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FEATURES OF THE TACTICS OF SURGICAL TREATMENT OF FLEXION-DISTRACTION INJURIES OF THE SUBAXIAL CERVICAL SPINE

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Objective. To analyze results of surgical treatment and correction of deformities associated with flexion-distraction injuries of the subaxial cervical spine.
Material and Methods. A retrospective analysis of treatment results in 78 patients who underwent anterior and combined stabilization of subaxial dislocations in 2010–2016 was carried out. The data of clinical examination and of MRI and MSCT studies were subjected to statistical processing.
Results. Significant ($p < 0.05$) loss of the achieved intraoperative correction of shearing and kyphotic types of deformities was noted after 3 months in the group of patients with unilateral and bilateral articular process fractures treated by anterior spinal fusion.
Conclusion. Unilateral or bilateral articular process fractures accompanied by bilateral dislocations at the level of damaged spinal segment are risk factors for the loss of post-traumatic deformity correction achieved after isolated anterior stabilization.
Key Words: anterior fusion, bilateral subaxial dislocations, anterior cervical plate, interlocked dislocation.

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To date, surgical treatment of unstable injuries of the subaxial cervical spine includes anterior, posterior, and combined stabilization techniques. However, there are still no clear indications for each of these techniques [1, 3, 4, 29]. Flexion-distraction injuries (FDIs) of the cervical spine are unstable ones and often accompanied by a neurological deficit [8, 9]. An analysis of the international literature data demonstrates that approaches to choosing the optimal technique for surgical treatment of these spine injuries are contradictory. Some authors argue the use of isolated anterior or posterior stabilization after reduction and decompression, while others argue for combined stabilization [16, 25, 39]. There are several factors that influence outcomes of isolated anterior stabilization in FDI at the subaxial cervical spine level. Synovial joint injuries, end plate and vertebral body fractures, and osteoporosis are considered as the most serious pathologies significantly contributing to the instability progression in the postoperative period [15, 24].

The study objective was to analyze the results of surgical treatment and correction of deformities in FDIs at the subaxial cervical spine level.

Material and Methods

We analyzed medical histories of 78 patients with FDIs at the C3–C7 level in the early period of spine and spinal cord injury who underwent surgical treatment at the Department of Spinal Pathology of Novosibirsk Research Institute of Traumatology and Orthopedics n.a. Ya.L. Tsivyan in 2010–2016. The inclusion criteria were as follows: bilateral monosegmental FDIs at the subaxial cervical spine level and the age over 15 years. The exclusion criteria included polysegmental injuries, Forestier's disease, and ankylosing spondylitis (Bekhterev's disease).

We performed a retrospective cohort study of three groups of patients. Group 1 ($n = 8$) included patients with bilateral articular process fractures; group 2 ($n = 28$) included patients with unilateral fractures of one or two adjacent articular processes at the dislocation level and with an intact contralateral articular process; group 3 ($n = 42$) consisted of patients with bilateral dislocations, with the articular processes remaining intact.

All patients underwent a full spectrum of clinical and radiological examinations, including MSCT and MRI, to determine the morphology of bone-ligament and intervertebral disc injuries, visualize the spinal cord and nerve roots, and assess the degree of neural structure compression. Patients without neurological manifestations underwent plain X-ray of the cervical spine in direct and lateral projections. Verification of injury and indications for surgical treatment were performed based on the Subaxial Cervical Spine Injury Classification System (SLIC) [19] and Cervical Spine Injury Severity Score (CSISS) [6], and the neurological deficit was assessed using the ASIA

