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The Role of Cervical Disc Arthroplasty in Elite Athletes

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Abstract

Purpose of Review Cervical disc arthroplasty (CDA) for the treatment of symptomatic cervical disc herniations (CDH) is a promising treatment for professional athletes. In recent years, a number of high-profile athletes have returned to professional play within three months after CDA, raising important questions about the potential of this procedure within this patient group. We provide the first comprehensive review of available literature for the safety and efficacy of CDA in professional contact sport athletes.

Recent Findings CDA provides theoretical biomechanical advantages over anterior cervical discectomy and fusion (ACDF) and posterior foraminotomy (PF), as CDA is the only operation for treatment of CDH that provides neural decompression, stability and height restoration, with preserved range of motion. While the comparative long-term results from each procedure are unknown, CDA has provided encouraging promise in its use in professional contact athletes.

Summary We aim to aid ongoing discussions regarding the controversies in spine surgery for professional athletes by providing a scientific review of the available evidence-based literature involving cervical disc arthroplasty in this population. In general, we believe that CDA is a viable alternative to ACDF and PF for the contact professional athlete who requires full neck range of motion and desires an expedited return to play. For collision athletes, the short- and long-term safety and efficacy profile of this procedure is promising but still unclear.

Keywords Cervical disc arthroplasty · Professional athletes · Cervical disc replacement · Spine surgery · Major League Baseball · National Football League

Introduction

The natural history and pathophysiology underlying cervical disc herniation (CDH) in elite athletes differ from that of the general population. In the general population, diagnosis of CDH most commonly occurs between the ages of 51 and 56, at the C5–7 location, with a history of trauma in only 14.8% of cases [1–3]. Conversely, professional American football athletes in the National Football League (NFL) are most likely to be diagnosed at an average age of 29 years old, most commonly at C3–4 or C5–6 (23% each) with a preceding history of sports-related trauma 82% of the time [2, 4]. Gray et al. characterized the incidence of disc herniation in NFL players over 12 years with findings of 23 herniations per year or 1.1 herniations per 10,000 exposures (i.e. any game or practice) [2]. In collision sports (e.g. football, ice hockey, mixed martial arts) and contact sports (e.g. soccer, basketball, wrestling), athletes experience repetitive axial loading on the cervical spine which increases the risk for acute injury and chronic degenerative changes [5]. This is compounded by increased physical demands, repetitive exposure to multi-directional high velocity trauma and resultant microtraumas from shearing forces [6].

While 92% of patients with CDHs in the general population heal with conservative management, one study found that only 50% of NFL athletes with CDH managed nonoperatively achieved a successful return to play (RTP) [7]. It must be noted that the definition of clinical success in professional athletes is complex and providers should consider multiple factors including RTP success, athletic performance and career length [8]. For example, the subtle changes after a cervical fusion in cervical spine mobility, reaction times and paraspinal muscle strength may be inconsequential to the general population, but can lead to significant differences in performance-based outcomes in elite athletes [8]. Any type of cervical pathology can be considered career-threatening

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in elite collision athletes, as demonstrated by Schroeder et al. who noted a significantly reduced ($p = 0.01$) median career length in NFL players with any prior diagnosis of cervical spine injury compared to matched controls [9]. Furthermore, in surveys of individuals age 30–49, 37% of retired American football athletes self-reported a diagnosis of neck pain and arthritis, compared to just 17% in the general population [10]. For these reasons, novel treatments for CDH that preserve range of motion while conferring both short- and long-term symptom reduction are an important consideration for professional athletes.

Benefits of CDA in Elite Athletes

The most common surgical modalities available for the treatment of CDH include anterior cervical discectomy and fusion (ACDF), posterior foraminotomy (PF) and cervical disc arthroplasty (CDA). Similar to ACDF, CDA not only allows for neural decompression, height restoration and stability, but also preserves neck ROM. PF also achieves neural decompression and maintenance of ROM; however, since there is no height restoration or stability, rates of limb paralysis may be higher [11].

