Chapter 5
Evaluation and Management of Cervical Radiculopathy in Athletes

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Abbreviations

ACDF	anterior discectomy and fusion
ASD	adjacent segment disease
CDR	cervical disc replacement
MED	microendoscopic
PCF	posterior cervical foraminotomy

Introduction

Cervical radiculopathy is a common source of pain and impairment in the general population. For athletes in particular, it provides challenges in diagnosis and management. One large population-based study reported an estimated incidence of 107.3 per 100,000 men and 63.5 per 100,000 for women [1]. The C6–7 level is by far the most frequently affected level, with C5–6 following as a distant second [2]. Although no population-based studies have examined incidence among athletes, a study of military patients found an incidence of 1.79 per 1000 person-years [3]. Analysis of a National Football League (NFL) database revealed an incidence of

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2208 spine injuries over 10 years, 987 of which affected the cervical spine [4]. This study did not isolate cervical radiculopathy, but of these 987 cervical spine injuries, 5.8% were disc herniations, 4.7% were impingement, and 45.9% were nerve injuries, commonly referred to as "stingers" or "burners." Notably, upper cervical sources of radiculopathy involving C2–3 and C3–4 are exceedingly rare in the general population, but are much more common in athletes, particularly those participating in high-velocity contact sports [5]. A study of 40 NFL players found that 37.5% had degenerative changes at C2–3 (1) or C3–4 (14) [6].

Cervical radiculopathy is a major concern among athletes and the medical staff that provide care for them, especially in high-velocity contact sports. Proper diagnosis and management of each individual athlete is critically important given the potential for catastrophic injury and potentially career-ending decisions if not managed appropriately. Decisions are frequently made during competition, and confirming a diagnosis of radiculopathy is crucial in order to eliminate the much more serious cervical myelopathy, or the less serious brachial plexus "stinger." Once a diagnosis is made, the severity of signs and symptoms often dictates early management and the need for radiographic work-up. The majority of these cases can be managed with conservative therapy measures, including physical therapy, chiropractic care, anti-inflammatories, and targeted cervical steroid injections. In cases refractory to conservative measures, the decision to proceed to surgical intervention poses significant challenges. Although outcomes from single-level cervical surgery in the general population are excellent, with 90–95% patient satisfaction [7], the decision process in athletes is complicated by timing of return to competition and possible career-ending factors. Cervical fusion limits segmental motion, flexibility, and strength, which can significantly impact sport-specific performance in high-level and professional athletes. At a minimum, it can often leave players with a psychological barrier from perceived limited ability, which can in turn impact time to return, intensity of play, and stoke fears of catastrophic spinal cord injury [8]. The type of surgical intervention can significantly impact these factors. An anterior cervical fusion, posterior cervical foraminotomy, or cervical disc arthroplasty can all be effective in managing cervical radiculopathy, but each has its own nuances regarding proper patient selection and timing of return to play. The following chapter covers the diagnosis, conservative management, operative management, and return-to-play decisions encountered when managing cervical radiculopathy in athletes.

Diagnosis

Clinical History

Cervical radiculopathy can often be diagnosed from the clinical history and physical examination alone. It is important to determine the nature of onset and the pattern of symptoms. For example, did the pain start suddenly during a game or

insidiously over days to weeks? Does the pain stop in the shoulder or radiate to the hand? Does the athlete notice any numbness or weakness? Do any positions improve or worsen the symptoms? How much of the pain is in the neck versus the arm? Classic symptoms include burning, shooting pain, and paresthesia in a dermatomal distribution based on the affected nerve root. Neck and shoulder pain may be present, particularly with disc herniations in the upper cervical spine (e.g., C2–3, C3–4, C4–5). It is also extremely important to determine if there are any bilateral arm symptoms, leg symptoms, alterations of gait, or bowel/bladder changes, as these symptoms suggest cervical myelopathy over radiculopathy and can have significant implications on subsequent management decisions.

Physical Examination

A complete neurological evaluation should be completed on every athlete presenting with cervical radiculopathy symptoms. The confirmation of specific myotome, dermatome, and reflex changes frequently allows identification of the specific root involved. No myelopathic findings should be present, and the lower extremity examination should be normal in the absence of a concomitant thoracic or lumbar spine injury. If greater than one ipsilateral nerve root or bilateral nerve roots are found to be involved, then this must be presumed to be myelopathy until proven otherwise, especially during competition. Provocative tests such as Spurling's maneuver can be helpful if present but are not highly sensitive. Upper cervical radiculopathies are much harder to diagnose on examination, but the pattern of pain radiation can be very helpful. This pattern of pain is generally suboccipital in C2 or C3 and to the top of the shoulder in C4.

