TREATMENT OF SUBAXIAL CERVICAL SPINAL INJURIES

RECOMMENDATIONS

Subaxial Cervical Facet Dislocation Injuries:

Standards: There is insufficient evidence to recommend treatment standards.

Guidelines: There is insufficient evidence to recommend treatment guidelines.

Options:

- Closed or open reduction of subaxial cervical facet dislocation injuries is recommended.
- Treatment of subaxial cervical facet dislocation injuries with rigid external immobilization, anterior arthrodesis with plate fixation, or posterior arthrodesis with plate fixation is recommended.
- Treatment of subaxial cervical facet dislocation injuries with prolonged bedrest in traction is recommended if more contemporary treatment options are not available.

Subaxial Cervical Injuries Excluding Facet Dislocation Injuries:

Standards: There is insufficient evidence to recommend treatment standards.

Guidelines: There is insufficient evidence to recommend treatment guidelines.

Options:

- Closed or open reduction of subluxations or displaced subaxial cervical spinal fractures is recommended.
- Treatment of subaxial cervical spinal injuries with external immobilization, anterior arthrodesis with plate fixation, or posterior arthrodesis with plate fixation is recommended.

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RATIONALE

Subaxial cervical vertebral fracture dislocation injuries are common following non-penetrating cervical trauma and are often associated with neurological injury. Prior to the advent of spinal instrumentation, many of these injuries were managed with traction, postural reduction, or external orthoses with frequent success. However, the morbidity and mortality associated with prolonged immobilization for three months or more prompted surgeons to investigate the utility of internal fixation in the management of these injuries. In order to develop treatment recommendations for closed subaxial cervical spinal injuries, an analysis of the articles examining their management is undertaken in this report. In particular, this focused review assessed the utility of closed reduction with or without external immobilization compared to arthrodesis with or without internal fixation.

SEARCH CRITERIA

A National Library of Medicine computerized literature search of publications from 1966 to 2001 was performed using the following headings limited to the English language: cervical vertebrae, spinal fractures, and dislocations. An exploded search of the headings led to 15,124, 3,010 and 17,811 citations respectively. The first heading was combined with the second two headings, leading to a subset of 688 and 1159 citations respectively. Another exploded search of therapeutics or treatment limited to the English language led to 1,566,596 citations. This was combined with each of the two prior subsets, leading to 198 and 287 citations respectively. The abstracts were reviewed and only those containing ten or more cases of subaxial cervical injury after non-penetrating cervical trauma were included. An exception was made for ankylosing spondylitis because of the paucity of reports including more than ten patients with this disorder.

Sixty-three articles met the selection criteria and provide the basis for this review. They are summarized in Evidentiary Table format.

SCIENTIFIC FOUNDATION

The variety and heterogeneity of subaxial cervical spinal injuries requires accurate characterization of the mechanics and type of cervical spinal injury in order to compare the efficacy of operative and nonoperative treatment strategies. The absence of a uniformly accepted classification scheme for cervical vertebral injuries limits the ability to compare the effects of treatment reported in multiple clinical studies. In 26 articles describing series of patients with cervical injuries, subaxial cervical injuries are not differentiated. The Allen and Ferguson (3) classification system has been the most commonly used scheme to differentiate and characterize subaxial vertebral injuries. Although few authors reported injuries by subtype, many of the reports described cervical injuries that could be grouped into the following broad categories as described by Allen and Ferguson: distractive flexion (DF), compressive flexion/vertical compression (CF/VC), extension, and subluxation. The effectiveness of treatments of subaxial cervical spinal facet dislocation injuries, a subset of DF injuries, may be different from other subaxial cervical spinal fracture-dislocation injuries and are considered separately (53). Finally, four articles described unique characteristics of the management of subaxial cervical injuries in patients with ankylosing spondylitis and are included in this review.

Several general principles can be analyzed in the review of 26 articles that describe the treatment of subaxial cervical injuries without accurate differentiation into specific injury types. Although closed reduction was successful in 64% to 91% of patients with traumatic subaxial cervical malalignment (5,28,35,43), patients with delayed treatment of injuries had a higher

failure rate of closed reduction (22.5%) compared those treated early.(5) Halo vest application was employed successfully to immobilize patients with subaxial cervical injuries on arrival to the hospital to facilitate transport and workup; none had neurological worsening.(32) Orthoses failed to maintain reduction of subaxial cervical fracture-dislocation injuries in 7% to 56% of patients.(10,16,18,21,22,23,27,35,53,46) Overall, 30% of these injuries (222 of 752) had recurrent displacement or inadequate alignment during external immobilization (503 - halo vest, 249 - traction). Six of these patients were reported to heal with good ultimate alignment after readjustment of the halo device (three patients), or continued postural reduction (three patients).(27,46) Nineteen percent (140 of 752 patients) were maintained in external immobilization despite displaced injuries and healed in an unreduced, non-anatomic position. (10,16,18,21,23,27,35,53,46) Eleven percent (82 of 752 patients) underwent subsequent surgical treatment, typically for correcting cervical malalignment.(10,16,18,22,23,27,35,53,46) Several risk factors were identified in association with failure of nonoperative management of subaxial cervical injuries. Patients with more than 40% compression of a cervical vertebra, more than 15^{o} of kyphotic angulation, or more than 20% subluxation of one vertebra on another were more likely to fail treatment with external immobilization (craniocervical traction alone or traction followed by external orthosis).(35)

