression and stabilization across the pars defects (Fig. 3).

Pedicle Screw Cable Fixation (Songer). The bone graft is inserted into the pars defect between the pedicle above and the lamina below. Pedicle screws are placed with the entry point just below the facet joint. A cable is passed underneath the left laminae, threaded through the right pedicle screw head, and finally draped around the cranial end of the spinous process. The 2 ends of the cable are tied together. A second cable is passed in a similar fashion under the right laminae and through the left pedicle screw head. The ends of the cables are crimped to apply tension to the cables (Fig. 4).

Postoperative Routine

The postoperative course and radiographic studies are managed and tailored by each surgeon and his or her rehabilitation team. In the early postoperative period, most authors have recommended plain radiographs for asymptomatic patients and CT or MR imaging studies only if symp-
toms persist or new symptoms appear; however, fusion and attenuation of pars fractures are mostly assessed 3–6 months from surgery by performing CT scanning. Early mobility and ambulation, as well as the avoidance of heavy lifting and strenuous activities for the first 3 months, are highly encouraged. Additionally, patients are discouraged from any hyperextension or flexion movement in the first 3 postoperative months. As regards to postoperative physical therapy, the literature does not provide enough reliable data; some authors recommend avoiding any physical therapy exercises as long as 3 months from the operation. As most patients are younger adult and teenage athletes, however, they typically have a fast recovery and are able to return to sports conditioning within 6 months of their operations.

At our institution, we follow up patients with plain anteroposterior/lateral and oblique radiographs 4 and 10 weeks from the surgery and with CT scanning in 6 months to confirm pars stabilization. Additionally, we gradually ease them into physical therapy exercises within 4 weeks after surgery while a team of physiatrists strictly monitors their progress. A team of pain specialists weans them from all narcotics within the first 2 months and, in general, by 10 weeks after surgery they are eased back into their sport activities but with limitations. They are fully released to competitive activities within 5–6 months post-operation.

In the literature, many studies outline the natural history, nonoperative treatment, and prevalence of lumbar spondylolysis in athletes. However, the literature lacks a review article on the most common surgical techniques for pars fractures and their respective outcomes in athletes. The objective in the present study was to review the surgical techniques for and outcomes of the treatment of symptomatic spondylolysis in athletes.

Methods

Literature Review

Both the PubMed and MEDLINE databases were searched to identify articles that had been published between 1950 and 2011 which were pertinent to the methods and outcomes of the surgical treatment of spondylolysis in athletes. The key words used in the search were “spondylolysis,” “pars fracture,” “repair,” “sport,” and/or “athlete.” Inclusion criteria were full-length English-language papers or abstracts, surgical treatment, athlete outcomes, prospective studies, and retrospective studies. Exclusion criteria were non–English-language papers or abstracts and inadequate information about outcomes and/or surgical treatment. The efficacy of the surgical treatment of spondylolysis in athletes was clarified. The primary end points were descriptions of the procedures in and the outcomes of surgical treatment.

An initial search using the key words “spondylolysis” and/or “sport” returned 262 articles. The search was further limited to the English-language literature (223 articles) and a patient age of 24 years or younger (123 articles). Two separate authors (D.D. and A.S.) reviewed abstracts from these articles, yielding 123 articles for detailed review.

Of these 123 articles, 105 were excluded from analysis because they failed to meet the surgical treatment criterion or to report postoperative outcomes. The remaining 18 articles were included in our analysis. Articles were reviewed for data on methodology (retrospective vs prospective), type of treatment, number of patients, mean patient age, and mean follow-up. Specifics on the patient and the fracture included which competitive sport, level of fracture, degree of spondylolisthesis, complications, and need for reoperation. Clinical outcome data, based on patient reporting and preoperative evaluation, were also recorded when available. In addition, we used modified Henderson criteria that subjectively assessed the patient’s pain and ability to return to sports (Table 1).