Imaging Studies

MRI is readily available and is frequently the initial source of imaging for evaluating cervical radiculopathy. It provides detailed visualization of the cervical anatomy and allows for assessment of nerve root or spinal cord compression. In the setting of a competition injury, CT scans of the cervical spine may be indicated to rule out a fracture, as they are preferable for the evaluation of bony anatomy. CT scans also provide a clearer view of the foraminal anatomy and are often helpful for clarifying the etiology of foraminal nerve root compression, specifically a disc herniation versus spondylotic foraminal narrowing. Disc herniations and spondylosis are equally common causes of radiculopathy, even in younger athletes (Fig. 5.1). Cervical x-rays with flexion and extension views are helpful in assessing the stability of the spine. Occasionally, in more challenging cases, cervical myelography with CT evaluation can be helpful.

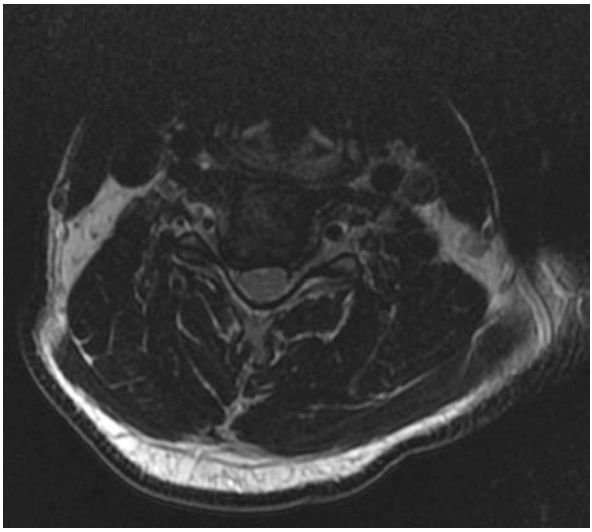

Fig. 5.1 Cervical spondylosis causing unilateral severe foraminal narrowing and right-sided radiculopathy

Ancillary Testing

Electrodiagnostic evaluation including electromyography (EMG) and nerve conduction velocity (NCV) can also play a role in the diagnosis of cervical radiculopathy, particularly in cases with an atypical history and/or examination. Their utility is limited in the setting of acute nerve injury, however, due to a high false-negative rate in the first 3 to 4 weeks after injury [9]. Positive results on these tests can help make the diagnosis, but many cases of painful and acute radiculopathy will be negative due to the low sensitivity in the acute period.

Differential Diagnosis

The variety of cervical radiculopathy syndromes can make diagnosis and management challenging, especially when considering return-to-play decisions and the role of surgical intervention. It is important and sometimes challenging to differentiate a radiculopathy from a "stinger" or "burner" and the more serious "spinal cord concussion," also known as cervical cord neuropraxia. A stinger or burner is a common injury seen in collision and contact sports characterized by unilateral burning and lancinating dysesthesia radiating down an upper extremity with variable motor and sensory changes [10]. The purported etiology is a traction injury to the upper brachial plexus from forced depression of the shoulder or from lateral hyperflexion of the head to the contralateral side. Symptoms usually resolve in minutes to hours. Cervical spine imaging should be obtained in the setting of prior episodes or persistent symptoms. Foraminal stenosis and congenital spinal stenosis are risk factors for stingers.

A cervical cord concussion, also known as cervical cord neuropraxia, represents a transient spinal cord injury [11]. It can usually be distinguished from stingers and radiculopathy by the presence of bilateral symptoms and/or involvement of the lower extremities. Patients are frequently observed to have quadriparesis, paresthesia, and dysesthesias, which may resolve over minutes to hours. Urgent medical evaluation and imaging are indicated to assess for congenital or acquired spinal stenosis. A small percentage of these patients will have no significant structural abnormality, and the mechanism of injury in this subset of patients is presumed to be transient cord compression secondary to a supraphysiologic range of motion.

