European Spine Journal (2021) 30:1574–1584
https://doi.org/10.1007/s00586-021-06763-x

ORIGINAL ARTICLE

C1-C2 Injury: Factors influencing mortality, outcome, and fracture healing

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Received: 5 June 2020 / Revised: 28 January 2021 / Accepted: 2 February 2021 / Published online: 26 February 2021

Abstract

Background C1-C2 injury represents 25–40% of cervical injuries and predominantly occurs in the geriatric population.
Methods A prospective multicentre study was conducted under the aegis of the french spine surgery society (SFCR) investigating the impact of age, comorbidities, lesion type, and treatment option on mortality, complications, and fusion rates.
Results A total of 417 patients were recruited from 11 participating centres. The mean ± SD age was 66.6 ± 22 years, and there were 228 men (55%); 5.4% presented a neurological deficit at initial presentation. The most frequent traumatic lesion was C2 fracture ($n = 308$). Overall mortality was 8.4%; it was 2.3% among those aged ≤ 60 years, 5.0% 61–80 years, and 16.0% > 80 years ($p < 0.001$). Regarding complications, 17.8% of patients ≤ 70 years of age presented with ≥ 1 complication versus 32.3% > 70 years ($p = 0.0009$). The type of fracture did not condition the onset of complications and/or mortality ($p > 0.05$). The presence of a comorbidity was associated with a risk factor for both death ($p = 0.0001$) and general complication ($p = 0.008$). Age and comorbidities were found to be independently associated with death ($p < 0.005$). The frequency of pseudoarthrosis ranged from 0 to 12.5% up to 70 years of age and then constantly and progressively increased to reach 58.6% after 90 years of age.
Conclusions C1-C2 injury represents a serious concern, possibly life-threatening, especially in the elderly. We found a major impact of age and comorbidities on mortality, complications, and pseudarthrosis; injury pattern or treatment option seem to have a minimal effect.

Keywords Spine trauma · Spine injury · C1 vertebra · C2 vertebra · Surgery

Introduction

The cervical spine can be divided into the sub-axial spine (C3-C7) and the upper cervical spine (C1-C2). Trauma of the upper cervical spine represents 25% to 40% of cervical injuries [1–5]; the majority of these occur in the geriatric population [1, 2], and such injuries often result in significant morbidity and mortality [3–5].

Biomechanically, the C1-C2 segment provides the greatest amount of flexion–extension and axial rotation mobility in the cervical spine. Thus, injury to the upper cervical spine can lead to severe instability and catastrophic neurological consequences, such as tetraparesis [5]. The presence of osteoporosis of the upper cervical spine and osteoarthritis of the sub-axial cervical spine explains the high frequency of these injuries in elderly patients, which typically occur after low energy trauma [6–12]. Two therapeutic strategies are possible [3, 13–18]**;** either surgical techniques (performed via an anterior and/or posterior approach), or conservative treatment based on immobilisation by an external brace. The goal of both these treatments is to stabilise the injuries, obtain fracture healing and allow patients to rapidly return to the same level of autonomy as before the injury [15–17]. However, outcomes of such trauma and the factors influencing this are poorly reported in the literature. Most published studies are retrospective database or national registry review [1, 2, 4, 10, 15, 17], focused on a small sample of elderly patients [3, 7], or only involved one injury pattern [6]. In addition, these studies are mainly descriptive and the prognostic factors influencing death, outcome, and

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fracture healing are rarely and/or only partially reported [5, 19]. Hasler et al. reported a large prospective cohort of cervical spine injuries ($n = 6802$ patients), but the study was not focused on the upper cervical spine (C1-C2) and the outcome was not investigated [18]. In this context, the objective of this prospective multicentre study, which involved 11 spinal units (both neurosurgical and orthopaedic), was to investigate mortality, complications, and fusion rates after C1-C2 injury treated conservatively or surgically.