Statistical Analysis

All descriptive statistics were calculated using JMP 7.02 (SAS Institute). Averages for age, duration of follow-

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
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<tbody>
<tr>
<td>excellent</td>
<td>no pain; return to normal occupation &amp; normal sport</td>
</tr>
<tr>
<td>good</td>
<td>occasional pain after strenuous activity; return to normal occupation &amp; less strenuous sport</td>
</tr>
<tr>
<td>poor</td>
<td>pain persists; unable to return to occupation &amp; participate in sport</td>
</tr>
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up, and Henderson criteria were calculated. Additionally, studies documenting patient-reported outcomes were summarized.

Illustrative Cases

History and Examination. A 23- and a 19-year-old male professional athlete both presented with several-year histories of ongoing and worsening low-back pain. At that time, both patients were being considered for competition at the highest level, and they described their symptoms as worsening with increased activity and training. The main symptom was primarily axial midlumbar back pain with occasional radiation into the gluteal region. It was aggravated by lumbar hyperextension and rotation positions and was relieved by rest. Prior to our evaluation, both patients had undergone nonoperative treatment including exhaustive physical therapy, core body strengthening, transcutaneous electrical nerve stimulation, massage, bracing, and trigger point injections. Both denied experiencing any weakness, radicular symptoms, or bowel or bladder incontinence. Each had been treated with intermittent extended periods of rest and inactivity but the symptoms would recur once training was restarted. In light of their high performance sports demands, each patient refused any invasive needle injections and permanent activity limitations or modifications. Subsequent advanced imaging was performed, and CT scans of the lumbar spine in both patients demonstrated bilateral L-5 pars fractures (Fig. 7). A SPECT CT scan confirmed increased activity at the bilateral pars fractures. Lateral flexion and extension lumbar spine radiographs showed no evidence of significant dynamic spondylolisthesis, and MR imaging showed preserved discs at L4–5 and L5–S1. Additionally, there were no signs of significant central or foraminal stenosis.

After a discussion of each patient’s high functional demands and an explanation of the procedure’s risks and benefits, we agreed to perform an intrasegmental bilateral pars repair using a pedicle screw rod fixation technique in each patient.

Operation. Using a standard limited midline approach centered over the L-5 lamina, we exposed the bilateral pars pseudarthroses with care not to disturb the facet capsule of L4–5. Under microscopic visualization, we used a high-speed drill bit to resect the sclerotic bony ends of the pars fracture. The underlying L-5 nerve root was identified and decompressed as it traversed the foramen. Pedicle screws were inserted into the bilateral L-5 pedicles in a laterally based trajectory to avoid facet abutment. An appropriately contoured curved rod was passed across the midline under the interspinous ligament and spinous process of L-5. The rod was affixed to each screw, causing direct compression across the pars fracture sites. Once the instrumentation was secured, the bilateral pars region was grafted with locally harvested autograft (and demineralized bone matrix, if necessary).

Postoperative Course. Following the operation, each patient gradually returned to regular activity within 4 weeks under a strict physical therapy regimen. Follow-up radiographs were obtained (Fig. 8). Both patients were completely weaned off narcotic medications and returned to sports conditioning for the next 8–10 weeks. A full return to competitive sports occurred at approximately 5 months posttreatment.

Results

We identified 9 studies that specifically included athletes. One of these studies was a case report, whereas the rest were case series. One was a prospective study and the rest were retrospective. All studies involved surgical treatment. Nine studies of nonathletes were used to compare the results of the techniques applied to repair spondylolysis; all of these studies were retrospective case series involving surgical treatment. Tables 2 and 3 show the outcomes of surgical treatment in athletes and non-athletes. Eighty-four athletes and 279 nonathletes with a mean age of 20 and 21 years, respectively, were reviewed (Fig. 9). Cricket, soccer, and baseball were the most common athletics described in the studies reviewed (Fig. 10).