Management

Nonsurgical

The benign natural history of cervical radiculopathy has been consistently reported in the general population, with over 90% of patients achieving complete symptom resolution within a few months [12, 13]. Consequently, nonoperative management is the initial treatment of choice in the vast majority of cases. Interventions that fall under this umbrella include activity modification, analgesia (NSAIDs, steroids, narcotics), epidural steroid injections, and physical therapy.

Nonoperative management is likewise the initial standard of care for cervical radiculopathy in athletes. Physical therapy plays a crucial role in this population, as complete symptom resolution, full range of motion, and full strength are required for return to play. Epidural steroids are safe and effective in this population [14]. It is worth noting, however, that multiple series report a lower return-to-play rate in athletes treated nonoperatively versus operatively. In Hsu's series of 99 NFL players, 72% (38 of 53) of players who underwent surgery returned to play, compared to just 46% (21 of 46) treated nonoperatively [15]. Moreover, athletes treated surgically went on to have longer and more productive careers than those treated nonoperatively. Similarly, Roberts' report of MLB pitchers showed an 88% (7 of 8) return-to-play rate in players treated surgically versus 33% (1 of 3) in those treated nonoperatively [16].

Surgical

Operative intervention is indicated for patients who fail initial nonoperative management, have significant motor deficits, cord signal change, or intractable, life-altering pain on presentation. There are three surgical techniques that can be used to address cervical radiculopathy: anterior cervical discectomy and fusion (ACDF), posterior cervical foraminotomy (PCF), and cervical disc replacement (CDR). The following pages discuss each of these procedures specifically in athletes, including their effectiveness, complications, and return-to-play considerations.

Effectiveness

Anterior Cervical Discectomy and Fusion

Anterior cervical discectomy and fusion (ACDF) is the most common surgical intervention for cervical radiculopathy. First described by Smith and Robinson in 1955, it has a long track record of proven success for treating a variety of cervical spine pathologies with good clinical outcomes and a favorable safety profile. ACDF similarly has become the workhorse operation for cervical radiculopathy in athletes. Among the three surgical options for cervical radiculopathy, ACDF has the strongest evidence base to support its safety and efficacy in professional athletes, even those who play high-velocity collision sports.

Andrews et al. were the first to report the use of ACDF for cervical radiculopathy in professional athletes [17]. Their retrospective review of 19 professional rugby players found that radicular pain was eradicated in 15 patients and improved in 2 patients, while neck pain was eradicated in 8 patients and improved in 9 patients. Thirteen of the cohort returned to their previous level of play.

A landmark paper by Hsu et al. first reported the use of ACDF for surgical management of cervical disc herniation in National Football League players [15]. In their cohort of 99 players, 53 underwent operative treatment—single-level ACDF in 32 cases, PCF in 3 cases, and an undetermined procedure in 18 cases. Those treated surgically were significantly more likely to return to play (72% vs. 46%), play more games (29.3 vs. 14.7), and have longer careers (2.8 years vs. 1.5 years) than those treated nonoperatively. Moreover, those who successfully returned to play had no significant difference in performance outcomes, and none suffered a subsequent spinal cord injury. Given that the average NFL career is 3.5 years and the average retirement age is 27 years [18], these results directly refuted the popular belief that a cervical disc herniation represented a devastating injury to a player's professional career.

Roberts et al. reported a series of 40 Major League Baseball (MLB) pitchers with cervical (11) or lumbar (29) disc herniations [16]. Of those with a cervical disc herniation, 8 underwent operative treatment—7 with single-level ACDF and 1 with cervical disc replacement. Overall, 88% (7/8) of those treated surgically returned to play, compared to 33% (1/3) of those treated nonoperatively. Surgical patients returned to play an average of 11.6 months postoperatively and pitched an average of 63 games over 3.7 years. Although these players pitched less innings per season, their performance status was not statistically different than before surgery.

Maroon et al. reported the experience of 15 professional football players and wrestlers who underwent ACDF for cervical radiculopathy (8) or neuropraxia (7) [19]. Thirteen (87%) returned to play on average 6 months after surgery, including all 8 who were treated for a cervical radiculopathy. In sum, these studies in high-level athletes demonstrate that the well-known efficacy and safety of ACDF in the general population has good generalizability to athletes.