Impairment Scale (AIS). All patients with or without neurological deficit underwent urgent treatment using Richet – Hueter one-step closed manual reduction of dislocation via skeletal traction with a Bazilevskaya brace attached to the parietal eminences, under increasing loads. Then, if indicated, anterior decompression and stabilization using a porous titanium nickelide interbody implant and an Atlantis anterior cervical locking plate (Medtronic) were performed. Given the pronounced instability of injuries, four patients from group 1 underwent combined (anterior and posterior) stabilization. In groups 2 and 3, all patients underwent closed reduction and decompression of the spinal cord and nerve roots, followed by anterior fusion using the porous titanium nickelide implant and fixation with the Atlantis plate. External fixation with a Philadelphia collar was used in patients with and without severe neurological deficit in the postoperative period. The treatment outcomes were analyzed using X-ray morphometry of the stabilized vertebral segments at the dislocation level immediately after surgery and at 3 months. The criteria of correction loss were as follows: angulation of 11° or greater (according to the Cobb method) and translation of 3.5 mm or more [15]. These criteria are used by many authors as critical values in assessment of angular and translational deformities in traumatic dislocations at the subaxial level [14, 15]. The formation of a bone-metal block was evaluated using the classification by Tan et al. [33].

Statistical analysis of the obtained data was performed using a nonparametric Mann – Whitney U-test. Categorical variables are presented as the mean (M) and standard deviation (±SD). All calculations were performed using the Statistica 10.0 software package.

Results

The female : male ratio was 2 : 6 in group 1, 2 : 26 in group 2, and 5 : 37 in group 3. The mean age was 52.2 ± 10.5 (31 to 63) years in group 1, 40.6 ± 17.3 (18 to 67) years in group 2, and 43.5 ± 14.6 (20 to 71) years in group 3. A road accident (57.0 %) was the prevalent injury mechanism. The prevalent injury level in all groups was C6–C7 (75.0 % in group 1, 40.7 % in group 2, and 31.0 % in group 3). A neurological deficit in group 1 occurred in 57.0 % (n = 4) of cases and manifested as spinal cord compression syndrome. Patients of all groups achieved complete correction of translational and kyphotic deformities immediately after surgery. The bone-metal block was observed at the surgery level upon assessment of treatment outcomes 3 months after surgery. There was no worsening of neurological deficit in the postoperative period. In 30.0 % of cases, there was an improvement in the neurological status in the form of improved motor and sensory functions. A total or subtotal bone-metal block developed at the surgery level in all patients.

In group 1, there was no significant loss of intraoperatively achieved correction of deformity in the segment. Patients had the most severe injuries accompanied by bilateral fractures. Before surgery, the mean kyphosis angle in this group was 10.8° ± 9.9°, and the mean translational displacement was 5.1 ± 2.9 mm (Table 1).

After 3 months, loss of the intraoperatively achieved deformity correction occurred in 50% of group 1 patients (n = 4) who were operated on only through the anterior approach. Cervical lordosis correction of 4.9° ± 2.1° was achieved immediately after surgery, which decreased by 4.6° after 3 months. Translational deformity immediately after surgery amounted to 0.0 ± 0.3 mm; after 3 months, the mean values of translational deformity progressed by 3.6 mm and eventually amounted to 3.9 ± 1.0 mm. These findings indicate a significant loss of correction in this group, given the selected criteria (Fig. 1).

In the other 50 % of patients (n = 4) in this group who underwent combined stabilization, there was no loss of the intraoperatively achieved correction of translational and kyphotic deformities in the segment. They had the most unstable FDIs accompanied by bilateral fracture-dislocations. In these patients, combined stabilization was initially planned due to the pronounced instability and severe injury of the ligamentous apparatus. Immediately after surgery, the mean lordosis in the segment was 2.1° ± 2.2°; after 3 months, it decreased by 1.4° and amounted to 0.7° ± 1.4°. In this group, translational deformity was 0.2 ± 0.6 mm immediately after surgery and increased by 1.4 mm to 1.6 ± 0.9 mm after 3 months (Fig. 2).