Methods

This is a multicentre prospective cohort study, focusing on fractures and/or luxation of the C1-C2 complex conducted under the aegis of the french spine surgery society (SFCR). The data collected concern the period from June 2014 to May 2016 (inclusion period). All patients were included consecutively in each centre. A total of 11 spine surgery centres participated in the study: Hospices Civils de Lyon (HCL); University Hospital of Nice; Assistance Publique des Hôpitaux de Marseille (APHM); Hospices Civils de Strasbourg; University Hospital of Grenoble; University Hospital of Bordeaux; University Hospital of Besançon; University Hospital of Lille; University Hospital of Nîmes; University Hospital of Dijon; and University Hospital of Montpellier. All patients included in the study were adults (≥ 18 years of age), operated or treated orthopedically, with a minimal follow-up of one year, and a pre-treatment and 1-year CT-scan. All data were collected using a specific online database, Keops data management (https://www.keops-spine.fr). For each patient, age, sex, type of trauma, type of spinal injury, ASIA score (neurological status), comorbidity, treatment option, complications, mortality, bone consolidation, and pseudoarthrosis at 1-year were assessed. Regarding conservative treatment, the compliance for wearing the orthotic device was considered as good if the patient respected correctly the recommendations of the surgeon (in terms of duration and conditions), mediocre if the patient respected only partially these recommendations, and poor if the patient did not respect at all the recommendation or very poorly. Finally, the complications were categorised into mechanical, general, infectious, and neurological.

Statistical analysis

Statistical analysis was performed using SAS software V9.3 (SAS Institute Inc, Cary, NC, USA). Categorical variables were expressed as frequencies (n) and percentages, and quantitative variables were expressed as means ± standard deviation or median interquartile range according to distribution; the normality of which was tested using the Shapiro test and graphically confirmed with a histogram. Categorical variables were compared using the Chi-squared test or Fisher's exact test, and quantitative variables using the Student's t test or the nonparametric Wilcoxon test, as appropriate. Overall survival curves were estimated using the Kaplan–Meier method, and the effect of different parameters was assessed using the Log-rank test.

Overall survival was defined from the date of diagnosis to the date of death or last known status. Prognostic factors were assessed using the semi-parametric Cox model after verification of the proportional hazard hypothesis, first in univariate analysis, then in a multivariate analysis including variables found to be significantly associated in univariate analysis as well as those considered as pertinent by the scientific board for the clinical interpretation of the results, such as sex. The statistical tests were bilateral, and the level of significance was set at 5% ($p < 0.05$).

Results

Description of the cohort

The study included 417 patients from 11 participating centres. The mean ± SD age of the patients was 66.6 ± 22 years (range: 18 to 100), and 228 patients were men (55%). The most frequent type of trauma was isolated cervical injury, and the majority of fractures were of C2 (Table 1).

Neurological status

The ASIA score was reported for 315 patients. Among these, the majority presented an ASIA score E (94.6%), i.e. with normal motor and sensory function (Table 1). Among the 17 patients with an ASIA score other than E (i.e. presence of neurological signs), 88.2% had a C2 lesion, and 70.6% corresponded to an oblique-posteriorly C2 fracture.

Comorbidities

A total of 161 patients (38.8%) presented at least one comorbidity. The most frequent were cardiovascular diseases (Table 1). The presence of a comorbidity was a risk factor for both death, $p = 0.0001$ (Wilcoxon test), and for a general complication, $p = 0.008$ (Wilcoxon test).

Type of Fracture

Among the 417 patients, the distribution of traumatic lesions was: 308 C2 fractures, 63 C1 fractures, 19 ligamentar C1-C2 injuries, and 17 others; for 10 patients, this was not available (Table 1).