Posterior Cervical Foraminotomy

The use of a posterior approach for surgical management of cervical radiculopathy was introduced over 70 years ago. The initial experience by Semmes and Murphy

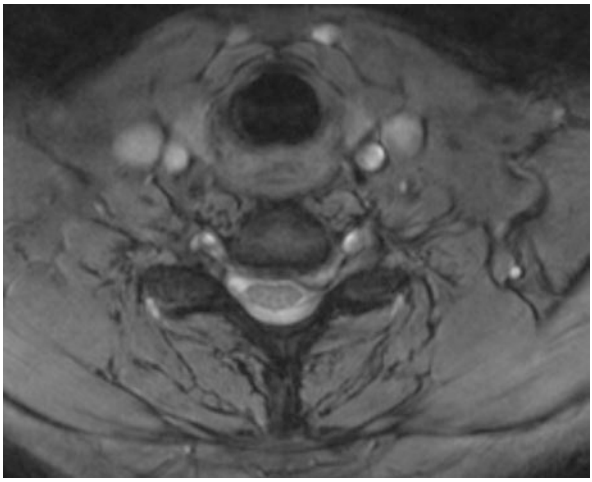

Fig. 5.2 Left paracentral cervical disc herniation causing foraminal stenosis and left-sided radiculopathy. This disc was removed by a PCF and symptoms resolved

[20] and Frykholm [21] described creation of a small laminoforaminotomy to treat lateral or foraminal disc herniations and spondylotic foraminal narrowing with good outcomes (Fig. 5.2). Although the anterior approach has largely supplanted posterior cervical foraminotomy for the surgical management of cervical disc herniation, concern over adjacent segment disease and recent advances in microendoscopic (MED) techniques make PCF a better alternative for appropriately selected patients. Contraindications to the approach include spinal deformity, instability, myelopathy, or bilateral disc herniation.

Adamson pioneered the use of microendoscopic (MED) techniques for the treatment of cervical radiculopathy nearly 20 years ago. In his first report of 100 consecutive patients, 97 achieved excellent or good outcome and were able to return to their previous employment and level of physical activity [22]. Only 3 patients experienced a surgical complication. Multiple other authors have reported similarly excellent outcomes [23, 24].

The efficacy, safety, and quick return-to-activity afforded by MED-PCF make it an attractive option for athletes who require surgical management of cervical radiculopathy. Adamson reported the first series in this population with encouraging results [25]. Ten athletes (8 professional football players and 2 professional race car drivers) were treated. Seven of the 8 football players returned to play after resolution of preoperative motor deficits. The one who did not return to play had a C5 motor deficit that never fully recovered. Both race car drivers were treated in the offseason and returned to driving within 4 weeks.

Adamson's personal series of over 1600 MED-PCFs performed since 1997 contains 22 athletes, including the 10 in the study cited above (unpublished data). The current series includes 16 collegiate or professional football players and 6 professional race car drivers. Fifteen of the 16 football players returned to play by the next season (10 in the same season, 5 in the next season), and all 6 race car drivers returned to competition after the off-season. One of the football players required additional surgery 1.5 years later for multilevel spondylotic disease.

In the aforementioned study by Hsu et al. [15], 3 of the 53 NFL players who underwent surgical treatment for cervical radiculopathy were treated with a

PCF. The reported outcomes did not stratify patients by surgical approach, but overall 72% of patients returned to play for an average of 29.3 games over a 2.8-year period. Notably, 5.3% of players required another operation at the index or an adjacent level during the study period.

Cervical Disc Replacement

Cervical disc replacement (CDR) was developed as alternative to ACDF with the goal of preserving motion at the index level and decreasing the rate of adjacent segment disease. The safety and efficacy of CDR has been consistently demonstrated in multiple FDA investigational device exemption (IDE) studies [26]. Currently, the FDA-approved indications for CDR include 1- and 2-level central and/or paracentral soft disc herniation from C3 to C7 for patients with radiculopathy with or without neck pain. Multiple studies have demonstrated a lower rate of adjacent-level reoperation in the long-term compared to ACDF [26–29].

Despite the abundance of literature evaluating CDR in the general population, there are few studies that specifically address the safety and efficacy of CDR for the treatment of cervical radiculopathy in athletes. Although not involving athletes, Tumialan et al.'s report of CDR in a military population shows good results in high-activity patients [30]. In their series, 12 patients underwent CDR for cervical radiculopathy. All 12 returned to full active duty at an average of 10.3 weeks after surgery with no complications.