In contrast, failure to maintain anatomic reduction of subaxial cervical fracture dislocation injuries after operative treatment ranged from 1% to 18%.(7,10,23,28,36,48,51,46,56) Anterior cervical fusion procedures (28,48,59,56) were associated with less frequent failure to maintain reduction (5% - ten of 213) when compared with posterior cervical fusion procedures (14% - 38 of 280) among all patients with subaxial cervical injuries treated operatively.(7,36,51) Overall, nine percent of patients (61 of 704) had recurrent angulation or subluxation despite

surgical management. (7,10,23,28,33,35,36,46,48,51,56,59) A second operation in treatment of progressive deformity was rare in these patients. Successful arthrodesis occurred in nearly every patient reported.(7,15,33,36,43,46,48,56) Surgical complications were relatively common in these series, ranging from 9% to 25%.(7,20,27,33,46,48,56,59) In particular, graft extrusion after anterior cervical surgery without plate fixation was observed in as many as 10% of patients managed in this way.(20,27) Overall four of 104 patients experienced graft displacement (4%) (20,23,27,35,52,59) after anterior fusion without plate fixation, compared to none of 291 patients treated with anterior fusion with plate fixation.(5,28,33,48,56) Complications have been reported utilizing posterior plate fixation as well; radiculopathy occurred in 25% of patients in one report describing these techniques.(7,36,51)

Subaxial cervical facet dislocation injuries:

Twenty-eight articles provided sufficient information to evaluate patients with subaxial cervical distractive flexion (DF) injuries. Most reports were retrospective series of patients with subaxial cervical spinal facet dislocation injuries, unilateral, bilateral, or both. (8,11-13,16,19,27,30,37,39,41,45,47,49,50,53,54,55,57,61) Overall, 26% of patients (181 of 701) with cervical spinal facet dislocation injuries had failure to achieve closed reduction with craniocervical traction. (8,11,12,17,19,30,39,41,42,45,47,50,53-55,57,61) Reduction, when accomplished, could not be maintained in 28% of patients (112 of 393) treated with subsequent external immobilization. (8,11-13,16,19,27,30,37,39,41,45,47,49,50,53-55,57,61) Mortality associated with closed treatment of facet dislocation injuries was 7% (28 of 392 patients) in series reporting this complication. (8,11-13,19,30,37,39,41,45,50,53,57,61) Prolonged bedrest and cervical traction alone for 12 weeks to 16 weeks duration was associated with the highest

mortality of all treatment strategies reported for these injuries, 27% in one series of 41 patients managed in this way.(13)

Vertebral subluxation, facet injury (ligamentous or fracture) or a locked/perched facet on the initial radiographs or subsequent CT or MRI studies have been cited as factors associated with failure of nonoperative treatment.(8,11,30,31,57) Facet fractures associated with cervical spinal facet dislocation injuries may preclude successful closed reduction. (30,57) They have also been associated with a high rate of arthrodesis with external immobilization alone (halo device) if closed reduction can be accomplished, 97% in one report on this issue. (30) Ligamentous disruption without facet fracture is associated with an increased likelihood of failure of external immobilization (halo device, Minerva cast) in the treatment of these injuries. (30,31) Laminar fractures have been associated with an increased risk of late kyphosis after surgical treatment of cervical spinal facet dislocation injuries.(40) Although patients with unreduced facet dislocations treated with external immobilization often achieve spinal stability once treatment has been completed, arthrodesis in a position of malalignment has been associated with persistent cervical pain.(8,50,55) No differences were observed in the success of achieving closed reduction and/or maintaining cervical spinal alignment in patients with unilateral facet dislocations compared to patients with bilateral facet dislocation injuries.

In contrast, open reduction was achieved in all but one of 24 patients treated with anterior fusion procedures (42,44,55) and in all but seven of 167 patients treated with posterior fusion procedures in series that reported this finding.(7,8,11,19,30,42,47,50,54,57,61) Delayed instability occurred in six of 101 patients (6%) treated with anterior fusion procedures (12,13,24,40,42,55,61), and six of 237 patients (3%) treated with posterior fusion procedures. (7,8,11,25,30,37,40,42,49,50,55,57,61) Not one of these six patients who failed to achieve

stability after anterior fusion was treated with plate fixation in addition to fusion. Seven of 85 patients (8%) treated with anterior fusion procedures developed kyphosis; none had been treated with anterior plate fixation.(7,8,11,25,30,37,40,42,49,50,55,57,61) Sixteen patients described by Shapiro also developed kyphotic angulation following anterior cervical fusion without internal fixation.(58) In contrast, 22 of 165 patients (13%) developed kyphosis after posterior cervical fusion with wiring, (25,40,54,55) while only one of 40 patients (3%) developed kyphosis after posterior fusion with lateral mass plate fixation.(25,55) Alternatively, Halifax interlaminar clamps were successfully used in five patients with facet dislocations treated with posterior arthrodesis.(2)