In group 2, a significant loss of the intraoperatively achieved correction of kyphotic and translational deformities occurred in 16 (57 %) patients. Before surgery, the mean kyphosis in the group was 15.0 ± 9.7°, and the mean translational deformity was 6.5 ± 4.5 mm. Intraoperatively, lordosis was corrected to 4.1 ± 6.3°, and translational dislocation was 0.0 ± 0.4 mm. Three months after surgery, lordosis decreased by 4.1° and amounted to 0.6° ± 1.3°, and translational dislocation amounted to 3.5 ± 1.2 mm. Despite X-ray signs of correction loss in this group in the postoperative period, 52 % of the patients developed neurological improvements.

In group 3, before surgery, the mean kyphosis was 15.5° ± 11.7°, and the mean translational dislocation amounted to 4.5 ± 3.5 mm. Intraoperatively, segmental lordosis of 5.0° ± 6.1° and translational deformity of 0.1 ± 0.6 mm were achieved. Three months after surgery, kyphosis amounted to 3.8° ± 5.4°, and translational dislocation was 0.4 ± 0.8 mm.

Despite the signs of postoperative correction loss in group 2 patients, the Neck Disability Index (NDI) demonstrated no decrease in the functional activity. In statistical analysis, we formulated a null hypothesis that the initial kyphotic deformity was not significantly different in the groups (Table 1). However, translational deformity values differed significantly in groups 2 and 3 (Table 2).

Therefore, instead of the null hypothesis, we adopted an alternative hypothesis indicating the differences between groups 2 and 3 in the initial translational deformity. This was reasonable because group 2 included patients with unilateral articular process fractures and dislocation, and group 3 included patients with

Table 1

The results of statistical analysis of kyphotic deformity values in damaged cervical spine segments in compared groups before surgery

Groups	Groups	
	1 (anterior stabilization)	2
2	p = 0.3568	–
3	p = 0.3138	p = 0.8324*

*p > 0.05.

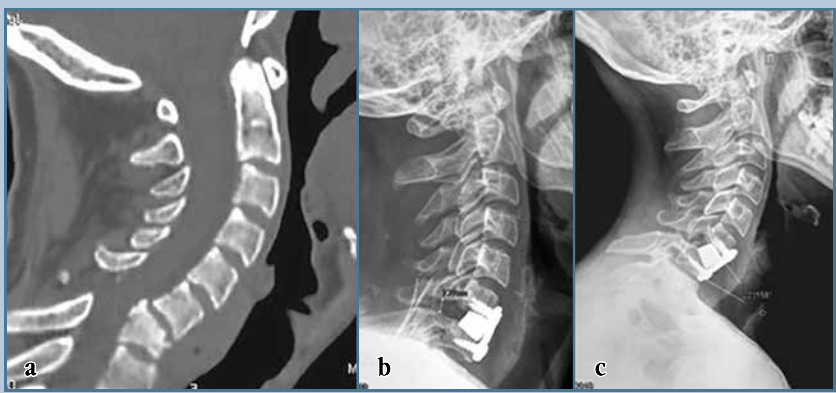

Fig. 1
A 25-year-old male patient Ts. with fracture-dislocation at the C6–C7 level and a bilateral fracture of the C7 superior articular processes; SLIC score – 7, CSISS – 17, Allen's grade 3 type: **a** – a lateral MSCT scan of the cervical spine before surgery; **b** – a lateral X-ray immediately after surgery; **c** – an X-ray 3 months after surgery; loss of intraoperatively achieved correction at the C6–C7 level is seen