The aforementioned study of MLB pitchers by Roberts et al. reported the first known case of a professional athlete who underwent CDR [16]. Eight of 11 patients with a cervical disc herniation were treated surgically, of which 1 was treated with CDR and successfully returned to play. More granular data concerning this patient were not provided. Reinke et al. evaluated return to play after CDR in 50 athletes, the majority of whom were semiprofessional or hobby athletes in noncontact sports [31]. All patients returned to some level of activity at a median of 4 weeks and to their preoperative level of activity at a median of 12 weeks postoperatively. Notably, there were only two professional athletes in the study (luge) and only two patients that participated in contact sports (martial arts).

Complications

ACDF has long been the gold-standard surgery for cervical radiculopathy due to its widespread use, efficacy, and safety. Even so, complications unique to the anterior approach (e.g., neck hematoma, esophageal injury, recurrent nerve palsy), concerns about adjacent segment degeneration (ASD), and limits to segmental motion and flexibility caused by fusion have increased interest in alternative options. Both PCF and CDR are motion-sparing alternatives to ACDF that have been consistently shown to have similar efficacy and safety to ACDF in the treatment of cervical radiculopathy [26, 32–36], and may be a better option for select patients. An area of intense study is the rate of index- and adjacent-level reoperation after these three procedures.

Index-Level Reoperation

Due to the focus on adjacent segment disease, few studies specifically report rates of index-level reoperation after ACDF. A recent meta-analysis comparing ACDF to PCF found a lower overall reoperation rate following ACDF (4.1% vs. 7.6%) [32]. Although no discrete data were provided, the authors stated that most of the reoperations after ACDF were at the adjacent level, while most of the reoperations after PCF were at the index level. These findings echo a common sentiment that unfortunately has little evidence basis. In their review of 303 patients who underwent single-level PCF for cervical radiculopathy, Clarke et al. found that only 10 patients developed index-level disease and required reoperation [37]. Estimated rates of index-level reoperation were 2.2%, 3.2%, and 5.0% at 1, 5, and 10 years, respectively. This contrasts with an 8.1% rate of index-level reoperation after single-level ACDF at 5 years in a recent meta-analysis [36]. Data from our unpublished series of PCF (8.3% at 15 years) support the findings of Clarke et al. and refute the notion that PCF results in a higher rate of index-level reoperation than ACDF.

There are scant data comparing reoperation rates following ACDF and PCF in athletes. Mai et al. reported the only known direct comparison in their analysis of 101 professional athletes treated over a 25-year span [38]. Six of 13 (46.2%) athletes who underwent PCF required index-level reoperation compared to 1 of 86 (1.1%) who underwent ACDF. There was notably a higher proportion of NFL players in the PCF (77.0%) versus the ACDF group (68.6%). In our unpublished series of 22 collegiate and professional athletes who underwent PCF, none required reoperation at the index level.

Numerous FDA-IDE studies have demonstrated a lower index-level reoperation rate after CDR than ACDF. A recent meta-analysis found a significantly lower 7-year index-level reoperation after CDR (5.2%) versus ACDF (12.7%) [36]. Similar findings were reported by Zhang et al. in their meta-analysis of 13 RCTs [26].

The paucity of studies examining CDR in athletes limits comparison to ACDF in this patient population. In the study by Mai et al., only two athletes underwent CDR, so they were excluded from the data analysis and their outcomes were not reported [40].

Adjacent-Level Reoperation

Arthrodesis, by definition, sacrifices motion at the index level, subsequently increasing stress on adjacent levels. Hilibrand et al. articulated the clinical consequences of this phenomenon in their landmark paper [39]. Fifty-five of 374 patients (14.7%) developed symptomatic adjacent segment degeneration during the study period. This occurred at a relatively constant rate of 2.9% per year, with an estimated risk of 25% within 10 years of surgery. Twenty-seven (7.2%) required an operation at the adjacent level.

In response to this study, the following decades saw an explosion of interest in motion-sparing alternatives to ACDF, with the goal of limiting the development of

Table 5.1 Estimates of index-level and adjacent-level reoperation rates at 5 years post-op

	Index-level reoperation	Adjacent-level reoperation
ACDF	8%	7 to 8%
PCF	5%	2 to 3%
CDR	5%	2 to 3%

adjacent segment degeneration and additional surgery. PCF represents one motion-sparing alternative to ACDF as it does not involve arthrodesis or instrumentation. Clarke et al. found that 15 of 303 patients (5.0%) developed symptomatic adjacent segment degeneration after single-level PCF, of which nine (3.0%) required surgery [37]. Estimated rate of development was 0.7% per year and 6.7% within 10 years of surgery. As mentioned previously, the meta-analysis by Fang et al. reported a lower rate of adjacent-level reoperation after PCF compared to ACDF, although no granular data were provided [32].