Table 1 Epidemiological, fracture type, and clinical characteristics of the patients at baseline

	Total population, $n=417$
Mean age ± SD, years	66.6 ± 22
Sex, male, n (%)	228 (54.7)
Type of trauma, n (%)	
Limited to cervical spine	196 (48.8)[a]
Associated with head trauma	131 (32.6)[a]
Associated with polytrauma	75 (18.7)[a]
Polytrauma including head trauma	35 (8.7)[a]
Polytrauma without head trauma	40 (9.9)[a]
Missing data	*15*
Multiple spinal injury, n (%)	59 (14.7)[a]
Type of lesion, n (%)	
C2 fracture	308 (75.7)[a]
C1 fracture	63 (15.5)[a]
C1-C2 ligamentar injury	19 (4.6)[a]
Other	17 (4.2)[a]
Missing data	*10*
ASIA score, n (%)	
A	6 (1.9)[b]
B	1 (0.3)[b]
C	6 (1.9)[b]
D	4 (1.3)[b]
E	298 (94.6)[b]
Missing data	*102*
Patients with ≥ 1 comorbidity, n (%)	Total, $n=161$
Heart disease	76 (47.2)[c]
Hypertension	75 (46.6)[c]
Peripheral artery disease	58 (36.0)[c]
Broncho-pulmonary	29 (18.0)[c]
Gastrointestinal	16 (9.9)[c]
Other (renal, hepatic, etc.)	34 (21.1)[c]
Total number of comorbidities	288

[a]percentages among $n = 402$; [b]among $n = 315$; [c]among $n = 161$

Table 2 Characteristics of the C1-C2 traumatic lesions

	Total population, $n=417$
C1 Fractures, n (%)	63 (15.1)
Type I (Fracture of anterior or posterior arch)	18 (28.6)[a]
Type II (Fracture of both anterior and posterior arch)	23 (36.5)[a]
Type III (Fracture of the lateral mass)	22 (34.9)[a]
Missing data	*None*
C2 Fractures, n (%)	308 (73.9)
Odontoid fractures, n (%)	204 (66.2)[b]
Anderson-D'Alonzo Classification	
Type I (Apex of the dens)	1 (0.6)[c]
Type II (Body of the dens)	131 (84.0)[c]
Type III (Base of the dens)	24 (15.4)[c]
Missing data	*48*
Roy-Camille Classification	
Oblique-posteriorly	115 (64.2)[d]
Oblique-anteriorly	29 (16.2)[d]
Horizontal	35 (19.2)[d]
Missing data	*25*
Other C2 fractures, n (%)	104 (33.8)[b]
Bi-isthmic	36 (11.7)[e]
Body of C2	30 (9.7)[e]
Other	38 (12.3)[e]
Missing data	*None*
C1-C2 ligamentar injuries, n (%)	19 (4.6)
C1-C2 antero-posterior subluxations	5 (26.3)[f]
C1-C2 rotatory subluxations	9 (47.4)[f]
Other	5 (26.3)[f]
Missing data	*None*

C1 fractures (n=63) were classified into 3 types: type I (fracture of 1 arch only); type II (fracture of both arches) and type III (fracture of the lateral mass). C2 fractures (n=308) were classified according to Anderson-D'Alonzo classification (divided into 3 zones: apex, body, and base of the odontoid) and according to Roy-Camille classification (based on the orientation of the fracture line: oblique-posteriorly, oblique anteriorly, and horizontal). Ligament injury was classified into antero-posterior (AP) and rotatory sub-luxations

[a]percentages among $n=63$; [b]among $n=308$; [c]among $n=156$; [d]among $n=179$; [e]among $n=104$; [f]among $n=19$

C2 fractures

There were 308/407 (75.7%) patients with C2 fracture. Among these, 204 presented an odontoid fracture, with a clear predominance of fractures of the base of the odontoid or type II according to the Anderson-D'Alonzo classification (131/156, 84%). According to the Roy-Camille classification, there was a clear predominance of oblique-posteriorly type fractures (115/179, 64.2%; Table 2), which was more frequent in the elderly (74% of patients aged > 70 years versus 41.5% of those aged ≤ 70 years; $p=0.002$, Chi^2).

C1 fractures

There were 63/407 (15.5%) patients with C1 fracture. The frequency of the 3 types of C1 fracture ranged from 28.6% to 36.5% (Table 2). In 25/63 (39.7%) of cases, the C1 fracture was associated with a C2 fracture.