Fig. 7. Illustrative case. Preoperative sagittal (A and B) and axial (C) reconstruction images showing bilateral L-5 spondylolytic defects.
The studies did not consistently document when a spondylolisthesis was present, but among the studies that did, there seemed to be a trend toward a higher likelihood of spondylolisthesis in nonathletes. Most of the fractures were at L-5 in both patient groups, specifically 96% in athletes and 92% in nonathletes. The average follow-up period was 26 months for athletes and 86 months for nonathletes. According to the modified Henderson criteria, 84% (71 of 84) of the athletes returned to their sports activities (Fig. 11). The time interval until their return ranged from 5 to 12 months. Of the remaining athletes, 7 returned to a less strenuous sport and 6 did not return to any sports in the study period.

Age-Related Outcomes

Direct surgical repair of spondylolysis has largely focused on patients younger than 30 years old. Most authors theorize that the outcomes are better for younger patients because their discs are less degenerative and more suitable for direct repair. The study by Ivanic et al.17 is most often cited as evidence for a 20-year age cutoff. In that study, 113 patients were treated using the Morscher technique. Of the 20 treated patients older than 20 years of age, 35% had pseudarthroses, whereas only 8.6% of the 93 patients younger than 20 years had pseudarthroses. There was persistent postoperative pain in 4 of the 20 patients older than 20 years and in only 4 of the 93 patients younger than 20 years. In a case series by Nozawa et al.,30 among 20 athletes treated using a Scott wiring technique, 13 were older than 20 years of age. Among the treated patients, 70% of those older than 20 years of age had an excellent clinical outcome, whereas 86% of the patients 20 years old or younger had an excellent clinical outcome.

Johnson and Thompson21 used a modified Scott technique and found “satisfactory” results for all 19 patients under 25 years of age. In the patients older than 25 years, 2 of 3 had “poor” results. Debuisscher and Troussel9 discussed their case series in which they used pedicle screw hook fixation with 12 patients 30 years of age or younger and 11 patients older than 30 years. In the younger group, all patients had a good or excellent clinical outcome, whereas only 73% of patients in the older group had a similar outcome.

Outcomes of Specific Techniques

Single Lag Screw Fixation (Buck). Outcomes following the Buck fixation have been widely published for both nonathletes and professional athletes in a variety of sports. The published outcomes for athletes in our extensive literature search consistently showed that > 90% of patients eventually return to their preoperative sports performance.5,8,14,31,32 Outcomes for nonathletes show similar but slightly lower success rates, possibly because athletes are often known to be highly motivated in their recovery process.7

Hook Screw Fixation (Morscher). The literature is lacking in data on outcomes following hook screw fixation in athletes, but there are several reports on the procedure in nonathletes. In a retrospective study of 113 patients, Ivanic et al.17 found that > 90% of patients had excellent clinical outcomes after hook screw fixation with a mean follow-up of 10.9 years.

Cerclage Wire Fixation (Scott). Many authors have published outcomes of the Scott method in both athletes and nonathletes. The data consistently show outcomes that are not as favorable as those for other direct repair techniques. Many studies show between 60% and 80% of patients having an excellent clinical outcome.3,21,30,35

Pedicle Screw Cable Fixation (Songer). In 1998, Songer and Rovin38 published a small study showing the outcomes associated with a new pedicle screw cable fixation technique. The study involved 7 patients, 5 of whom had excellent clinical outcomes. Bozarth et al.5 modified the Songer technique in 3 patients and found that they all had excellent clinical outcomes. Our literature search did not yield further data on this technique.

Pedicle Screw Hook Fixation. Data from several retrospective studies on pedicle screw hook fixation with small numbers of nonathlete patients have been published. Noggle et al.29 showed an excellent clinical outcome in 5 of 5 patients. Two slightly larger studies, one by Kakiuchi22 and another by Debuisscher and Troussel,9 showed about 80% of patients having an excellent clinical outcome.