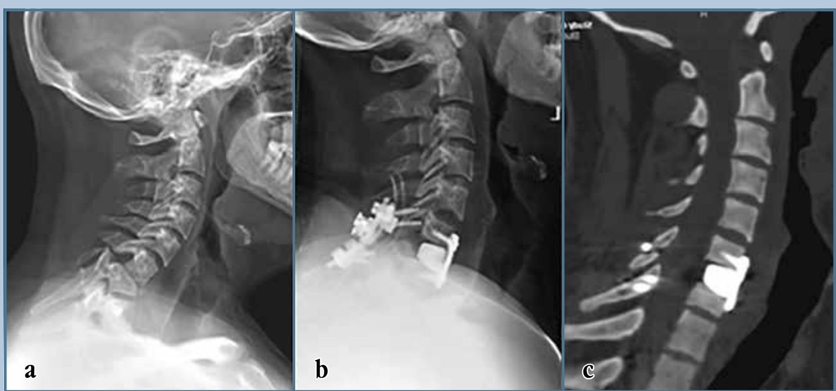

Fig. 2
A 29-year-old male patient K. with fracture-dislocation at the C6–C7 level and a bilateral fracture of the C6 inferior articular processes; SLIC score – 7, CSISS – 18, Allen's grade 3 type: **a** – a lateral X-ray of the cervical spine before surgery; **b** – a lateral X-ray after surgery; **c** – a MSCT scan 3 months after surgery

dislocations but without articular process fractures, which confirmed the representativeness of the three groups.

The results of statistical analysis of the data obtained 3 months after surgery are presented in Tables 3 and 4. They demonstrate the differences between groups 1 and 3 in kyphosis, which indicates the reliability of the differences in indicators between these groups. At 3 months, there were significant differences in the kyphotic angle between groups 1 and 3 as well as between groups 2 and 3 (Table 3) and in the dislocation value between groups 1 and 2 as well as between groups 2 and 3.

These findings enable assessing the representativeness of the three groups as well as the reliability of the data indicating the effect of articular process fractures on radiographic outcomes of surgical treatment of FDIs at the subaxial level. No significant effect of age, gender, and neurological deficit on the increase in deformity in the postoperative period was found.

Discussion

Cervical spine injuries are the most severe variants of spine and spinal cord trauma and are characterized by a variety of fracture types, high risk of severe neurological complications, and high lethality [2, 18, 23, 38].

Cervical spine injuries and road accident traumas account for 2 to 10 % [9, 11, 17, 34] and up to 25 % [11, 17, 20] in the structure of polytrauma patients, respectively. According to some authors, cervical spine injuries account for 20–40 % [1, 2, 28] to 50–80% [11, 17] of all spine injuries. C3–C7 injuries account for up to 75 % of cervical spine injuries [1, 2, 29]. Dislocations at the subaxial level account for 6–15 % of all cervical spine injuries [17]. Injuries are more common in males than in females and range from 1.8 : 1 to 3.5 : 1, respectively. The mean age of patients is 49 years (4 to 94 years); males account for 74% of patients [29]. The C5–C6 and C6–C7 spinal motion segments are mostly prone to dislocations, (30–40 %) and (40–60 %), respectively, [15]. Up to 40% of unilateral and up to

80% of bilateral dislocations are accompanied by intervertebral disc rupture [17]. In this case, up to 90% of bilateral subaxial dislocations are accompanied by a neurological deficit of varying severity [22, 27]. Bilateral fracture-dislocations develop due to hyperflexia and distraction and are accompanied by complete spinal cord injury in 65–87 % of cases and incomplete spinal cord injury in 13–25 % of cases; the spinal cord remains intact in less than 10 % of cases [26]. In 38–60 % of cases, vertebral dislocations at the subaxial level are accompanied by fractures of the vertebral bodies, articular processes, laminae, pedicles, and costotransverse and spinous processes [22].

At initial stages of the evolution of surgery for cervical spine dislocations, most of surgical interventions were performed through the posterior approach, and the most frequent surgery was laminectomy with various modifications of bone grafting, especially in the case of complicated injuries [7, 39].

Modern ideas about surgical treatment of FDIs of the cervical spine are based on the fact that surgery should provide the earliest spinal cord decompression, elimination of spinal canal deformity, and reliable anterior, posterior, or combined stabilization [39, 21]. Decompression of the spinal cord is achieved by reduction of dislocation using any of the existing closed or open techniques, which restores spinal canal clearance [30, 36].