C1-C2 Ligamentar injuries

There were 19/407 (4.6%) patients with C1-C2 ligament injuries. Among these, the most frequent (9 patients, 47.4%) was a C1-C2 rotational sub-luxation; 5 patients (26.3%) had an antero-posterior C1-C2 subluxation, and in the remaining 5 patients the type of ligament injury was not specified.

Treatment

Conservative treatment

There were 255 (61.1%) patients treated by orthotic treatment; the mean ± SD age was 66.1 ± 24 years (range: from 17 to 100 years). There were 260 orthotic devices used by these patients; the type of device included: rigid cervical collar ($n=184$, 70.8%), semi-rigid ($n=36$, 13.8%), soft ($n=36$, 13.8%), and/or brace ($n=4$, 1.5%); no halo-vest was used, and 5 patients received 2 orthotic devices. Compliance was available for 152 patients; it was considered as good for 77.0% ($n=117$) of patients, mediocre for 17.8% ($n=27$), and bad for 5.3% ($n=8$). The rates of non-surgical treatment differed according to the type of injury, $p=0.06$ (Fisher test): conservative treatment was provided to 71.4% of patients with C1 fractures ($n=45/63$), 59.1% with C2 fracture ($n=182/308$), and 52.6% with C1-C2 sub-luxations ($n=10/19$). Among the 255 patients initially treated conservatively, 23 subsequently underwent surgery.

Surgical treatment

A total of 161 (38.6%) patients were operated at first attempt, 75 by an anterior approach and 86 by a posterior approach**.** The mean ± SD age of these patients was 68.5 ± 20 years (range: from 16 to 97 years). For anterior surgery, anterior odontoid screw fixation was the most frequent technique ($n=65$, 86.7%), and the most frequent posterior procedure was the C1-C2 fusion according to the Harms technique ($n=26$, 30.2%).

Complications, mortality, and outcome

In the total study population, overall mortality was 8.4% (35 deaths). At least one complication was present in 106 patients (25.4%; Table 3), and this was more frequent in the elderly (17.8% of patients aged ≤ 70 years versus 32.3% of those > 70 years; $p=0.0009$). There was no difference in the frequency of patients with ≥ 1 comorbidity (C1: 3.2%; C1-C2: 10.5%; C2: 9.7%, $p=0.20$) or mortality according to the type of fracture (C1: 17.5%; C1-C2: 31.6.5%; C2: 19.8%, $p=0.39$). There was an increase in mortality in function of age; up to 16.0% among those aged > 80 years, $p<0.001$. The frequency of patients with ≥ 1 complication was higher among more elderly patients; it was 23.1% among those aged > 80 years, $p=0.03$ (Fig. 1).

There was a trend towards more frequent mortality among those who were treated surgically (10.6% versus 6.7% among those treated conservatively; $p=0.15$); there was a higher frequency of general (9.4% versus 1.6%, $p=0.0002$) or infectious complications in such patients (4.4% vs none; $p=0.004$). Mechanical complications were more frequent in those who received orthotic treatment (20.4% versus 13.8%; $p=0.09$), and among the latter this complication was more frequent in the elderly (28.8% aged > 70 years versus 11.9% aged ≤ 70 years; $p=0.0001$). Among those who were treated surgically, mortality was more frequent among the elderly (16.7% aged > 70 years versus 1.5% aged ≤ 70 years; $p=0.002$, Table 3). Overall survival curves estimated using the Kaplan–Meier method are presented in Fig. 2. Age and the presence of a comorbidity were found to be independent prognostic factors (Tables 4 and 5).

Fracture healing

For the assessment of 1-year consolidation on CT-scan, data were available for 292 patients. Bony consolidation was complete in 184 patients (63.0%), partial in 50 patients (17.1%), and considered as pseudoarthrosis for 58 patients (19.9%). The mean ± SD age of patients differed according to the level of consolidation; 63.4 ± 23 years (range: 17–97) for complete consolidation, 64.6 ± 24 years (range: 19–100) for partial consolidation, and 79.2 ± 17 years (range: 23–98) for those with pseudoarthrosis ($p=0.0001$). The frequency of pseudoarthrosis ranged from 0 to 12.5% up to 70 years of age and then constantly and progressively increased to reach 58.6% after 90 years of age (Fig. 3).