Graft displacement was the most common complication after attempted anterior arthrodesis without internal fixation (8%, seven of 85 patients).(6,13,24,40,42,44,55) Seven percent of patients (8 of 113) died after anterior fusion procedures (13,24,40,42,44,45,55,61); three percent of patients (7 of 268) died after posterior fusion procedures. (7,11,19,25,30,42,47,49,50,55,57,61) All but one of the 15 patients who died following surgery in an attempt to correct deformity and stabilize the spine in these reports had complete cervical spinal cord injuries.(7,42,57,61)

Subaxial Cervical Spinal Injuries Excluding Facet Dislocation Injuries:

Fourteen articles provided sufficient information to evaluate patients with subaxial cervical spinal compression fracture injuries. (1,4,6,11,13,14,16,17,24-26,34,37,39) Although some authors differentiated compressive flexion (CF) injuries from vertical compression (VC) injuries, others considered these injuries together. Many nonoperative treatment strategies were described including traction and external immobilization in collar, plaster jacket, or halo vest.

Overall, 5% of patients (17 of 349) treated with immobilization for compressive injuries of the subaxial cervical spine had persistent instability after non-operative treatment employed for eight weeks to 12 weeks.(6,11,13,17,26,37,39) In contrast, nearly every patient with these injuries treated with anterior (22 of 22) or posterior (26 of 27) fusion procedures developed a stable union.(1,4,25,27) Subluxation or kyphosis developed in two of 18 patients who were treated with posterior fusion.(11,25) Operative complications were more common in patients treated with posterior fusion procedures (37%, ten of 27) when compared with anterior fusion procedures (9%, three of 33).(1,4,24,25) Graft displacement was the most common complication described in patients treated with anterior cervical fusion without internal fixation (9% - three of 33).(1,24)

Only seven articles reported sufficient data to analyze patients treated for extension injuries of the subaxial cervical spine.(4,11,13,24,37,38,43) Twenty-four percent of patients (19 of 79) failed treatment with external immobilization.(11,13,37,38,43) In contrast, not one of 19 patients failed treatment with anterior cervical fusion.(37,38) Two patients had irreducible vertebral displacements and three patients developed kyphotic deformities among eleven patients with cervical spinal extension injuries treated with attempted posterior cervical fusion.(38)

Eight articles reported sufficient data to analyze patients treated for vertebral subluxation injuries of the cervical spine.(4,6,11,13,17,18,25,49) Sixty-four percent of patients with these injuries had successful treatment with external immobilization; patients with greater than 50% subluxation were twice as likely to maintain anatomic cervical realignment after closed reduction (72% vs. 36%).(6) Thirty-six percent of patients (39 of 108) failed external immobilization following closed reduction (11,13,17,18,49) compared to seven percent of patients with these injuries managed surgically.(4,49) A kyphotic deformity developed in four percent of reported

patients (three of 74) treated with posterior cervical fusion and lateral mass plate fixation procedures.(4,25)

Several characteristics of subluxation injuries of the subaxial cervical spine were associated with failure of nonoperative treatment.(6,53) Patients with subluxation or kyphotic angulation frequently failed to achieve a good anatomical result after treatment with halo vest immobilization (45% - 46 of 103). Combined fractures to all parts of the cervical spinal column and the presence of facet fractures were not associated with a higher likelihood of failure of treatment with external immobilization.(53) Closed reduction was more successful with a subluxation greater than 50% of the vertebral body diameter.(6)

Comparatively few studies examined the specific difficulties associated with the management of patients with ankylosing spondylitis who sustain cervical spinal injuries.(9,17,29,60) In four articles reporting patients with this entity and injury, nine of 22 total patients died. Four patients managed non-operatively died. Two of nine survivors treated with external immobilization failed treatment. One worsened neurologically when placed in a halo and was subsequently successfully treated with laminectomy and fusion. The other patient had persistent cervical subaxial spinal instability but refused further therapy. In contrast, five of nine ankylosing spondylitis patients with cervical fracture injuries treated primarily with surgery died. One patient was neurologically worse after surgery. Three patients healed successfully without instability.

SUMMARY

In conclusion, closed reduction is successful for most subaxial cervical spinal fracture-dislocation injuries. Failure of closed reduction is more common with facet dislocation injuries.