Pedicle Screw Rod Fixation. Data on pedicle screw and rod fixation have been published by 2 different authors. Gillet and Petit23 used a V-shaped rod, whereas Altaf et al.1 used a U-shaped rod. Both were small studies of 10 and 20 patients, respectively. Gillet and Petit found excellent clinical outcomes in only 60% of patients, whereas Altaf et al. documented excellent outcomes in 90% of patients. It is difficult to draw conclusions about this technique with only 2 small studies.
### TABLE 2: Literature review of athletes with spondylolysis who underwent direct surgical repair*

<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>No. of Pts</th>
<th>Direct Repair Method (no. of pts)†</th>
<th>Sport</th>
<th>Mean Age in Yrs (range)</th>
<th>% Pts w/ Bilat Defects</th>
<th>% Pts w/ Spondylolisthesis</th>
<th>No./Vertebral Level</th>
<th>Average FU in Mos (range)</th>
<th>Outcome in % of Pts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardcastle et al., 1992</td>
<td>10 Buck</td>
<td>cricket</td>
<td>cricket</td>
<td>20.9 (15–25)</td>
<td>50</td>
<td>10</td>
<td>L-5, L-4</td>
<td>17.9 (6–47)</td>
<td>90‡</td>
</tr>
<tr>
<td>Ranawat et al., 2003</td>
<td>9 Buck</td>
<td>cricket</td>
<td>cricket</td>
<td>21.7</td>
<td>50</td>
<td>NA</td>
<td>NA</td>
<td>68 (22–120)</td>
<td>100‡</td>
</tr>
<tr>
<td>Reitman &amp; Esses, 2002</td>
<td>4 Buck</td>
<td>soccer, gymnastics, baseball</td>
<td></td>
<td>17.8 (13–22)</td>
<td>NA</td>
<td>25</td>
<td>L-5</td>
<td>26 (21–38)</td>
<td>100‡</td>
</tr>
<tr>
<td>Noggle et al., 2008</td>
<td>5</td>
<td>pedicle screws, rod &amp; laminar hook</td>
<td>variety</td>
<td>15.8 (15–17)</td>
<td>100</td>
<td>NA</td>
<td>L-5</td>
<td>7.2 (6–9)</td>
<td>100§</td>
</tr>
<tr>
<td>Debnath et al., 2003</td>
<td>22</td>
<td>modified Buck (19) &amp; Scott (3)</td>
<td>variety</td>
<td>20.2 (15–34)</td>
<td>68</td>
<td>NA</td>
<td>NA</td>
<td>7</td>
<td>95 (Buck), 0 (Scott)‡</td>
</tr>
<tr>
<td>Brennan et al., 2008</td>
<td>1</td>
<td>modified Buck</td>
<td>baseball</td>
<td>17</td>
<td>100</td>
<td>100</td>
<td>L-5</td>
<td>6</td>
<td>100‡</td>
</tr>
<tr>
<td>Bozarth et al., 2007</td>
<td>3</td>
<td>Scott &amp; Songer</td>
<td>soccer, baseball</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>100‡</td>
</tr>
<tr>
<td>Nozawa et al., 2003</td>
<td>20</td>
<td>Scott</td>
<td>variety</td>
<td>23.7 (12–37)</td>
<td>NA</td>
<td>19 L-5, 2 L-4, 1 L-4–5</td>
<td>3.5 (1.3–8.6)**</td>
<td>75¶</td>
<td></td>
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<tr>
<td>Gillet &amp; Petit, 1999</td>
<td>10</td>
<td>pedicle screws, V-shaped rod</td>
<td>tennis††</td>
<td>26 (16–48)</td>
<td>NA</td>
<td>0</td>
<td>L-5, L-4</td>
<td>35 (7–64)</td>
<td>60§</td>
</tr>
</tbody>
</table>

