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| **­­Table 1: Studies discussing return to play (RTP) in American football athletes with cervical spine injuries** | | | | | | | | | | | | | |
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| **Stinger/Burner**  **Strain/Sprain**  **Author** | **TQ/Stenosis** | **CDH** | **Fracture** |  | |  | | **Objective** | | **Methods** | | **Results** | **Conclusions/**  **RTP discussion** | |
| Bailes et al42  2005 |  |  | x |  |  | | To discuss return to play (RTP) in athletes with transient spinal cord injury (TSCI) | | * 10 athletes evaluated for TSCI, with 7 being football players | | * Spinal stenosis of 8 to 13 mm in length at three or more levels was evident in all cases * 4 patients returned to play without recurrent TSCI; six individuals retired | | * Two groups of athletes experience TSCI: Those with 1) normal findings or 2) cervical stenosis * Single episode of TSCI with normal MR or cervical stenosis may not increase risk of injury |
| Brigham et al6  2003 |  | X | X |  |  | | To present an NFL player with history of neurapraxia and congenital stenosis who suffered spinal cord injury (SCI) | | * Case report involving one 22 year-old NFL linebacker followed from 2 years pre-injury to two years post-injury | | * Patient suffered axial load injury to neck with numbness in all four extremities and bilateral upper extremity dysesthesias * Upper extremity dysesthesias persist 2 years later | | * NFL athletes with congenital stenosis may be at increased risk of permanent SCI * RTP decisions must be made on a case-by-case basis knowing that permanent SCI is possible |
| Brigham and Capo et13 2013 |  |  | X |  |  | | To report outcomes for athletes who sustained cervical spinal cord contusion | | * Case series of four professional athletes, including three NFL players, with cervical stenosis and contusions * Follow up for minimum of 2 years | | * All underwent ACDF at level of contusion * Two athletes developed new contusions * No correlation between MRI finding and symptoms * Two NFL players RTP in 5 to 6 months after ACDF | | * MRI for symptomatic athlete; acute CDH, fracture, fracture is contraindication to RTP * Otherwise, can RTP when asymptomatic * Stenosis increases risk of recurrent contusion |
| Cantu et al4  2005 |  |  | X |  |  | | To provide a framework for RTP decisions after an episode of transient quadriplegia (TQ) | | * Case series of 3 football players with history of transient quadriplegia * Included 1 NFL player | | * Relative contraindications: healed fracture, cervical disc herniation (CDH) or spondylosis without functional stenosis; Absolute contraindications: persistent symptoms, MRI with cord edema | | * Athletes with history of neurapraxia, normal imaging and absence of symptoms may RTP * Contraindications: bony or ligamentous injury, cord contusion, or functional stenosis. |
| Chung et al2  2019 | X | X | X | X | X | | To describe the epidemiology of cervical spine injuries in NCAA football players | | * NCAA-ISP database * Rates of injury calculated as number of injuries divided by the total number of athlete-exposures (AEs) | | * 7,496 cervical spine injuries were identified; rate of 2.91/10000 AEs with stingers/strains most common * Most players returned to play within 24 hours of the injury (64.4%), while 2.8% remained out for > 21 days | | * Rate of disabling cervical spine injuries is low in NCAA football, likely due new tackling rules, improved protective gear, and better rehab |
| Clancy et al31  1977 |  | x |  |  |  | | To discuss the role of brachial plexus axonotmesis in football | | * 13 cases with 10 documented by electromyography. * All involved the upper trunk | | * All significant or repeated cervical nerve pinch injuries should be reexamined at 2 weeks * All but one patient recovered by 42-weeks | | * Patients with a history of axonotmesis should not RTP unless physical exam is unremarkable and electromymyogram is within normal limits |