Similarly, treatment with external immobilization is frequently successful in the management of most subaxial cervical spinal injuries, although failure to maintain reduction is more frequent with facet dislocation injuries as well. Virtually all forms of external immobilization have been employed in the treatment of subaxial cervical spinal injuries. More rigid orthoses (halo, Minerva) appear to have better success rates than less rigid orthoses, (collars, traction only) for fracture-dislocation injuries once reduction has been accomplished. Treatment with traction and prolonged bedrest has been associated with increased morbidity and mortality.

Both anterior and posterior cervical fusion procedures are successful in achieving spinal stability for the majority of patients with subaxial cervical spinal injuries. Indications for surgical treatment offered in the literature include failure to achieve anatomic injury reduction (irreducible injury), persistent instability with failure to maintain reduction, ligamentous injury with facet instability, spinal kyphotic deformity greater than 15^{o}, vertebral body fracture compression of 40% or greater, vertebral subluxation of 20% or greater, and irreducible spinal cord compression. Anterior fusion without plate fixation is associated with an increased likelihood of graft displacement and the development of late kyphosis, particularly in patients with distractive flexion injuries. Similarly, late displacement with kyphotic angulation is more common in patients treated for facet dislocation injuries with posterior fusion and wiring compared to those treated with posterior fusion and lateral mass plate fixation. Although patients with persistent or recurrent cervical spinal malalignment often achieve spinal stability with either external immobilization or surgical fusion with or without internal fixation, a greater proportion of these patients have residual cervical pain compared to similarly treated patients in whom anatomic spinal alignment was achieved and maintained.

KEY ISSUES FOR FUTURE INVESTIGATION

To better compare the advantages and disadvantages of nonoperative versus operative treatment strategies for subaxial cervical injuries, future studies must differentiate between the mechanisms of injury which have resulted in subaxial injury. Although the Allen and Ferguson classification offers a commonly used framework for stratifying these patients, the number of subtypes in their scheme precludes many investigators from obtaining sufficient numbers of patients with specific injuries. A broader classification of patients into compressive flexion (CF), distractive flexion (DF), vertical compression (VC), and extension injuries would allow comparison of most patients who sustain subaxial cervical spinal injuries. A multicenter study would allow more rapid accumulation of patients with these various categories of subaxial cervical injuries. A prospective examination of the efficacy of rigid external immobilization compared to surgical arthrodesis with internal fixation (anterior and posterior approaches) may further refine the most effective treatment for patients with subaxial cervical spinal injuries.

EVIDENTIARY TABLES: Injury Types Mixed

First Author Reference	Description of Study	Data Class	Conclusions
Kalff R et al, 1993, Neurosurg Rev	Retrospective study 97 cervical injuries (79 ant and 18 ant-post fusion w/ plate) 16 DF, 14 VC, 64 Fx-dislocation	Class III	9% operative complications related to fixation devices, but less than half require reoperation. All patients fuse.
Lemons VR & Wagner FC, 1993, Surg Neurol	Retrospective study 64 cervical fractures 14 VC, 12 CF, 12 UFD, 16 BFD 10 extension 38 halo 38 fusion (12 failed halo,26 primary) 26 post w/ wire or plates, 4 ant w/o plate, 4 ant-post	Class III	12 of 38 halo treated injuries were unstable and were fused. 4 healed malaligned. None with extension injuries were unstable. 5 of 38 treated w/ fusion were unstable. Risk for orthosis failure: >40% compression, >15^{o} angulation, >20% subluxation.
Cybulski GR et al, 1992, Spine	Retrospective study 21 cervical injuries failing posterior wiring txed with anterior fusion	Class III	2 of 21 had graft extrusions.
Della Torre F & Rinonapoli E, 1992, Inter Orthop	Retrospective study 28 cervical injuries 3 CE, 7 CF, 4 DF **treated** with halo	Class III	4 of 7 CF injuries were not reducible. All were stable with immobilization.
Heary RF et al, 1992, J Trauma	Retrospective study 78 cervical injuries Halo for transport 49 subaxial **fractures**, 45 subaxial subluxation	Class III	No patient worsened neurologically in halo before receiving definitive treatment.
Levine AM et al, 1992, Spine	Retrospective study 24 facet fractures Posterior fusion with plates	Class III	11 complications including 4 who lost correction and 6 with radiculopathy. All achieved fusion.
Roy-Camille et al, 1992, Spine	Retrospective study 221 cervical injuries 89% post fusion 11% ant fusion	Class III	15% develop kyphosis after surgery.
Nazarian SM & Louis RP, 1991, Spine	Retrospective study 23 cervical injuries Posterior fusion with plates 11 **unilateral facet dislocation (UFD)**, 4 **bilateral facet dislocation (BFD)**, 3 **subluxation**, 5 facet **fractures**	Class III	3 of 12 failed closed reduction and 3 were unstable in an orthosis. All achieved fusion.
Ripa et al, 1991, Spine	Retrospective study 92 cervical injuries Ant fusion w/ plate 48 multifx, 20 VC, 13 DF, 6 extension	Class III	No patient worsened neurologically. 12 of 15 complications were hardware related. 1 patient had pseudarthrosis.

