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Combined injuries in the upper cervical spine: clinical and epidemiological data over a 14-year period

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Abstract Concomitant traumatic injuries in the upper cervical spine are often encountered and rarely reported. We examined the data concerning 784 patients with cervical spine injuries following trauma, including 116 patients with upper cervical spine injuries. Twenty-six percent of patients with upper cervical spine injuries (31 cases) were found to have combined injuries involving either the upper or the upper and lower cervical spine. The frequent patterns were combined type I bipedicular fracture of the axis and dens fracture, and combined dens fracture and fracture of the posterior arch of C1. Other patterns posed specific problems, such as combined

dens and Jefferson fracture and combined dens and C2 articular pillar fracture. Seventy percent of atlas fractures, 30% of C2 traumatic spondylolistheses and 30% of dens fractures were part of a combination. A total of 1.7% of patients with lower cervical spine injuries had a combined injury in the upper cervical spine. A comprehensive therapeutic schedule is outlined. Combined injuries in the upper cervical spine should be sought in any patient with a cervical spine injury.

Key words Spine · Cervical vertebrae · Spinal fractures · Spinal injury · Atlas · Axis

Introduction

Concomitant fractures in the spine are a common finding in patients with spine injuries, and the frequent occurrence of such lesions involving different spinal levels has been emphasized [1, 11, 16, 25, 30]. Although combined injuries following trauma to the upper cervical spine (UCS) are often encountered in clinical practice, they are rarely reported in the literature, and their frequency and characteristics are not well known. Overlooking such associations can lead to suboptimal management; the risks are residual spine instability or non-union of an occult fracture, possibly resulting in secondary neurological involvement. When a combined injury is recognized, surgical difficulties arise because some injuries may render operative procedures difficult, and some combined patterns require a different approach to treat both lesions.

The purpose of this study is to establish the frequency of combined lesions in the UCS in patients with cervical spine injuries, determine frequent combined patterns and predisposing factors, and discuss surgical management.

Materials and methods

From 1980 to 1994, 784 patients were admitted to our institution with a cervical spine injury as the initial diagnosis. Among them, 116 had a UCS fracture or ligament injury. The diagnostic was made using standard diagnostic procedures at the time of treatment, including conventional X-rays, functional X-rays, computed tomography (CT), and magnetic resonance imaging (MRI) when it became available. A retrospective study seeking for known or overlooked combined lesions in the UCS in spine trauma patients was conducted using all charts and radiographs available. Recorded material was assessed by an independent reviewer who had not participated in treating any patient nor performing surgery. Combined injuries involving the UCS and the lower cervical spine

(LCS) were recorded at the same time. All patients had a follow-up duration of more than 12 months. Among the 116 UCS lesions, all patients had conventional tomographies, 24 patients only underwent a CT examination at the time of trauma, and 32 had functional X-rays. The diagnostic was made within the 1st week after injury in all cases; 57 had dens fractures, 43 had traumatic spondylolisthesis of the axis and 27 had C1 fractures. Thirty-one patients were found to have combined injuries involving either the upper or the upper and lower cervical spine. Charts were reviewed to determine the frequent patterns and correlate them to the causative mechanisms. Associated factors and general epidemiological data were recorded and compared with those of the patients with uncombined injuries. A statistical analysis was made using the Student *t*-test for quantitative data and the Fischer "exact test" for categorical data. The risk α was set at 0.05.

We recorded as "combined injuries", injuries involving two or more different sites, on the same vertebra or on different vertebrae, that were not part of the same pathological entity. Combined fractures of the anterior arch and the posterior arch of C1 were recorded as "Jefferson fractures" [14] and not "combined injuries". Combined injuries were classified in two groups: group I comprised injuries involving the UCS alone, group II was made up of injuries involving both the upper and lower cervical spine.