Discussion

Among cervical spine trauma, upper cervical fractures are quite frequent [1, 2, 6–12, 19–21], ranging from 2 to 15% for C1 fractures, and from 17 to 25% for C2 fractures [6, 15]. The integrity of the cervical spine and upper cervical spine is essential for both survival and maintenance of primary functions, due to the neurovascular structures contained within its osteo-ligamentous elements [16]. This large prospective multicentre observational study, which is one of the largest of this type, describes the epidemiology, treatment, and outcome of C1-C2 injury in young and elderly subjects.

A systematic review published in 2018 that analysed epidemiological trends from 2005 to 2013 found a mean age in

Table 3 Mortality and complication rates during the first year after C1-C2 injury for the total population, as well as according to treatment group (surgical/conservative) and to age ≤ or > 70 years

	Total population, $n=417$		
A. Patients with 1 ≥ complication, n (%)	106 (25.4)		
General	19 (4.6)[a]		
Infectious	7 (1.7)[a]		
Mechanical[§]	74 (17.8)[a]		
Neurological	1 (0.2)[a]		
Missing data	*5*		
B. Overall Mortality, n (%)	35 (8.4)		
C. Complications according to the treatment option, n (%)	Conservative, $n=255$	Surgery, $n=160$	p
Patients with ≥ 1 complication	58 (22.7)[b]	48 (30.0)[c]	0.13[#]
General	4 (1.6)[b]	15 (9.4)[c]	0.0002[#]
Infectious	0 (0.0)[b]	7 (4.4)[c]	0.001[*]
Mechanical[§]	52 (20.4)[b]	22 (13.8)[c]	0.09[#]
Neurological	0 (0.0)[b]	1 (0.06)[c]	0.39[*]
Missing data	*2*	*3*	-
D. Mortality according to the treatment option, n (%)	17 (6.7)[b]	17 (10.6)[c]	0.15[#]
[#]test du Chi^2, [*] test exact de Fisher			
E. Complications according to the age (≤ or > 70 years), n (%)	≤ 70 y-old, n = 185	> 70 y-old, n = 223	p
Patients with ≥ 1 complication	33 (17.8)[d]	72 (32.3)[e]	0.0009[#]
General	4 (2.2)[d]	15 (6.7)[e]	0.03[#]
Infectious	6 (3.2)[d]	1 (0.4)[e]	0.05[*]
Mechanical[§]	21 (11.4)[d]	52 (23.3)[e]	0.0002[#]
Neurological	1 (0.5)[d]	0 (0.0)[e]	0.45[*]
Missing data	*1*	*4*	-
F. Mortality according to the age n (%)	5 (2.7)[d]	29 (13.0)[e]	0.0002[#]
[#]test du Chi^2, [*] test exact de Fisher			
G Complications and mortality according to the age and the treatment option, n (%)			
G.1 Conservative	≤ 70 y-old, $n=118$	> 70 y-old, $n=132$	*p*
Patients with ≥ 1 complication	14 (11.9)[f]	43 (32.6)[g]	< 0.0001[#]
General	0 (0.0)[f]	4 (3.0)[g]	0.12[*]
Infectious	0 (0.0)[f]	0 (0.0)[g]	/
Mechanical[§]	14 (11.9)[f]	38 (28.8)[g]	< 0.0001[#]
Neurological	0 (0.0)[f]	0 (0.0)[g]	/
Missing data	*None*	*1*	-
Mortality	4 (3.4)[f]	13 (9.8)[g]	0.04[#]
[#]test du Chi^2, [*] test exact de Fisher			
G.2 Surgery	≤ 70 y-old, $n=66$	> 70 y-old, $n=90$	*p*
Patients with ≥ 1 complication	19 (28.8)[h]	29 (32.2)[i]	0.65[#]
General	4 (6.1)[h]	11 (12.2)[i]	0.20[#]
Infectious	6 (9.1)[h]	1 (1.1)[i]	0.04[*]
Mechanical[§]	7 (10.6)[h]	8 (8.9)[i]	0.28[#]
Neurological	1 (1.5)[h]	0 (0.0)[i]	0.42[*]
Missing data	*1*	*9*	-
Mortality	1 (1.5)[h]	15 (16.7)[i]	0.002[*]
[#]test du Chi^2, [*] test exact de Fisher			