First Author Reference	Description of Study	Data Class	Conclusions
Sears W & Fazl M, 1990, J Neurosurg	Retrospective study 173 cervical injuries 103 non-facet dislocation injuries Halo treatment Operative procedure unreported	Class III	31 of 103 patients failed nonoperative treatment (3 were irreducible, 10 were neurologically worse, 16 subluxed in halo, 2 had late instability). Sublux and angulation predicted failed treatment, while fracture did not.
Benzel E and Keterson L, 1989, J Neurosurgery	Retrospective study 50 cervical injuries 25 fx-subluxation Post fusion w/ wire	Class III	1 complete patient of 25 patients died. Remainder healed.
Goffin et al, 1989, Neurosurg	Retrospective study 41 cervical injuries Anterior fusion with plate	Class III	2 of 41 subluxed, requiring surgery. 3 of 12 dislocations were irreducible. All 4 deaths were in quadriplegics.
Shoung H and Lee L, 1989, Acta Neurochir	Retrospective study 37 cervical injuries Ant fusion w/ plate	Class III	All 37 healed. No graft extrusion. 1 death, 1 infection, 2 screw loosening.
Argenson C et al, 1988, Spine	Retrospective study 47 cervical injuries 7 posterior fusion 40 anterior fusion	Class III	17 of 22 were reducible, but 5 old dislocations were irreducible. 1 died of vertebrobasilar thrombosis.
Bucci MN et al, 1988, J Trauma	Retrospective study 49 cervical injuries: 20 halo alone (1 refused) 28 fusion w/immob, proced unreported	Class III	12 of 20 with halo stable. 26 of 28 fused were stable ($p<0.01$). 2 in each group lost reduction. 1 in each group neuro worse.
Donovan WH et al, 1987, J Neurosurg	Retrospective study 61 cervical injuries: 17 fusion w/immob (4 ant, 13 post) 43 6wk tx to halo 1 lami w/o fusion	Class III	18 of 43 had alignment in halo . 3 of 9 DF unstable:2 surgery/1 asymp. All patients treated with fusion were stable but 3 developed kyphosis.
Savini R et al, 1987, Spine	Retrospective study 12 cervical injuries with late instability after closed **treatment**	Class III	No grafts dislodged when anterior fusion was performed before posterior reduction.
Ersmark H & Kalen R, 1986, Arch Orthop Trauma Surg	Retrospective study 64 cervical injuries with halo vest (36 subaxial)	Class III	29 dislocations and 5 VC injuries were stable after halo vest treatment.
Glaser et al, 1986, J Neurosurg	Retrospective study 245 cervical injuries 125 complex fxs Halo treatment Fusion posteriorly w/ wire or anteriorly w/o plate.	Class III	17 of 86 lost alignment in the halo. 2 interbody grafts displaced after surgery w/o plate.
De Smet L et al, 1984, Acta Orthop Belgica	Retrospective study 28 cervical injuries with traction	Class III	4 of 28 failed early reduction. 2 of 24 had late instability.
Cahill DW et al, 1983, Neurosurg	Retrospective study of 25 DF or CF injuries txed with posterior fusion with wiring	Class III	18 of 18 with 3 month F/U were stable and none had complications.

First Author Reference	Description of Study	Data Class	Conclusions
Chan RC et al, 1983, J Neurosurg	Retrospective study 188 cervical injuries 150 subaxial w F/U Halo treatment	Class III	4 of 55 fx-disloc or complex fx, 13 of 53 had UFD/BFD and 2 of 41 VC unstable
Cooper PR et al, 1979, J Neurosurg	Retrospective study 33 cervical injuries txed halo	Class III	2 of 11 "complex" fxs. 1 of 3 subluxations unstable
Verbeist H, 1969, J Bone Joint Surg Am	Retrospective study 47 cervical injuries Ant fusion w/o plate	Class III	5 patients died, 4 with complete spinal cord injuries. 6 had residual malalignment and 1 other had reop for lost alignment.
Paeslack et al, 1967, Proceedings Vet Admin Spinal Cord Injury Conf	Retrospective study 221 cervical injuries 68 CF, 114 DF Postural reduction, Traction 31 cervical injuries Ant or post fusion	Class III	75 aligned, 67 wedged, 43 partially reduced, 36 failed reduction. Four of 221 had late instability, 3 stable with further treatment and 1with surgery. 2 of 31 were unstable after surgery.
Koskinen EVS & Nieminen R, 1967, Inter Surg	Retrospective study 159 cervical injuries Various treatments	Class III	No difference in pain, neck mobility, radiculopathy, or mortality when comparing operative and nonoperative treatments.