According to the current domestic and foreign clinical recommendations for FDI, successful closed reduction should be followed by either anterior, or posterior, or combined stabilization of an injured spine segment [26]. Isolated anterior fixation of similar injuries after reduction is not always effective, and loss of correction and dislocation of fixation implants can occur [39]. Failure of isolated anterior stabilization in FDIs is 7–25 % and is caused by different factors [14]. This is mainly related to the morphology of injuries, namely to the type of injury of the articular processes and vertebral bodies, presence of osteoporosis, degree of kyphosis and translation, and severity of injury to the ligamentous structures [31].

Table 2

The results of statistical analysis of translational deformity values in damaged cervical spine segments in compared groups before surgery

Groups	Groups	
	1 (anterior stabilization)	2
2	p = 0.5040	–
3	p = 0.5286	p = 0.0211*

*$p < 0.05$.

Table 3

The results of statistical analysis of kyphotic deformity values in operated cervical spine segments in compared groups 3 months after surgery

Groups	Groups	
	1 (anterior stabilization)	2
2	p = 0.4879	–
3	p = 0.0175*	p = 0.0309*

*$p < 0.05$.

Table 4

The results of statistical analysis of translational deformity values in operated cervical spine segments in compared groups 3 months after surgery

Groups	Groups	
	1 (anterior stabilization)	2
2	p = 0.000001*	–
3	p = 0.0732	p = 0.0037*

*$p < 0.05$.

Henriques [12] believes that the tension band mechanism is important for anterior cervical stabilization, which is related to the posterior longitudinal ligament integrity. With the ligament being intact, fixation of the anterior cervical plate provides relative stability in the fusion region, which leads to expected adequate stabilization in the controlled position [12]. Allen et al. [5] described four FDI grades (Fig. 3): grade 1 – flexion subluxation with the intact articular processes and widening of the interspinous space; grade 2 – unilateral dislocation; grade 3 – bilateral dislocation with displacement of the body anteriorly up to 50 %; grade 4 – spondyloptosis (floating vertebra).

The tension band mechanism is important for achieving complete fusion in grade 1 and 2 FDIs (according to Allen et al. [5]) accompanied by the posterior longitudinal ligament integrity. At the same time, grade 3 and 4 injuries are accompanied by rupture of both the posterior longitudinal ligament and the deep muscles as well as interspinous and supraspinous ligaments. In these cases, the instantaneous rotation axis is displaced to the plate and the tension band mechanism does not work, which leads to loss of correction and re-dislocation. According to Henriques [12], anterior fixation is ineffective in 50 % of grade 3 flexion-distraction injuries. In this case, as noted in a study by Vaccaro et al. [37], grade 3 FDI is characterized by the frequent formation of traumatic hernias at the dislocation level. Therefore, this group of injuries requires anterior decompression and stabilization in any case.

An alternative approach is the use of posterior fixation in FDIs. A biomechanical study by Do Koh et al. [10] demonstrated a significant advantage of posterior lateral mass screw fixation compared to anterior plate and screw fixation, as well as the dependence of successful anterior plate fixation on the posterior longitudinal ligament integrity. Japanese authors consider anterior surgery in the case of traumatic intervertebral disc herniations in persistent anterior compression of the spinal cord. Tofuku et al. [35] consider sequential combined posterior and anterior stabilization to be necessary in all cases of irreducible bilateral dislocations. In this case, a surgical intervention should start with posterior open reduction. Steinmetz and Benzel [32] believe that treatment of bilateral dislocations can be carried out in several ways: closed reduction, open posterior reduction, and stabilization; open anterior decompression, correction, and stabilization. Anterior surgery is mandatory for large disc herniations, which enables direct open decompression of the spinal cord. If anterior open reduction of dislocation fails, correction and stabilization from the posterior approach followed by anterior stabilization are necessary; in the literature, this sequence of procedures is called “540° fusion” [32].