* FU = follow-up; NA = not available; Pts = patients.
† If no number is listed in parentheses, all patients underwent listed method of repair.
‡ Returned to preoperative sports performance (athletes).
§ Asymptomatic or with minimal symptoms.
¶ Excellent outcome by Henderson criteria, that is, no pain; return to normal occupation and normal sport.
** Values expressed in years.
†† One athlete.
<table>
<thead>
<tr>
<th>Authors &amp; Year</th>
<th>No. of Pts</th>
<th>Direct Repair Method</th>
<th>Mean Age in Yrs (range)</th>
<th>% Pts w/ Bilat Defects</th>
<th>% Pts w/ Spondylolisthesis</th>
<th>No./Vertebral Level</th>
<th>Average FU in Yrs (range)</th>
<th>Outcome in % of Pts</th>
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<tr>
<td>Ivanic et al., 2003</td>
<td>113</td>
<td>Morscher</td>
<td>16.9 (7.5–39)</td>
<td>NA</td>
<td>95</td>
<td>11 L-5, 1 L-4, 1 L-4–5</td>
<td>10.9 (1–15.5)</td>
<td>93*</td>
</tr>
<tr>
<td>Johnson &amp; Thompson, 1992</td>
<td>22</td>
<td>modified Scott</td>
<td>15.5</td>
<td>91</td>
<td>82</td>
<td>21 L-5, 1 L-4</td>
<td>4</td>
<td>73†</td>
</tr>
<tr>
<td>Schlenzka et al., 2006</td>
<td>25</td>
<td>Scott</td>
<td>18.2</td>
<td>NA</td>
<td>NA</td>
<td>20 L-5, 3 L-4, 2 L-3</td>
<td>14.8 (11–16)</td>
<td>64*</td>
</tr>
<tr>
<td>Songer &amp; Rovin, 1998</td>
<td>7</td>
<td>pedicle screws &amp; cables</td>
<td>20.5 (12–32)</td>
<td>NA</td>
<td>43</td>
<td>all L-5</td>
<td>25.5 (19–37)‡</td>
<td>71*</td>
</tr>
<tr>
<td>Buck, 1970</td>
<td>16</td>
<td>Buck</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>81*</td>
<td></td>
</tr>
<tr>
<td>Kakiuchi, 1997</td>
<td>16</td>
<td>pedicle screws, rod &amp; laminar hook</td>
<td>32.4 (12–60)</td>
<td>NA</td>
<td>38</td>
<td>13 L-5, 1 L-2–3, 1 L-3–4, 1 L-3</td>
<td>25.2 (24–28)‡</td>
<td>81*</td>
</tr>
<tr>
<td>Debusscher &amp; Troussel, 2007</td>
<td>23</td>
<td>pedicle screws, rod &amp; laminar hook</td>
<td>34 (16–52)</td>
<td>100</td>
<td>52</td>
<td>20 L-5, 3 L-4</td>
<td>59 (6–113)§</td>
<td>100§ 30 yrs old (12 pts); 73§ &gt;30 yrs old (11 pts)</td>
</tr>
<tr>
<td>Altaf et al., 2011</td>
<td>20</td>
<td>pedicle screws, U-shaped rod</td>
<td>13.9 (9–21)</td>
<td>NA</td>
<td>45</td>
<td>all L-5</td>
<td>4 (2.3–7.3)</td>
<td>90§</td>
</tr>
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<td>Askar et al., 2003</td>
<td>14</td>
<td>Scott</td>
<td>17.4 (13–24)</td>
<td>100</td>
<td>36</td>
<td>12 L-5, 1 L-4, 1 L-3</td>
<td>10.9 (8–15)</td>
<td>43*</td>
</tr>
</tbody>
</table>

* Asymptomatic or minimal symptoms.
† Excellent outcome according to Henderson criteria, that is, no pain; return to normal occupation and normal sport.
‡ Values expressed in months.
§ Excellent according to Oswestry Disability Index criteria (0%–20% disability index).
Direct surgical repair of spondylolysis in athletes