EVIDENTIARY TABLE: Distractive Flexion (DF)

First Author Reference	Description of Study	Data Class	Conclusions
Ordonez et al, 2000, J Neurosurg	Retrospective study 6 UFD, 4 BFD 9 anterior reduction and fusion, 1 A-P-A	Class III	10 with stable fusions, although 1 was incompletely reviewed.
Shapiro S et al, 1999, J Neurosurg	Retrospective study 51 UFD 24 SP wiring 22 SP wire + plates 5 Ant-Post-Ant	Class III	1 of 24 with wire failed and 13 of 24 had late kyphosis. All patients with plate fixation had stable fusions.
Fehlings et al, 1994, J Neurosurg	Retrospective study 44 cervical injuries 19 facet dislocations Post. fusion w/ plate	Class III	5 of 19 patients had complications including 2 late failed reductions.
Lieberman IH & Webb JK, 1994, J Bone Joint Surg Br	Retrospective study 41 cervical injuries 9 facet dislocations Patients >65 years old	Class III	5 patients died, one treated with traction and 4 with halo. 3 of 4 survivors treated with traction healed. All 4 survivors with halo treatment healed.
Lukhele M, 1994, S Afr J Surg	Retrospective study 43 facet dislocations 12 with laminar fx Post fusion w/ wire	Class III	5 of 12 patients developed kyphosis.
Pasciak M & Doniec J 1993, Arch Orthop Trauma Surg	Retrospective study 32 UFD 23 nonoperative (tx + halo or plaster vest) 9 operative	Class III	All 9 treated with surgery healed. 8 of 23 who failed closed reduction were fused. 7 of 15 who failed to maintain reduction were fused.
Shapiro SA, 1993, Neurosurgery	Retrospective study 24 UFD Post fusion w/ wire	Class III	23 of 24 patients with surgery healed. 1 with re-subluxation healed with ACF. Nine of 17 who failed closed reduction had fractures of laminae.
Hadley et al, 1992, Neurosurgery	Retrospective study 31 UFD 37 BFD	Class III	18 of 29 UFD and 20 of 37 BFD successful closed reduction. 16 UFD and 15 BFD healed in halo. 7 of 31 failed halo treatment. (5 of 7 without assoc. facet fractures). When facet fractures present, once reduced, 97% success rate in halo. UFD/BFD results similar.
Mahale YJ & Silver JR, 1992, J Bone Joint Surg Br	Retrospective study 13 missed BFD with neurologically worse and late treatment	Class III	All 13 reduced (10 completely). 12 of 13 healed with traction, 1 needed surgery.
Beyer et al, 1991, J Bone Joint Surg Br	Retrospective study 36 UFD +/- fx 24 tx, halo or orthosis 10 posterior ORIF	Class III	15 of 24 reduced in halo. 8 of 10 reduced with surgery. 11 of 24 failed halo. All 10 healed with surgery. Pain was more frequent despite healing if unreduced.

First Author Reference	Description of Study	Data Class	Conclusions
Wolf A et al, 1991, J Neurosurg	Retrospective study 52 BFD 44 post fusion w/wire 3 ant fus+plate, 2 both	Class III	12 of 52 failed closed reduction. All 3 deaths had complete quadriplegia.
Cotler HB et al, 1990, Spine	Retrospective study 23 UFD (10 nonop) 12 BFD (4 nonop) 30 fused (21 primary)	Class III	1of 2 failed halo. 8 of 12 failed traction. Complications were not reported.
Rockswold et al, 1990, J Trauma	Retrospective study 140 cervical injuries 8 facet dislocations (6 UFD, 2 BFD) txed halo or surgery	Class III	1 of 6 UFD failed halo. 0 of 4 failed surgery. 1 of 2 BFD failed halo. 2 of 9 failed surgery.
Sears W & Fazl M, 1990, J Neurosurg	Retrospective study 173 cervical injuries 70 dislocation injuries (38 UFD, 32 BFD)	Class III	19 healed with halo, 16 in good alignment. 16 failed reduction and 23 subluxed in halo required surgery. Subluxation and angulation were not associated with failure of halo. UFD/BFD results similar.
Benzel E and Kesterson L, 1989, J Neurosurg	Retrospective study 50 cervical injuries 19 UFD, 6 BFD Post fusion w/ wiring	Class III	All healed with fusion 1 BFD neuro worse required ACF, 1 UFD incomplete pt died
Bucholz R and Cheung K, 1989, J Neurosurg	Retrospective study 124 cervical injuries 20 DF injuries tx halo or surgery	Class III	9 of 20 failed halo. 1 neuro worse postop, unreported if DF or subluxation patient
Osti OL et al, 1989, J Bone Joint Surg Br	Retrospective study 167 dislocations 82 nonoperative (Traction) 85 operative (Ant fusion w/o plate)	Class III	6 of 82 who failed reduction were fused. 14 of 76 with late instability were fused 7 operatively treated within 24 hr died (all ASIA A).
Lind B et al, 1988, Spine	Retrospective study 83 injuries treated with halo	Class III	4 of 31 failed halo. Loose pins common.
Rorabeck CH et al, 1987, Spine	Retrospective study 26 UFD	Class III	20 of 26 failed closed reduction. 10 healed in halo. 8 of 10 remaining reduced with surgery. Pain common with failed reduction.
Glaser et al, 1986, J Neurosurg	Retrospective study 245 cervical injuries 17 dislocations	Class III	3 of 12 UFD failed halo. 1 of 5 BFD failed halo.
Maiman DJ et al, 1986, Neurosurgery	Retrospective study 26 BFD with data 14 post fus w/ wire 12 ant/AP fusion	Class III	10 of 18 reduced with closed reduction. 3 died, all complete injuries.
Chan RC et al, 1983, J Neurosurg	Retrospective study 188 cervical injuries 150 subaxial w F/U 40 halo alone 20 halo, post fusion	Class III	27 of 40 healed with halo. All 20 with primary surgery healed.