Therefore, we revealed signs of correction loss after anterior stabilization in FDIs in the long-term period and determined the significant value of the contribution of articular process fractures to achieving stability in anterior spinal fusion.

Conclusion

FDIs at the subaxial cervical spine level accompanied by unilateral and bilateral articular process fractures require combined stabilization. The reliability of anterior stabilization significantly depends on the articular process integrity; if the articular processes are intact, anterior fusion provides necessary fixation for the entire period of bone-metal block formation.

The study did not have sponsorship. The authors declare no conflict of interest.

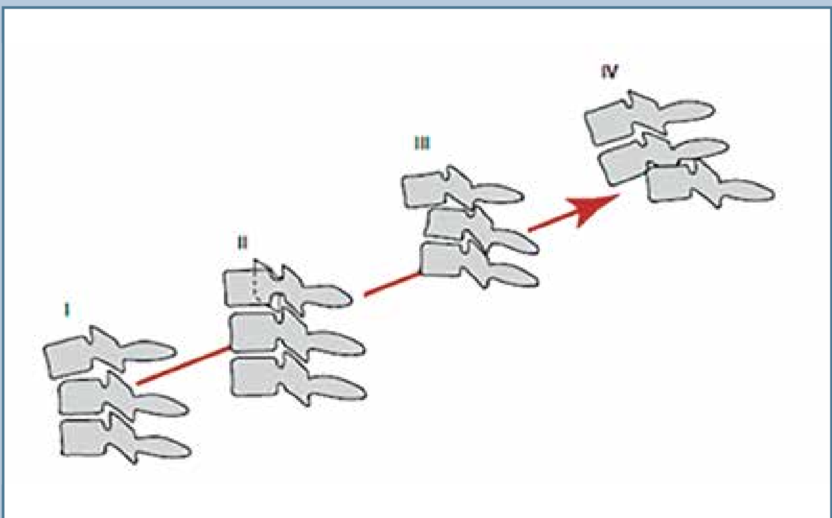

Fig. 3
Grades of flexion-distraction injuries at the subaxial level [5, 14]