A randomized controlled trial comparing long-term outcomes of ACDF (1-level $n = 81$, 2-level $n = 105$) vs. CDA (1-level $n = 164$, 2-level $n = 225$) in the general public over a 7-year follow-up found significantly greater improvements in Neck Disability Index (NDI) score in the 2-level CDA group compared to 2-level ACDF ($p = 0.04$), and significantly greater patient satisfaction in both the 1- and 2-level CDA groups when compared to the ACDF groups ($p = 0.028$ and 0.039, respectively) [12•]. While CDA as treatment of multi-segment disease in professional athletes has not yet been documented, a retrospective analysis of multi-level CDA in 36 patients reported significant improvement in NDI and visual analogue scale with preserved range of motion and no major complications with a mean follow-up of 8.5 years [13].

Recovery time after surgery and RTP success are among the most important considerations for the professional athlete. Prior studies report RTP success rates after single-level ACDF and PF to be approximately 80% and 70%, respectively [5], at an average time to RTP of 9.5 months and 7.9 months, respectively [5, 14, 15•]. In a case series by Reinke et al. examining RTP rates after single-level CDA in 2 professional, 20 semiprofessional and 24 hobby athletes, all successfully returned to play with an average recovery time of only 4 weeks. Furthermore, patients' modified Tegner scores demonstrated no significant difference in activity level between pre-injury and postoperative sport participation (4 and 3.5, respectively, $p = 0.806$) [16••]. Mai et al. published a comparative study of 101 professional athletes after ACDF, PF and CDA, finding RTP rates of 70.9%, 92.3% and 100%, respectively, although the CDA group in this study included only 2 athletes [15•]. Although data for professional athletes is lacking, a 2010 retrospective chart review of active-duty military personnel revealed twelve patients with CDA, all of whom returned to unrestricted full duty with average time to return of 10.3 weeks. This finding was significant when compared to time to return of the group who received ACDF (16.5 weeks, $p = 0.008$) [17•]. While these results are promising, the available data on CDA outcomes is lacking, and RTP guidelines for professional athletes have not achieved a standardized professional consensus [18].

Still, the emergence of CDA as a motion-sparing alternative to ACDF for the treatment of CDH has resulted in a multitude of professional athletes electing to pursue CDA in recent years. In a review of recent literature and news reports, a total of 17 elite athletes who underwent CDA returned to play at a median time of 3 months with no publicly reported complications to date (Table 1). Several of the athletes achieved notable professional success in the months or years following CDA, including a tournament win in Golf and a US National Championship gold medal in skydiving [19].

Of note, 11/17 (65%) of the athletes mentioned above are players of a collision sport (e.g. rugby, American football, hockey, mixed martial arts), which may represent increased incidence and comparable efficacy of this surgery in collision athletes when compared to other elite athletes. The earliest reported CDA in a professional athlete was an Australian rugby league player who received the procedure in 2007 and went on to complete a 3-year professional contract afterwards [20]. Since then, several case studies of collision athletes competing at a high level following CDA have appeared in peer-reviewed literature. A 2021 case study describes a national champion in Women's Kickboxing who underwent CDA and won a medal 3 months later at the World Championship. When re-evaluated by the authors at 7-year follow-up, she reported no complications or recurrence of her previous signs or symptoms [21••]. Satalich et al. published two case studies in 2022 on collegiate football players who underwent CDA: one achieved successful RTP after 8 weeks and was still competing without complications at 9-month follow-up [22••]. The other experienced complete resolution of symptoms 3 weeks following a 2-level CDA, although RTP and follow-up were not reported [23••]. Finally, it should be noted that two martial artists were included in the aforementioned study by Reinke et al. which reported a 100% RTP rate in athletes following CDA. Although the study design excluded contact sport participation for 6 months postoperatively, both martial artists resumed noncontact sport participation after 4 weeks and returned to their preoperative activity level in full-contact sport within 6 months [16••].