First Author Reference	Description of Study	Data Class	Conclusions
Dorr LD et al, 1982, Spine	Retrospective study 117 cervical injuries 25 flex-rot injuries	Class III	2 of 3 ACF had complications (1 graft displaced,1 kyphosis).
Sonntag VKH, 1981, Neurosurgery	Retrospective study 15 BFD Halo or surgery	Class III	10 of 15 reduced with closed reduction. 4 halo heal (2 no FU) 8 post fusion with wire healed,1 died (complete).
Stauffer ES & Kelly EG, 1977, J Bone Joint Surg Am	Retrospective review 10 dislocations 5 fractures 1 fracture subluxation Anterior fusion	Class III	16 of 16 had recurrent angular deformity after ACF without plate. 3 of 16 fused angulated.
Burke DC and Tiong TS, 1975, Paraplegia	Retrospective review 175 cervical injuries txed traction, traction-manipulation, collar	Class III	2 of 14 UFD and 0 of 13 BFD failed nonoperative treatment.
Burke DC & Berryman D, 1971, J Bone Joint Surg Br	Retrospective review 76 facet dislocations 41 UFD, 35 BFD 41 manipulation 35 traction (3/35 failed manipulation) 3 fusion primarily	Class III	4 of 41 failed manipulation and 4 of remaining 37 had late instability. 0 of 32 failed traction.
Cheshire DJE, 1969, Paraplegia	Retrospective review 257 cervical injuries treated with traction or collar (33 excluded)	Class III	3 of 40 UFD and 2 of 35 BFD failed nonoperative treatment.

EVIDENTIARY TABLE: Compressive flexion or vertical compression

First Author Reference	Description of Study	Data Class	Conclusions
Fehlings et al, 1994, J Neurosurg	Retrospective study 44 cervical injuries Posterior fusion with plates	Class III	Complications in 6 of 17 including 1 residual kyphosis and 1 new kyphosis (reop).
Lieberman IH & Webb JK, 1994, J Bone Joint Surg Br	Retrospective study 41 cervical injuries Patients >65 years old	Class III	1 of 4 died. 2 in collar and 1 fused patient were stable.
Kiwerski JE, 1993, Inter Orthop	Retrospective "cross-over" study: 273 VC 1st 70 traction 2nd 203 anterior fusion	Class III	Fewer died and more recovered neurologic function when treated with surgery.
Aebi M et al, 1991, Spine	Retrospective study 22 cervical injuries Anterior corpectomy with plate	Class III	All 22 achieved stable fusion. 2 screw complications occurred.
Anderson PA et al, 1991, Spine	Prospective study 30 cervical injuries Post fusion with plate	Class III	All 9 achieved stable fusion, though 1 had late kyphosis.
Bucholz R and Cheung K, 1989, J Neurosurgery	Retrospective study 32 cervical injuries 19 VC, CF injuries	Class III	1 of 19 failed halo treatment. Pt failed post fusion w/ wire
Cabanela M & Ebersold MJ, 1988, Spine	Retrospective study 8 tear drop fractures Ant fusion with plate	Class III	All 8 achieved stable fusion with none developing kyphosis.
Lind B et al, 1988, Spine	Retrospective study 83 cervical injuries Halo treatment	Class III	2 of 19 were unstable. Drainage and loose pins were common.
Chan RC et al, 1983, J Neurosurg	Retrospective study 188 cervical injuries 150 subaxial w F/U Halo treatment	Class III	All 22 burst fxs and 17 of teardrop fxs achieved stable fusion.
Dorr LD et al, 1982, Spine	Retrospective study 117 cervical injuries 32 VC injuries	Class III	1 of 11 had graft displacement after ant fusion w/o plate.
Burke DC and Tiong TS, 1975, Paraplegia	Retrospective study 175 cervical injuries treated with traction, traction-manipulation, collar	Class III	1 of 46 failed nonoperative treatment.
Frankel H et al, 1973, Proceed Vet Admin Spinal Cord Injury Conf	Retrospective study 218 cervical injuries 45 Burst, 97 Teardrop Closed treatment	Class III	7 of 142 failed postural reduction. 103 had residual deformities.
Cheshire DJE, 1969, Paraplegia	Retrospective review 257 cervical injuries treated with traction or collar (33 excluded)	Class III	3 of 63 failed nonoperative treatment.
Beatson TR, 1963, J Bone Joint Surg Br	Retrospective study 59 cervical injuries All immobilized	Class III	All 16 were stable with immobilization.