| France et al38  2016 |  |  | X | X | x | | To offer analysis of expert opinion regarding RTP after SCI | | * 10 scenarios presented to 25 spine surgeons including various cervical spine injuries | | * Consensus reached regarding RTP without symptoms or stenosis, surgically repaired herniated discs, and non-operatively healed C1 or C2 fractures * No consensus exists for pts with persistent symptoms | | * Consensus exists for patients with normal imaging and no symptoms to RTP. RTP recommendations for patients with stenosis or persistent symptoms are controversial |
| Grant et al10 1976 |  |  | X |  |  | | To describe a case of TQ in an NCAA football player | | * Case of 18M linebacker who suffered episodes of TQ | | * Cervical stenosis diagnosed using lateral xrays * Patients counseled not to resume contact sports | | * Authors recommend against RTP in cases of cervical stenosis. |
| Gray et al16 2013 |  |  |  | X |  | | To assess incidence, location, and type of CDH in NFL athletes | | * Retrospective review of NFL surveillance database 2000 to 2012 | | * 22% of disc herniations occur in the cervical spine * CDH was associated with a median of 69 days lost from participation, 24 practices lost, 7 games lost | | * Cervical CDH represent a significant injury burden in the NFL, although indications for RTP unclear |
| Herzog et al11 1991 |  |  | X |  |  | | To establish normal morphometric values for the cervical spine in NFL players | | * 80 veteran and rookie and NFL players on one team * n= 80 underwent XR evaluation, n=16 CT/MPR, n=9 MRI | | * Spinal canal diameters of NFL athletes were slightly larger than those of non-athletes subjects * Of asymptomatic athletes, 49% had an abnormal Torg ratios (Ratio < 0.80) | | * Torg ratio is sensitive in detecting significant cervical stenosis but has low predictive value * If NFL athlete has small canal on XR (<12.5mm on sagittal view), order MRI; RTP criteria are unclear |
| Hsu et al18  2011 |  |  |  | X |  | | To evaluate performance of NFL athletes with CDH. | | * Retrospective comparing NFL performance before/after CDH | | * 99 NFL athletes identified * 72% RTP after surgery, 46% RTP without surgery * Defensive back with poorer outcomes after surgery * Performance and games started not significant | | * Fusion for CDH is associated with higher RTP rates and longer careers * Defensive backs have poorer prognosis after CDH diagnosis |
| Mai et al17 2016 |  |  |  | X |  | | To assess the impact of CDH level on NFL performance | | * Retrospective cohort study   NFL players divided into two groups, C2-C4 (upper) and C4-T1 (lower)   * 40 players: 15 upper and 25 lower | | * 66% RTP in upper CDH group compared to 72% RTP in lower CDH group, although not significant * Differences in performance scores not significant * 10% of ACDF patients needed reoperation for ASD * 50% foraminotomy athletes later required fusion | | * No statistical difference in RTP and performance between upper and lower level cervical spine surgery patients in NFL p=layers |
| Mai et al26 2017 |  |  |  | X |  | | To compare outcomes after ACDF, posterior foraminotomy (PF), or total disc replacement (TDR) in NFL athletes | | * Retrospective case series * NFL, MLB, NHL, and NBA athletes with CDH managed operatively * ACDF, PF, and TDR cohorts | | * 101 athletes (86 ACDF, 13 PF, 2 TDR) * PF with better RTP rate and shortest time to RTP * Re-operative rate highest for PF v ACDF (42% v 6%) * No difference in performance scores for all cohorts | | * ACDF/PF are appropriate for professional athletes * PF has quicker RTP but higher risk of re-operation. * TDR cohort too small to draw conclusions |
| Mall et al1 2012 | X | X |  | X | X | | To review epidemiology of spinal and axial skeleton injuries in NFL athletes | | * 2208 spinal injuries, 2000 to 2011 * 44.7% occurred in the cervical spine * Mean loss of 25.7 days per injury | | * Cervical fracture associated with 120 days missed * CDH associated with 85 days missed * Defensive secondary suffered most cervical spine injuries, representing 17.8% of all cervical injuries | | * Spinal and axial skeleton injuries may result in significant time missed |