Discussion

Sports involving repetitive hyperextension of the spine along with axial loading seem to most predispose athletes to spondylolysis. Specifically, these actions are thought to overload the posterior elements, leading to pars fractures. Nearly all sports carry some elevated risk of spondylolysis. The sports with relatively high incidences of such injuries include gymnastics, football, hockey, diving, wrestling, baseball, volleyball, racquet sports, and weightlifting, with gymnastics and football generally considered to have the highest risk. Two studies have estimated the incidence of low-back pain in athletes with spondylolysis to be 79.8% in high school football players, 72.5% in high school rugby players, and 80.5% in college football players. Soler and Calderón documented the prevalence of spondylolysis in Spanish professional athletes, and the results are summarized in Table 4. According to these data, activities such as rowing, gymnastics, volleyball, weightlifting, and track and field carry the highest risk of symptomatic spondylolysis.

Gymnastics is widely considered to carry one of the highest risks for pars fractures, probably because gymnasts regularly combine hyperextension of the spine with large axial forces. Studies have shown the incidence of spondylolysis among gymnasts to be anywhere from 11% to 14%. Hall recorded the impact forces produced by collegiate gymnasts executing various acrobatics using a force pad. Back handsprings led to the greatest mean lumbar curvature, as well as to a high mean force of vertical impact. Other maneuvers, such as front and buck walkovers and front handsprings, resulted in large lumbar curvatures with front handsprings carrying a particularly high impact force.

The incidence of pars fractures has been found to be up to 15% in college football players. Although various positions are affected, linemen seem to be at particular risk for spondylolysis. Ferguson et al. hypothesized that this finding was due largely to the motions of blocking, specifically extension of the lumbar sacral spine combined with the axial force of collision. Unlike other positions, linemen experience these stresses regularly and repeatedly with every play, ostensibly placing them at particular risk.

In cricket, fast bowlers seem to be most at risk for spondylolysis. One study found that the incidence of pars interarticularis defects among young fast bowlers was 55%. In this case, hyperextension, lateral flexion, and thoracolumbar rotation in combination with the jerk force of bowling were hypothesized to cause spondylolysis. Repeated as many as 500 times per week, these motions put immense stresses on the spine.

Tennis also carries an elevated risk of pars injury. Hyperextension is thought to be the cause of these injuries, specifically those that occur during a serve. In attempts to “top spin” a serve, this hyperextension may be even more pronounced. The modern forehand shot and two-handed play with its repetitive rotation also result in additional hyperextension.

Baseball has also been associated with pars fractures. In professional Japanese baseball players, the incidence of pars fractures has been anywhere from 27.5% to 53.5%, far higher than in the general population. Similar to injuries seen in cricket, the pitching motion is hypot-
esized to cause most pars fractures, probably as a result of hyperextension of the spine and the rapid rotation associated with launching the ball.

Return to Athletics

For the athlete undergoing direct repair of spondylolysis, a return to preinjury athletic performance is often the primary goal. Authors reporting on surgical outcomes in athletes with these injuries use a variety of methods to measure outcome. In 1966, Henderson proposed a set of criteria to measure the outcome in patients undergoing surgical treatment for spondylolisthesis (Table 1). These criteria are still used today and provide an overall view of outcomes in a large patient population.

Although the literature contains limited data on athletes, the available data reveal that professional athletes can undergo various methods of surgical treatment and achieve excellent outcomes and a return to their previous athletic performance. For example, Ranawat et al. reported the case of a professional fast bowler who had undergone L3–S1 fusion after conservative treatment had failed. During play the next season, the patient noticed swelling in the lumbar region. It was discovered that a screw had broken, and the patient was taken to surgery to remove the screw. Screw breakage happened a second time during the season, and thus all hardware from the fusion was removed.

Nonunion has been reported in several cases. Pseudarthroses have been reported not uncommonly, with Ivanic et al. finding that 15 of 113 patients treated with the Morscher technique had pseudarthroses and 5 required second surgeries. Rarely, authors report persistent low-back pain after surgery.