In Mai et al.'s study of ACDF vs. PCF in athletes, 4 (4.7%) patients developed ASD after ACDF and required reoperation [38]. No patients who underwent PCF developed ASD. Similarly, none of the 22 athletes in our unreported series developed ASD after PCF.

CDR is another motion-sparing alternative to ACDF that has gained popularity in recent decades. There is overwhelming evidence from numerous randomized controlled trials for lower rates of adjacent segment reoperation following CDR compared to ACDF. A recent meta-analysis reported a 4.3% adjacent-level reoperation rate after CDR compared to 10.8% after ACDF at 7 years [36]. Similar findings were corroborated by a subsequent meta-analysis [26]. Unfortunately, there is no literature directly comparing these techniques in athletes (Table 5.1).

Return to Play

Return to play after ACDF is a controversial topic with no consensus guidelines. Current recommendations are based on the few aforementioned studies and expert opinion. The decision-making process involves a number of variables including the extent of initial injury, number of instrumented levels, resolution of symptoms, quality of fusion, and type of sport. In general, athletes who undergo a single-level ACDF with radiographic evidence of fusion and complete resolution of symptoms without motor deficit can safely return to play, including collision and contact sports [40, 41]. Common scenarios are briefly reviewed below.

Two-level ACDF has generally been viewed as a contraindication to return to play, especially for collision and contact sports, despite limited data to support this recommendation. The major underlying concern is an increased risk of adjacent segment degeneration for which surgical management (i.e., three-level ACDF) would unequivocally preclude return to play. Current expert opinion supports return to play in noncontact sports but is mixed for collision and contact sports, with some experts allowing return to football after a fully healed two-level ACDF [41].

The management of pseudarthrosis after ACDF poses a significant challenge that requires case-by-case evaluation. In general, all symptomatic patients should be considered for operative intervention regardless of sport. If a patient is asymptomatic, the sport type becomes crucial. Noncontact athletes can safely return to play, whereas contact or collision athletes require operative intervention with either a revision anterior procedure or a posterior procedure.

Myelomalacia represents another variable that requires nuanced decision making. While most experts prohibit return to play even after successful treatment, some allow return to play if there is a normal canal diameter and adequate cord decompression [41].

Athletes can return to play after PCF once soreness has resolved and any preoperative motor deficits have completely recovered. In our experience, this ranges from 2.5 to 6 weeks. Athletes with persistent symptoms should be held out of competition and considered for ACDF.

The paucity of literature evaluating the efficacy and safety of CDR in athletes limits return-to-play recommendations. CDR should be viewed as a contraindication to return to play in collision and contact sports. Although Reinke et al. reported a return to activity in two martial arts athletes [31], the sample size is small, and level of contact these athletes experienced was unclear. Thus, this study should not be used to validate return to play in contact sports. Return to play in noncontact sports appears acceptable. In Tumialan et al.'s study of military patients, those who underwent CDR returned to full active duty without complication significantly sooner than those who underwent ACDF (10.3 vs. 16.5 weeks) [30]. Return to duty required complete resolution of preoperative symptoms.

Conclusion

Cervical radiculopathy, whether from disc herniation or spondylosis, is a relatively common problem for athletes. The work-up and management of these cases require careful history taking, physical examination, and often imaging in order to adequately determine the differential diagnosis and eliminate the potentially catastrophic spinal cord concussion and myelopathy patients. Multimodal conservative therapy is very helpful in the majority of cases. However, there is a growing body of evidence that even professional athletes in collision and contact sports can safely return to play after operative intervention and might even perform better than those who are treated nonoperatively. Of the three surgical options, ACDF has the longest track record and most evidence to support its use, but PCF has been shown to be an equally effective alternative with the potential for a quicker return to play, no loss of motion, and much less risk of adjacent segment disease compared to ACDF. CDR is an emerging, motion-preserving technique that has been very effective in the general population as well as an initial experience in the military, but there has been limited experience in athletes, especially American football. Overall management and return-to-play considerations are nuanced decisions that must be individualized with input from the athlete, team, and surgeon.

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