Results

Patients were followed at the clinic where they had been examined and had X-rays taken. The minimum follow-up duration was 12 months. One patient who sustained severe head trauma died of intracranial complications after 2.5 days and one patient died after 4 months of unrelated causes. In patients with combined or uncombined UCS injuries (116 cases), the mean follow-up was 13.6 ± 5.4 months (SD) and the range was 12–48 months. The mean age at the time of injury was 44.8 ± 22.9 years (range 15–90 years). The cause of the trauma was a traffic accident in 74, a fall in 26, a suicide attempt in 5, a sports accident in 2, an aeroplane accident in 1, and was unknown in 8. Thirty-nine patients had combined peripheral injuries involving the limbs, chest or abdomen. Eight had severe head trauma, and 69 had no combined peripheral injury. One hundred and seven patients had no neurological signs at the time of admission to the hospital, although three had transient paresthesias, which ceased within a few minutes. Two patients had incomplete tetraplegia. Two patients had complete tetraplegia, which remained complete at the latest follow-up examination. Two patients had only radicular signs, and two had only paresthesia in the limbs, with a normal neurological examination. One patient with severe head trauma could not be examined. According to the Frankel grading system, two patients were A, one B, one C, one D, and 110 E. Thirty-one patients had combined injuries in the UCS. Patients with combined injuries had either two lesions or three lesions involving the cervical spine; no patient had more than three injuries. Seventeen patients had two lesions involving the UCS, and two had three combined lesions in the UCS; those cases were classified in group I. Five patients had two combined lesions involving both the upper and

Table 1 Distribution of combined injuries (number of cases). Group I comprises cases that had combined injuries in the upper cervical spine, whereas group II comprises cases that had combined injuries in the upper and in the lower cervical spine

	Combined injuries		
	Group I (<i>n</i> = 19)	Group II (<i>n</i> = 12)	Total (<i>n</i> = 31)
Two injuries	17	5	22
Three injuries	2	7	9

lower cervical spine, and seven had three combined lesions in the UCS and LCS; those were classified in group II (Table 1). In patients with combined injuries (*n* = 31), the mean age was 46.9 ± 23.7 years (18–88 years) and the mean follow-up was 13 ± 3.5 months (12–29 months). The cause of the trauma was a traffic accident in 20, a fall in 7, a sports accident in 1 and was unknown in 3. A peripheral injury was present in ten cases, and severe head trauma in six (19.4%). Two patients were Frankel A, 1 C, and 27 E. Two patients had complete tetraplegia, one had incomplete tetraplegia, two had radicular signs and 25 had no neurological signs. One patient could not be examined due to severe head trauma.

Frequent combined injuries

Some frequent combinations were found: type I bipedicular fracture of the axis and dens fracture in four cases (12.9% of combined injuries, and 3.4% of UCS injuries), dens fracture and fracture of the posterior arch of C1 in six cases (19.4% of combined injuries, 5.2% of UCS injuries). Other combinations were less frequent, but posed specific problems to the surgeon, such as dens and Jefferson [14] fracture in two cases (6.5% of combined injuries, 1.7% of UCS injuries) and dens and C2 articular pillar in two cases (6.5% of combined injuries, 1.7% of UCS in-

Fig. 1 A C1 posterior arch fracture combined with an Effendi type I traumatic spondylolisthesis of the axis (lateral view). Non-operative treatment was indicated

Table 2 C1 injuries and combinations (number of cases)

	C1 injury (n = 30)					
	Anterior arch (n = 1)	Posterior arch (n = 15)	Jefferson (n = 8)	Lateral masses fracture (n = 3)	Transverse lig. (n = 1)	Rot. Subluxation (n = 2)
Total combined (n = 21)	1	12	3	2	1	2
Ped C2 type I (n = 6)	0	4	0	2	1	0
Ped C2 type II (n = 1)	0	1	0	0	0	0
Dens type II (n = 8)	1	5	2	0	0	2
Dens type III (n = 1)	0	1	0	0	0	0
Lower C spine (n = 6)	0	5	1	0	0	0

Table 3 Dens fractures and combined injuries (number of cases)

	Dens fractures (n = 57)	
	Type II (n = 36)	Type III (n = 21)
Total combined (n = 17)	13	4
Anterior arch C1 (n = 1)	1	0
Posterior arch C1 (n = 6)	5	1
Jefferson (n = 2)	2	0
Rot subluxation (n = 2)	2	0
Ped C2 Type I (n = 4)	1	3
Lower C spine (n = 4)	3	1