Complications of the Techniques

Authors report a variety of potential complications with these techniques. Hardware failure is uncommon but has been reported with all of the techniques, including screw breakages, wire and cable fractures, and wires pulled out from the transverse process. For example, Ranawat et al. reported the case of a professional fast bowler who had undergone L3–S1 fusion after conservative treatment had failed. During play the next season, the patient noticed swelling in the lumbar region. It was discovered that a screw had broken, and the patient was taken to surgery to remove the screw. Screw breakage happened a second time during the season, and thus all hardware from the fusion was removed.

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In general, the available studies on direct repair techniques are too small to accurately gauge complication rates.

This survey illustrates the wide differences of opinion regarding the timing and safety of returning an athlete to his or her sport following spinal surgery. Factors that must always be considered include the amount of time that has elapsed since surgery, the instrumentation that has been used, and the degree of contact or collision common to the athlete’s sport, which could endanger the surgical repair and, consequently, the athlete’s safety.

TABLE 4: Prevalence of asymptomatic and symptomatic spondylolysis in elite athletes from Spain

<table>
<thead>
<tr>
<th>Sport</th>
<th>No. of Athletes</th>
<th>Prevalence of Spondylolysis (no. [%])</th>
<th>Athletes w/ Spondylolysis Who Were Symptomatic (no. [%])</th>
</tr>
</thead>
<tbody>
<tr>
<td>track &amp; field</td>
<td>685</td>
<td>69 (8.9)</td>
<td>32 (52.5)</td>
</tr>
<tr>
<td>gymnastics</td>
<td>235</td>
<td>33 (14.0)</td>
<td>19 (57.6)</td>
</tr>
<tr>
<td>combat sports</td>
<td>207</td>
<td>23 (11.1)</td>
<td>9 (39.1)</td>
</tr>
<tr>
<td>swimming</td>
<td>176</td>
<td>18 (10.2)</td>
<td>6 (33.3)</td>
</tr>
<tr>
<td>weightlifting</td>
<td>65</td>
<td>11 (12.9)</td>
<td>6 (54.5)</td>
</tr>
<tr>
<td>rowing</td>
<td>77</td>
<td>13 (16.8)</td>
<td>8 (61.5)</td>
</tr>
<tr>
<td>volleyball</td>
<td>70</td>
<td>7 (10.0)</td>
<td>4 (57.1)</td>
</tr>
</tbody>
</table>

Fig. 12. Bar graph illustrating the published results of techniques used to repair spondylolysis in athletes.
Direct surgical repair of spondylolysis in athletes

Conclusions

For a young athlete with a symptomatic pars defect, any of the described techniques of repair will probably produce acceptable results. An appropriate preoperative workup is important. The ideal candidate is younger than 20 years of age with minimal or no listhesis and no degenerative changes of the disc. Limited participation in sports can be expected from 5 to 12 months postoperatively. Familiarity with the various fixation techniques and anticipation of the anatomical variations will allow the surgeon to select the most appropriate surgical technique for repairing lytic defects in the lumbar spine.

Disclosure

Dr. Rasouli is a consultant for DePuy Spine and Synthes. Dr. Kim is a consultant for EBI/Biomet. Dr. Johnson is a consultant for Alphatec, Pioneer, and Spine Wave.

Author contributions to the study and manuscript preparation include the following. Conception and design: Drazin. Acquisition of data: Drazin, Jeswani, Ching, Rosner, Rasouli. Analysis and interpretation of data: Drazin, Shirzadi, Ching, Rasouli, Pashman. Drafting the article: Drazin, Shirzadi, Jeswani, Ching, Rosner, Kim. Critically revising the article: Johnson, Drazin, Shirzadi, Jeswani. Reviewed submitted version of manuscript: Drazin, Johnson, Rasouli, Kim, Pashman. Study supervision: Johnson.

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