Table 1 CDA in high-profile athletes [19, 20, 21••, 22••, 23••, 24–34]

Sport	Year	Age	Sex	Level	Implant	Return to sport	Follow-up	Outcome
Rugby	2007	31	Male	NA	Steel	3 months	16 years	No complications
Kickboxing	2011	34	Female	C5–C6		3 months	7 years	No complications
Golf	2014	46	Male	NA	Prodisc-C	2 months	9 year	No complications
Rugby	2015	31	Male	NA		3 months	9 years	No complications
Golf	2016	40	Male	NA	Prodisc-C	3 months	7 years	No complications
Powerboat racing	2017	46	Male	NA		2 months	6 years	No complications
MMA	2019	34	Male	C6–C7	Prestige LP cervical disc	2 months	2 years	No complications
MMA	2019	36	Male	C5–C6		3 months	4 years	No complications
Hockey	2021	24	Male	NA	Titanium	3 months	2 years	No complications
Hockey	2021	30	Male	NA		3 months	2 years	No complications
Skydiving	2021	39	Female	NA		2 months	2 years	No complications
Cricket	2021	36	Male	NA		2 months	2 years	No complications
MMA	2021	31	Male	C6–C7		13 months	1 year	No complications
Football	2022	21	Male	C5–C6, C6–C7		NA	NA	Complete symptom resolution postoperatively
Football	2022	23	Male	C6–C7		2 months	9 months	No complications
Hockey	2022	22	Male	NA		3 months	1 year	Low performance
Baseball	2023	28	Male	NA		NA	NA	No complications

Risks of CDA in Elite Athletes

While no complications have been reported following CDA in elite athletes, this procedure is relatively novel and short time periods have elapsed since the dates of surgery. Players must be aware of the potential for sequelae such as adjacent segment disease (ASD), heterotopic ossification, implant wear and consequent reoperation.

The intense physical stresses placed on professional athletes, especially in contact sports, have been postulated to accelerate the rate of ASD in professional athletes, although this has not been confirmed in the literature [8]. A study performed by Reink et al. examining complication rates after single-level CDA in 2 professional, 20 semiprofessional and 24 hobby athletes reported no ASD after CDA at an average follow-up time of 4.4 years [16••]. Studies performed on the general population suggest a significantly lower risk of symptomatic ASD in patients undergoing single-level CDA (0.7% annually) when compared to single-level ACDF (2.7% annually) over 7-year follow-up [7]. This is consistent with the results of a 2022 randomized controlled trial that found evidence of radiographic progression of ASD in 53% of CDA patients and 77% of ACDF patients at 7-year follow-up [35]. In summary, these data suggest that CDA may modulate development of ASD compared to ACDF, though future studies with longer duration of follow-up are warranted.

Concern remains among team physicians regarding reports of high incidences of heterotopic ossification (HO) after CDA, as prior studies have shown that up to 60% of patients undergoing CDA will have evidence of HO on follow-up radiographic imaging [36]. In a recent retrospective study of 105 patients who underwent CDA, 51% of patients had evidence of HO on follow-up radiographic imaging, with 53.7% classified as low-level HO and 46.3% classified as high-level HO. The high-level HO cohort demonstrated significantly reduced range of motion when compared to the low-level HO and control groups ($p < 0.001$) [37]. However, a similar retrospective study determined that there was no significant difference in functional outcomes (Short-Form 36 and NDI scores) among CDA patients with HO compared to those without HO at 36-month follow-up, suggesting that this high incidence of HO may not be clinically relevant [38]. These results suggest that the risk of HO should remain a consideration for team physicians and professional athletes pursuing CDA, but performance may not be affected.