| Maroon et al49 2007 |  | X | X |  |  | | To determine RTP after cervical spine injuries in NFL athletes | | * Case series of 4 NFL players and one collegiate athlete undergoing ACDF | | * 5 players returned to play < 8 months after ACDF * Two athletes had career ending CDH after ACDF (one above and one below fusion level) * One required repeat decompression after CDH | | * RTP is acceptable after one-level ACDF if exam within normal limits * NFL athletes are at increased risk of repeated herniation above or below the fused level |
| Maroon et al20 2013 |  |  | X | X |  | | To characterize RTP decisions for professional athletes with cervical spine injuries | | * Retrospective review of professional athletes who were patients of one spine surgeon from 2003 to 2012 | | * 15 professional athletes, including 7 NFL players * Cervical stenosis was diagnosed in 14 athletes * 13 of 15 players returned to play in 2 to 12 months after ACDF with a mean of 6 months | | * Athletes may return to play after RTP but may be at higher risk of adjacent segment disease (ASD) * Cord signal may not preclude RTP in NFL athletes |
| McAnany et al19 2017 |  |  | X | X |  | | To assess RTP after ACDF in professional athletes | | * Systematic literature review and meta-analysis | | * 5 articles, 48 athletes, including 31 NFL players, who underwent ACDF * Pooled success rate for RTP was 74% | | * Elite contact athletes return to play 74% of time after ACDF |
| Meredith et al48 2013 |  |  |  | X |  | | To describe presentation of CDH in NFL athletes | | * Retrospective review of one NFL team, including athletes diagnosed with CDH by MRI from 2000 to 2011 * Minimum of 1-year follow-up | | * 16 athletes with symptoms; 3 underwent ACDF, and one returned to play; 3 underwent CSI with temporary relief; 5 managed conservatively with no RTP; 8 treated conservatively and returned to play | | * Cord compression + signal change is indication for surgery; CDH abutting cord may be managed conservatively but no RTP until asymptomatic and MRI demonstrates no cord compression |
| Milles et al44 2014 |  |  | X |  |  | | To describe a case of TQ in a NCAA football player | | * Case report of 22-year-old man with episodes of TQ after hit | | * MRI with no congenital narrowing of canal * Syringomeylia C5 to C7 visible on post-injury MRI * Decision to disqualify patient from contact sports given abnormal MRI and 48h neurologic symptoms | | * Recommend against RTP for patients with episode of transient quadriparesis, prolonged duration of neurologic symptoms, and syrinx |
| Morganti et al8  2001 |  |  | X |  |  | | To offer consensus analysis of expert opinion for unique case factors regarding RTP | | * 10 cervical injury scenarios presented to 25 spine surgeons from Level-1 trauma centers | | * Consensus regarding RTP in contact sports for cases of cervical cord neurapraxia without symptoms or stenosis, repaired herniated disks, and non-op healed C1 ring or C2 hangman's fractures | | * Patients with normal imaging and resolution of symptoms may RTP; however, patients with cervical stenosis or clinical symptoms are a challenge to manage |
| Petraglia et al28 2012 | X |  |  |  |  | | To report the case of a collegiate football player presenting with sprain/strain and found to have bipartite C1 | | * 19-year-old male collegiate football player with neck pain after hyperextension injury | | * CT with congenital bipartite atlas, xrays normal * MRI with increased edema in pre-vertebral tissue * RTP after resolution of symptoms and normal MRI at 1.5 months post-injury | | * Diagnosis of a bipartite atlas in an asymptomatic patient with no evidence of instability is not a contraindication to RTP. |
| Rodts et al27 2018 |  |  |  |  | X | | To report the case of an NFL player treated surgically for an unstable Jefferson fracture | | * 23-year-old NFL player with neck and occipital pain after suffering hit * Neurologically intact | | * CT with a widely displaced anterior arch and minimally displaced posterior arch of C1 * MRI with intact ligaments * Underwent 2-stage transoral and posterior treatment | | * ORIF of anteriorly displaced fracture required 2nd stage MIS posterior arthrodesis * Patient has full ROM and no neck discomfort * Patient decided not to RTP |