References

1. **Baskov AV, Grin AA, Yarikov DE.** Surgical treatment in trauma of the backbone neck section. The Russian Journal of Neurosurgery. 2003;(1):6–13. In Russian.
2. **Krylov VV, Grin AA.** Spine and Spinal Cord Injury. Moscow, 2014. In Russian.
3. **Ramikh EA.** Lower cervical spine injury: diagnosis, classification, treatment. Hir. Pozvonoc. 2005;(3):8–24. In Russian.
4. **Rerikh VV, Lastevsky AD.** Surgery for lower cervical spine injuries. Hir. Pozvonoc. 2007;(1):13–20. In Russian.
5. **Allen BL, Ferguson RL, Lehmann TR, O'Brien RP.** A mechanistic classification of closed, indirect fractures and dislocations of the lower cervical spine. Spine. 1982;7:1–27. DOI: 10.1097/00007632-198200710-00001.
6. **Anderson PA, Moore TA, Davis KW, Molinari RW, Resnick DK, Vaccaro AR, Bono CM, Dimar JR 2nd, Aarabi B, Leverson G.** Cervical spine injury severity score. Assessment of reliability. J Bone Joint Surg Am. 2007;89:1057–1065. DOI: 10.2106/JBJS.F.00684.
7. **Bartels RH, Donk R.** Delayed management of traumatic bilateral cervical facet dislocation: surgical strategy. Report of three cases. J Neurosurg. 2002;97(3 Suppl):362–365.
8. **Bohlman HH.** Acute fractures and dislocations of the cervical spine: an analysis of three hundred patients and review of the literature. J Bone Joint Surg Am. 1979;61–A:1119–1142. DOI: 10.2106/00004623-197961080-00001.
9. **Clayton JL, Harris MB, Weintraub SL, Marr AB, Timmer J, Stuke LE, McSwain NE, Duchesne JC, Hunt JP.** Risk factors for cervical spine injury. Injury. 2012;43:431–435. DOI: 10.1016/j.injury.2011.06.022.
10. **Do Koh Y, Lim TH, Won You J, Eck J, An HS.** A biomechanical comparison of modern anterior and posterior plate fixation of the cervical spine. Spine. 2001;26:15–21.
11. **Fredo HL, Rizvi SA, Lied B, Ronning P, Helseth E.** The epidemiology of traumatic cervical spine fractures: a prospective population study from Norway. Scand J Trauma Resusc Emerg Med. 2012;20:85. DOI: 10.1186/1757-7241-20-85.
12. **Henriques T.** Biomechanical and Clinical Aspect on Fixation Techniques in the Cervical Spine. Uppsala: Uppsala University, 2003.
13. **Holtz A, Levi R.** Spinal Cord Injury. New York: Oxford University Press, 2010.
14. **Jack A, Hardy-St-Pierre G, Wilson M, Choy G, Fox R, Nataraj A.** Anterior surgical fixation for cervical spine flexion-distraction injuries. World Neurosurg. 2017;101:365–371. DOI: 10.1016/ j.wneu.2017.02.027.
15. **Johnson MG, Fisher CG, Boyd M, Pitzen T, Oxland TR, Dvorak MF.** The radiographic failure of single segment anterior cervical plate fixation in traumatic cervical flexion distraction injuries. Spine. 2004;29:2815–2820. DOI: 10.1097/01.brs.0000151088.80797.bd.
16. **Lee AS, MacLean JCB, Newton DA.** Rapid traction for reduction of cervical spine dislocations. J Bone Joint Surg Br. 1994;76:352–356.
17. **Leucht P, Fischer K, Muhr G, Mueller EJ.** Epidemiology of traumatic spine fractures. Injury. 2009;40:166–172. DOI: 10.1016/j.injury.2008.06.040.
18. **Lowery DW, Wald MM, Browne BJ, Tigges S, Hoffman JR, Mower WR.** Epidemiology of cervical spine injury victims. Ann Emerg Med. 2001;38:12–16. DOI: 10.1067/mem.2001.116149.
19. **Moore TA, Vaccaro AR, Anderson PA.** Classification of lower cervical spine injuries. Spine. 2006;31(11 Suppl):S37–S43. DOI: 10.1097/01.brs.0000217942.93428.f7.
20. **Mulligan RP, Friedman JA, Mahabir RC.** A nationwide review of the associations among cervical spine injuries, head injuries, and facial fractures. J Trauma. 2010;68:587–592. DOI: 10.1097/TA.0b013e3181b16bc5.
21. **Patel AA, Hurlbert RJ, Bono CM, Bessey JT, Yang N, Vaccaro AR.** Classification and surgical decision making in acute subaxial cervical spine trauma. Spine. 2010;35(21 suppl):S228-S234. DOI: 10.1097/BRS.0b013e3181f330ae.