Table 4 Traumatic spondylolisthesis of the axis and combined injuries (number of cases)

	C2 pedicles (n = 43)		
	Type I (n = 35)	Type II (n = 7)	Type III (n = 1)
Total combined (n = 13)	12	1	0
Transverse Lig (n = 1)	1	0	0
Posterior arch C1 (n = 5)	4	1	0
Lateral masses C1 (n = 2)	2	0	0
Dens type II (n = 1)	1	0	0
Dens type III (n = 3)	3	0	0
Lower C spine (n = 5)	5	0	0

Table 5 Other C2 fractures and combined injuries (number of cases)

	Other C2 fractures (n = 8)			
	C2 teardrop (n = 4)	Posterior arch (n = 1)	C2 Body fracture (n = 1)	Articular mass (n = 2)
Total combined (n = 5)	1	1	1	2
Posterior arch C1 (n = 1)	0	0	1	0
Dens type II (n = 1)	0	0	0	1
Dens type III (n = 1)	0	0	0	1
Lower C spine (n = 2)	1	1	0	0

juries). Other combined lesions show a wide range of patterns. Although this classification is questionable, we included in combined injuries the combination of a dens fracture and a rotatory subluxation of C1 with facet dislocation. This pattern was found in two cases.

Frequency of combinations

Out of 15 fractures of the posterior arch of C1, 12 (80%) were part of a combination (Fig. 1). The single anterior C1 arch fracture was combined with an Anderson & D'Alonzo type II dens fracture.

Two of three C1 lateral mass fractures (66.7%) were associated with a type I traumatic spondylolisthesis of the axis and three of eight C1 burst (Jefferson) fractures (37.5%) were combined (dens in two and LCS in one) (Table 2).

Seventeen (29.8%) of 57 dens process fractures (Table 3), 13 (30.2%) of 43 traumatic spondylolistheses of the axis (Table 4) and one of four "extension teardrop" fractures of C2 (Table 5) were part of a combination.

In group II (combined upper and lower cervical spine fractures), the frequent patterns in the UCS were traumatic spondylolisthesis of the axis and dens fractures. The frequency of combinations in the UCS in patients with lower cervical spine injuries was 1.7% (12 cases in LCS injuries). Eight of 43 C2 pedicle fractures (18.6%) and 4 of 57 dens fractures (7%) were combined with a LCS in-

Fig. 2 A group II combination, including a type I C2 pedicle fracture combined with a C3 fracture separation of the articular mass, showing some instability

jury. The LCS injuries that were combined with a UCS injury were fracture of an articular process in two cases, facet dislocation in three cases and fracture separations of the articular mass [15, 20] (Figs. 2, 5) in three. (Fracture separation of the articular mass is defined as a fracture of the pedicle, transverse process and lamina on the same side, leaving the articular mass free and causing instability.) One patient had a type II dens fracture and combined C5-C6 soft tissue disruption showing instability that required fixation. Overall, the involved levels comprised the entire cervical spine from C3 to C7, although C3 was involved more often (four cases). One patient had fractures at the C4, C5 and C6 levels in addition to a C1 posterior arch fracture, and one patient had fractures at C5 and C6 that were combined with a C1 burst (Jefferson) fracture.

Predisposing factors

Patients with combined injuries were not statistically different from the general population that had UCS injuries in their age, gender, cause of the trauma, and occurrence of complications. There was a significant association between combined injuries and the occurrence of head trauma ($P = 0.0014$) or neurological complications such as tetraplegia ($P = 0.026$), but this was not significant when patients with LCS injuries were excluded.

Treatment

Out of 31 patients who had combined lesions, 13 received surgical treatment (41.9%) and 18 were treated nonoperatively. Patients with combined UCS injuries were operated on more often than patients with no combination, although the association was not significant ($P = 0.0518$) and this was not the case when patients with LCS injuries were excluded ($P = 0.79$). Of the 13 operated patients, six

had combinations in the UCS alone and eight had upper and lower cervical spine combined injuries. Performed surgery included a modified Gallie arthrodesis in seven cases, posterior C1-C2 screw fixation in two, C2 pedicle screw fixation in three and posterior plate fixation of the LCS in five. No complications occurred in these cases and all patients healed within 3 months. In the 20 patients with uncombined injuries who underwent surgery (21.7%), complications included deep infection in one case and non-union in two.