| Schroeder et al41 2014 |  |  | X | X |  | | To determine the effect of cervical spine pathology on athletes entering the NFL | | * Cohort study of NFL athletes 2003-2011 during combine * Measured career statistics | | * 143 NFL players with cervical spine diagnosis * 10 with sagittal canal diameter <10mm and 7 with history of cervical spine surgery; both groups showed no difference in longevity or performance | | * Cervical spine pathology is not associated with performance or games started * Patients with cervical stenosis and those with previous surgery may not be at increased risk |
| Tempel et al12 2015 |  |  | X |  |  | | To assess T2 hyperintensity in the cervical spinal cord in professional athletes | | * Retrospective review o T2f hyperintensity on MRI, 2007-2014, in five professional athletes, including NFL players | | * 4 underwent ACDF, one treated conservatively; 3 had no signal intensity at 9 months; 4 were released to return to play; clearance for RTP preceded complete resolution of hyperintensity on MRI in three of four athletes; 2 returned to play and have had no re-injury | | * NFL players undergoing ACDF for CDH may return to play despite residual T2 hyperintensity if they are asymptomatic, neuro intact, and have no signs of instability on imaging |
| Torg et al37  1993 |  | X | X | X | X | | To describe spear tackler's spine | | * Review of 15 cases between 1987 to 1990 in football players | | * 11 had complete neurologic recovery, 4 had permanent neurologic deficits: 2 quadriplegia, 1 incomplete hemiplegia, 1 residual long track signs | | * Individuals with history of spear tackler's spine should not RTP to collision sports that put the cervical spine at risk |
| Torg et al35  1997 |  |  | X |  |  | | To describe cervical cord neurapraxia (CCN) and RTP considerations | | * Retrospective review * 110 cases of CCN, 52 football players, most professional or collegiate | | * 11% of all cases treated surgically * Patients returning to football had higher recurrence than other sports * For non-op patients, football participation and degree of stenosis increased risk of recurrence | | * Routine MRI in all cases of CCN * Patients without significant stenosis, instability, or persistent symptoms can return to sport after non-op treatment * Significant of stenosis on RTP is controversial |
| Torg9  2009 | X | X | X | X | X | | To assess contraindications to RTP after cervical spine injury in contact athletes | | * Systematic review * National Football Head and Neck Registry and anecdotal experience | | * 1200 cervical spine injuries in NFL athletes * Includes overview of relative and absolute contraindications for multiple cervical and lumbar spine injuries in NFL athletes | | * Proposes four general principles for RTP * After cervical spine injury, the athletes must be (1) asymptomatic, (2) pain-free, (3) neurologically intact, and have full strength and ROM of neck |
| Wakins et al21 2018 |  |  | X | X |  | | To determine the rate and time of RTP among professional athletes after ACDF | | * Prospective and retrospective review of athletes undergoing ACDF from 1982 to 2016 | | * 27 ACDF surgeries on 26 professional athletes, including 12 NFL players; 26 showed radiographic fusion; 20 of 27 athletes returned to play (80%) | | * After single-level ACDF, 80% pro athletes able to RTP at approximately 9 months |

**Notes**: TQ, transient quadriplegia; RTP, return to play; ACDF, anterior cervical discectomy and fusion; NFL, National Football League; MLB, Major League Baseball; NHL, National Hockey League; NBA, National Basketball Association; CDH, cervical disc herniation; ROM, range of motion; CSI, corticosteroid injection; CCN, cervical cord neurapraxia; MRI, magnetic resonance imaging; CT/MPR, Multiplanar computed tomography; ASD, adjacent segment disease

**Source**: Results of PubMed, EMBASE literature search