EVIDENTIARY TABLES: Extension

First Author Reference	Description of Study	Data Class	Conclusions
Lifeso RM & Colucci MA, 2000, Spine	Retrospective and prospective study 32 CE1 injuries (3 lost to F/U)	Class III	All 18 treated with brace failed (17 were unreduced). 9 of 11 healed with PCF, but 3 had stable kyphosis. 2 of 11 healed w/o reduction.
Lieberman IH & Webb JK, 1994, J Bone Joint Surg Br	Retrospective study 41 cervical injuries Patients >65 years old	Class III	1 of 3 healed with collar and 1 of 3 healed with surgery.
Anderson PA et al, 1991, Spine	Prospective study 30 cervical injuries Posterior fusion with plates	Class III	All 30 healed but 1 had screw loosening.
Rockswold et al, 1990, J Trauma	Retrospective study 140 cervical injuries txed halo or surgery	Class III	All 3 treated with halo healed. All 3 treated with surgery healed.
Bucholz R and Cheung K, 1989, J Neurosurgery	Retrospective study 32 cervical injuries 12 extension injuries	Class III	1 of 12 failed halo treatment. 1 pt stable post fusion w/ wire
Dorr LD et al, 1982, Spine	Retrospective study 117 cervical injuries 45 extension injuries	Class III	40 of 45 were treated with brace. Of all cervical injuries treated with brace, 5 of 86 failed.
Burke DC and Tiong TS, 1975, Paraplegia	Retrospective review 175 cervical injuries txed traction, traction-manipulation, collar (30 excluded)	Class III	All 45 healed without surgery.

EVIDENTIARY TABLE: Subluxation

First Author Reference	Description of Study	Data Class	Conclusions
Fehlings et al, 1994, J Neurosurg	Retrospective study 44 cervical injuries Posterior fusion with plates	Class III	2 of 5 lost reduction, including 1 who died.
Anderson PA et al, 1991, Spine	Prospective study 30 cervical injuries Posterior fusion with plates	Class III	19 of 19 healed with fusion. 8 of 19 had complications, including 2 with increase kyphosis & 3 requiring additional levels to be fused.
Rockswold et al, 1990, J Trauma	Retrospective study 140 cervical injuries treated with halo or surgery	Class III	12 of 26 failed halo treatment. 2 of 10 failed surgical treatment.
Bucholz R and Cheung K, 1989, J Neurosurgery	Retrospective study 32 cervical injuries 6 subluxation injuries	Class III	2 of 6 failed halo treatment. 1 worse postop, unreported if DF or sublux patient
Cooper PR et al, 1979, J Neurosurg	Retrospective study 33 cervical injuries treated with halo	Class III	1 of 3 failed halo treatment.
Burke DC and Tiong TS, 1975, Paraplegia	Retrospective study 175 cervical injuries treated with traction, traction-manipulation, collar (30 excluded)	Class III	1 of 14 failed nonoperative treatment.
Cheshire DJE, 1969, Paraplegia	Retrospective study 257 cervical injuries treated with traction or collar (33 excluded)	Class III	4 of 19 failed nonoperative treatment.
Beatson TR, 1963, J Bone Joint Surg Br	Retrospective study 59 cervical injuries (3 excluded)	Class III	8 of 22 with <50% subluxation reduced. 2 of 14 remaining had surgery. 13 of 18 with >50% subluxation reduced. 5 of 5 remaining had surgery.

EVIDENTIARY TABLE: Ankylosing Spondylitis **(AS)**

First Author Reference	Description of Study	Data Class	Conclusions
Weinstein et al, 1982, J Neurosurg	Retrospective study 13 AS 7 traumatic cervical 6 quadriplegic 2 central cords w/o fx	Class III	2 treated with traction died of pneumonia. 2 treated with traction/brace healed. 1 worse halo treated surgically. 1 lami/fusion worse, 1 lami/fusion had pseudoarthrosis.
Bohlman HH, 1979, J Bone Joint Surg	Retrospective study 300 cervical injuries 8 AS	Class III	5 of 8 patients died. 2 healed after brace treatment and 1 after laminectomy.
Cheshire DJE, 1969, Paraplegia	Retrospective study 257 cervical injuries 1 AS	Class III	1 C5-C6 extension injury healed with surgical fusion
Grisolia et al, 1967, J Bone Joint Surg Am	Retrospective study 6 AS	Class III	3 of 4 healed with brace +/- traction. 2 with laminectomy and PCF died of PE.

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