Discussion

Frequency

Combined injuries in the UCS are seldom reported in the literature; individual injuries in the dens were reported in large series by Anderson and D'Alonzo [2] and in the atlas by Fowler et al. and Levine and Edwards [9, 19]. Traumatic spondylolisthesis of the axis was first described by Cornish [6], and was classified by Effendi et al. [7] with special reference to combined injuries. Individual combinations were reported by Roy-Camille et al. (dens plus traumatic spondylolisthesis of the axis) [23], Esses et al. and Lipson (dens plus C1 burst fracture) [8, 21] and Signoret et al. (dens and lateral articular process of C2) [26]. Conversely, only limited statistical data are available concerning combinations.

The frequency of individual injuries is similar in our series to that found by Bohlman [3] in 300 cervical spine injuries, in which 69 had UCS and 231 had LCS fractures.

Fractures of the posterior arch of C1 were recognized by Fowler and by Levine to be frequently associated with other injuries, with such an association being found in all cases in the series of Fowler et al. [9], in 53% in Levine and Edwards' [19] and in 80% in our data. Jefferson fractures were combined with other injuries in 23.5% in the series reported by Kesterson et al. [17], in 33.3% in Fowler et al. [9] and in 37.5% in the present study.

Fig. 3 **A** Plain lateral radiograph demonstrating a teardrop fracture of C2 following an extension injury. **B** Same patient. Reconstruction computed tomographic scan demonstrating a combined lateral mass fracture of C1 (case was too recent to be included in the series)

Concerning fractures of C2, our data are close to those reported by Roy-Camille [24]: 28% versus 38% combined injuries in dens fractures, and 37% versus 27% in traumatic spondylolisthesis of the axis. Other authors have found combinations less frequently than we have [5, 10]. No data are available concerning the risk factors of combinations. As stated by Levine and Edwards [19], a combined lesion does not worsen any cervical spine instability once the diagnosis is made, for example, in a traumatic spondylolisthesis of C2 and fracture of the posterior arch of C1. However, our data are consistent with the fact that combinations in the UCS are far from uncommon. Since different treatments may be recommended for combined injuries, and the risk of overlooking some injuries may be high, we believe the issue should be kept in mind while examining any cervical spine injured patient. In the case that any doubt arises, more radiographs should be obtained, and polytomographies or a CT scan should be made, until the possibility is ruled out (Fig. 3).

Surgical management

When a combined injury is identified, most of the time the treatment is not changed by the association, and both fractures are considered as independent injuries that can be treated separately (Fig 4). In some cases, the ideal treatment is made difficult or impossible, and the combination has to be treated as a whole. Operative treatment may be indicated in the presence of an injury impairing the imme-

Fig. 4 **A** Lateral radiograph: Effendi type I C2 pedicle fracture combined with a C1 posterior arch fracture. A C6-C7 facet fracture-dislocation injury is also present. Operative treatment was indicated on the facet dislocation, which consisted in posterior arthrodesis with plate fixation, and was followed by a 3-month minerva plaster cast immobilization. **B** Same patient. Five-year postoperative radiograph showing complete healing. The patient reported no complaints