22. **Payer M, Tessitore E.** Delayed surgical management of a traumatic bilateral cervical facet dislocation by an anterior-posterior-anterior approach. J Clin Neurosci. 2007;14:782–786. DOI: 10.1016/j.jocn.2006.04.021.
23. **Rahimi-Movaghar V, Sayyah MK, Akbari H, Khorramirouz R, Rasouli MR, Moradi-Lakeh M, Shokraneh F, Vaccaro AR.** Epidemiology of traumatic spinal cord injury in developing countries: a systematic review. Neuroepidemiology. 2013;41:65–85. DOI: 10.1159/000350710.
24. **Rogers WA.** Treatment of fracture-dislocation of the cervical spine. J Bone Joint Surg. 1942;24:245–258.
25. **Sabiston CP, Wing PC, Schweigel JF, Van Peteghem PK, Yu W.** Closed reduction of dislocations of the lower cervical spine. J Trauma. 1988;28:832-835.
26. **Sahoo SS, Gupta D, Mahapatra AK.** Cervical spine injury with bilateral facet dislocation, surgical treatment and outcome analysis: A prospective study of 19 cases. Indian J Neurotrauma. 2012;9:40–44. DOI: 10.1016/j.ijnt.2012.04.002.
27. **Sanchez B, Waxman K, Jones T, Conner S, Chung R, Becerra S.** Cervical spine clearance in blunt trauma: evaluation of a computed tomography-based protocol. J Trauma. 2005;59:179–183.
28. **Schoenfeld AJ, Sielski B, Rivera KP, Bader JO, Harris MB.** Epidemiology of cervical spine fractures in the US military. Spine J. 2012;12:777–783. DOI: 10.1016/j.spinee.2011.01.029.
29. **Singh A, Tetreault L, Kalsi-Ryan S, Nouri A, Fehlings MG.** Global prevalence and incidence of traumatic spinal cord injury. Clin Epidemiol. 2014;6:309–331. DOI: 10.2147/CLEP.S68889.
30. **Sokolowski MJ, Jackson AP, Haak MH, Meyer PR Jr, Szewczyk Sokolowski M.** Acute outcomes of cervical spine injuries in the elderly: atlantaxial vs subaxial injuries. J Spinal Cord Med. 2007;30:238–242. DOI: 10.1080/10790268.2007.11753931.
31. **Song KJ, Lee KB.** Anterior versus combined anterior and posterior fixation/fusion in the treatment of distraction-flexion injury in the lower cervical spine. J Clin Neurosci. 2008;15:36–42. DOI: 10.1016/j.jocn.2007.05.010.
32. **Steinmetz MP, Benzel EC.** Benzel's Spine Surgery: Techniques, Complication Avoidance and Management, 2-Volume Set, 4th ed. Elsevier, 2017.
33. **Tan GH, Goss BG, Thorpe PJ, Williams RP.** CT-based classification of long spinal allograft fusion. Eur Spine J. 2007;16:1875–1881. DOI 10.1007/s00586-007-0376-0.
34. **Thompson WL, Stiell IG, Clement CM, Brison RJ.** Association of injury mechanism with the risk of cervical spine fractures. CJEM 2009;11:14–22. DOI: 10.1017/S1481803500010.
35. **Tofuku K, Koga H, Yone K, Komiya S.** Distractive flexion injuries of the subaxial cervical spine treated with a posterior procedure using cervical pedicle screws or a combined anterior and posterior procedure. J Clin Neurosci. 2013;20:697–701. DOI: 10.1016/j.jocn.2012.03.045.
36. **Vaccaro AR, Fehlings MG, Dvorak MF.** Spine and Spinal Cord Trauma: Evidence-Based Management. Thieme, 2010:427–432.
37. **Vaccaro AR, Madigan L, Schweitzer ME, Flanders AE, Hilibrand AS, Albert TJ.** Magnetic resonance imaging analysis of soft tissue disruption after flexion-distraction injuries of the subaxial cervical spine. Spine. 2001;26:1866–1872. DOI: 10.1097/00007632-200109010-00009.
38. **Van den Berg ME, Castellote JM, Mahillo Fernandez I, de Pedro-Cuesta J.** Incidence of spinal cord injury worldwide: a systematic review. Neuroepidemiology. 2010;34:184–192. DOI: 10.1159/000279335.
39. **Walters BC, Hadley MN, Hurlbert RJ, Aarabi B, Dhall SS, Gelb DE, Harrigan MR, Rozelle CJ, Ryken TC, Theodore N.** Guidelines for the management of acute cervical spine and spinal cord injuries: 2013 update. Neurosurgery. 2013;72(Suppl 1):82–91. DOI: 10.1227/01.neu.0000430319.32247.7f.

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