The professional athlete is subject to significantly greater physical demands compared to the general population, potentially leading to accelerated implant wear. A 2022 retrospective study found revision rates of CDA, ACDF and PF to be 6.9%, 3.2% and 3.6%, respectively, at 6-month follow-up [11]. Additionally, a prospective study of 382 patients in the general population who had CDA revealed that the M6-C and CP-ESP implants resulted in revision rates of 34% and 22.5%, respectively, over a mean follow-up time of 67 months [39]. However, the other four devices (PCM, Discover, Mobi-C, Prodisc-C Vivo) led to revisions in only 3% of patients over the same time period and accounted for 84% of the total procedures. Notably, patient-reported

outcome measures of those who had revisions were similar to those who did not, indicating that the wear-induced osteolysis necessitating the revisions may be largely asymptomatic [39]. Therefore, team physicians should remain cognizant of the risks related to implant wear and debris-related pathology when informing athletes about the risk of CDA and maintain consistent long-term follow-up with serial radiographic imaging to identify and address potential implant-related pathology.

It has been theorized that CDA carries a risk of catastrophic injury to the spinal cord in the event of implant retropulsion, but artificial disc migration is exceedingly rare. Only two case reports of artificial disc failure appear in the literature, neither of which resulted in sustained neurologic injury following revision surgery [40, 41]. Of the studies included in this review, none of the athletes has thus far suffered artificial disc implant failure.

Although cohort studies are limited, the risk of reoperation has been shown to be greater in athletes undergoing PF (46.2%) when compared to ACDF (5.8%) over a mean follow-up of 13.5 years [8, 15•]. A prospective randomized controlled trial of 2-level ACDF vs CDA revealed reoperation rates of 16% and 4%, respectively, at 5-year follow-up [42]. While there are no reports of reoperation in professional athletes who have undergone CDA at an average 6-year follow-up [15•, 16••, 21••], cohort studies with a longer duration of follow-up are yet to be performed.

Limitations and Future Directions

There are several limitations associated with this study. As CDA is a relatively novel procedure, there is limited data on long-term outcomes and complications. The peer-reviewed literature discussed in this review amounts to a sample size of only eight professional athletes with CDA, with the possibility of some overlap [15•, 16••, 21••, 22••, 23••, 43]. However, the non-peer-reviewed data discussed here relied primarily on nonconfidential publicly available information to identify professional athletes who underwent CDA. Lastly, this study is limited by the number of sports reported and specifically female professional athletes. Team physicians and players should use caution when utilizing these data to guide surgical decision-making in these patients.

Future comparative studies should be performed to better understand the potential differences in clinical outcomes in professional athletes after undergoing CDA vs. ACDF or PF. Differences in post-treatment career length, games played after treatment and the risk of ASD have yet to be adequately described in the professional athlete population. Finally, long-term studies regarding the degree of cervical disc implant wear, especially in professional athletes, have yet to be described, leaving an important gap in the literature.

Conclusion

Available data from professional athletes who have undergone CDA are promising compared to other more established procedures for the treatment of symptomatic CDH. CDA may provide biomechanical and clinical advantages over ACDF and PF by preserving range of motion and potentially reducing the risk of complications. In elite athletes, CDA provides comparable and sometimes superior clinical outcomes over ACDF and PF in terms of RTP success rates, time to RTP, performance following surgery and rate of complications. However, the data quantity is severely limited and further comparative studies are warranted. This review is intended to help shape discussions regarding the ongoing controversies in spine surgery for professional athletes, emphasizing the importance of future clinical studies in providing optimal patient care to the elite athlete.

Author Contribution Dr. Hogan Brecount – idea generation, manuscript research and writing
Alyssa Goodwin – manuscript research and writing
Dr. David Hiltzik – manuscript research, writing and preparation
Dr. Wellington Hsu – idea generation, manuscript editing

Data Availability Not applicable.

Code Availability Not applicable.

Compliance with Ethical Standards

Conflict of Interest Dr. Hogan Brecount – No conflicts; Alyssa Goodwin – No conflicts; Dr. David Hiltzik – No conflicts; Dr. Wellington Hsu – Advisory board member of Stryker, Medtronic, Asahi, Bioventus.

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