diate or future stability of the spine [4]. In our data, operative treatment was performed in 21.7% of general UCS injuries and in 41.9% of combined lesions. Conversely, the choice of operative treatment is limited if another stable or unstable fracture is present. When operative treatment is indicated, it should be conducted where possible with a single surgical approach and in one session. Combined injuries in the UCS can be made up of several unstable injuries, of one unstable and one or several stable injuries, or of only stable injuries. Injuries that usually require surgical treatment in the UCS are Anderson & D'Alonzo type II and some type III dens fractures [13], types II and III traumatic spondylolistheses of the axis according to Levine and Edwards [18], and transverse atlantal ligament injuries with an atlas–dens interval of more than 5 mm [21, 28]. Injuries that may require surgical treatment in the LCS are disc and soft tissue disruption showing instability, bilateral or unilateral facet dislocation and fracture-dislocation, lateral mass separation fracture [20], comminuted burst fracture of the vertebral body and teardrop fractures [29]. Injuries that usually do not require surgical treatment in the UCS are anterior arch and posterior arch fracture of C1, burst “Jefferson” fracture in C1 with lateral displacement of less than 7 mm [19], type I and some type III dens fractures [2], and type I traumatic spondylolisthesis of the axis [18]. In the LCS, stable injuries are disc herniation, flexion sprain, anterior wedge fractures and some burst fractures [29].

Operative treatment in frequent combined injuries

Combined upper cervical spine injuries

Traumatic spondylolisthesis of the axis and dens fracture. If both injuries are considered stable (type I spondylolisthesis and types I and III dens), conservative non-surgical treatment is indicated. If one injury is considered unstable, operative treatment should be considered. If the dens fracture is unstable and the traumatic spondylolisthesis is stable, C1-C2 posterior fusion by the Gallie technique may not be sufficient to achieve the stability and union. We advocate transarticular C1-C2 screw fixation [12, 22] to spare cervical motion, instead of an occipito-cervical arthrodesis. If the traumatic spondylolisthesis is unstable (i.e. type II or III), transarticular C1-C2 screw fixation or an occipito-cervical arthrodesis should be done.

Dens fracture and C1 burst (Jefferson) or lateral mass fracture (Fig. 5). C1 fractures are considered a stable injury, although patterns with more than 7 mm of lateral displacement pose special problems. The surgical indication depends on the dens fracture [8, 21]; if the latter is type II, a posterior arthrodesis is impossible and anterior screw fixation inadequate. This is a preferred indication for C1-C2 transarticular screw fixation [27], which allows accurate fixation of both injuries.

Fig. 5 **A** Lateral radiograph: combined Anderson & d'Alonzo type II dens fracture plus C1 burst (Jefferson) fracture. **B** Same patient. Twelve-month lateral postoperative radiograph: direct reduction and fixation with two plates and screws and a posterior Gallie arthrodesis provided complete fusion with adequate stability. Screws were inserted into C1 lateral masses and C2 pedicles. The technique allows fixation whenever C1-C2 screw fixation is difficult for technical reasons. A C7 fracture separation of the articular mass was also present in this patient, and posterior fixation was done at the same time using the Roy-Camille technique

Dens and posterior arch of C1. Whenever the dens fracture is considered stable (type III and less than 5 mm of displacement in the anterior plane, less than 10° of angulation), orthopedic treatment alone is indicated. In type II dens fractures, a C1-C2 posterior arthrodesis is not feasible, and the treatment should be either anterior screw fixation or a posterior C1-C2 transarticular fixation.

Dens and superior articular process of C2. Articular process fractures may be combined to an unstable dens fracture, making operative treatment desirable. Moreover, occipito-cervical arthritis may be a complication [26]. Fixation of the fractured dens alone is not sufficient; C1-C2 posterior screw fixation necessitates insertion of a screw in the fractured articular process, and is not a desirable option. In this case, we advocate a posterior C1-C2 Gallie arthrodesis.

Combined injuries in both the upper and lower cervical spine

If the bone and ligaments between the two injuries are normal, treatment is that of each lesion considered independently. For example, in a fracture-dislocation in the LCS combined with a type II dens fracture, we would perform fixation in the LCS and posterior C1-C2 Gallie arthrodesis or C1-C2 screw fixation. Fixation in the lower cervical spine could be done either by a posterior or an anterior approach, and we would try to fix both injuries in the same operative session through the same approach.

Conclusion

Combined injuries in the UCS occur frequently enough to be looked for carefully in any cervical spine trauma, whatever the accident, patient characteristics or neurological damage. No spine instability is added by any combination once the diagnosis is recognized; however, operative treatment may be influenced or changed by the presence of an associated stable or unstable combined injury.

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