[§]Mechanical complications included pseudarthrosis

[a]percentages among n = 412; [b]among $n=255$; [c]among $n=160$; [d]among $n=185$; [e]among $n=223$; [f] among $n=118$; [g] among $n=132$; [h] among $n=66$; [i] among $n=90$

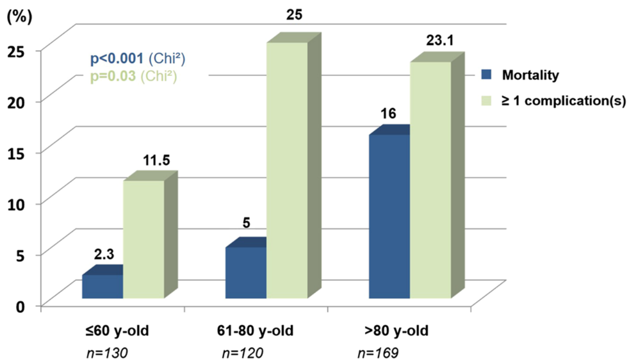

Figure 1 Impact of age on mortality and the presences of ≥ 1 complication after C1-C2 injury.

cervical trauma of about 56 years [15]. In the present study, the mean age was 66.6 years. This difference is likely to be related to the inclusion of C1 and C2 injuries exclusively as involvement of the upper cervical spine has been reported to be twice more frequent among the elderly [8]; furthermore, the majority of patients included herein had C2 fractures that are particularly frequent among elderly—for instance, odontoid fractures have been reported to be the most common cervical spine traumas and to represent > 50% of such injuries in patients aged > 80 years [17]. In the present prospective study, which is one of the largest of this type, the most frequent types of cervical trauma were isolated (48.8%) or associated with head trauma (32.6%), while this was in a context of polytrauma in only 18.7% of patients; this is consistent with the literature as cervical fractures in the elderly are generally are isolated and due to low-energy trauma [6–12]. Another point to consider is that spinal cord injury (SCI) occurred in 5.4% of patients herein, which is of note as SCIs are a serious condition that are associated with traumatic cervical spine fracture and often cause significant morbidity and mortality [22–28]. This frequency is similar to that reported elsewhere (3.62% [19] and 4.7% [20]); in particular in the systematic review reported by Jubert et al. [22], upper cervical spine fracture resulted in a neurological deficit in 4.7% of cases and with tetraparesia in 0.8%. The results do, however, diverge with the literature regarding the severity of SCI as 4.2% had an ASIA grade A, B or C. It is of note that Patel et al. reported neurological deficits in 9.6% of odontoid fractures, all ages combined (42–89 years) with a high mortality rate because 50% of these patients died within 3 months after injury [23].

In the present study, 38.8% of patients had at least one comorbidity and the most frequent were heart disease, hypertension, and peripheral artery disease. We also found that the presence of at least one comorbidity increased the risk of mortality or post-treatment complication. Gubler et al. reported that the most frequent predictive factors for negative outcomes in geriatric traumatology were comorbidities and injuries concomitant to the initial trauma [24]; in addition, a study that aimed to compare the performance of the Charlson and Elixhauser comorbidity-based scores for the prediction of early mortality after cervical spine injury found that comorbidities were significantly correlated with mortality [25], which is consistent with the findings reported herein.

Regarding the type of lesion, for most patients the affected vertebra was C2 and among them a majority presented a fracture of the odontoid with a clear predominance of fractures of the base or type II according to Anderson and D'Alonzo's classification. Odontoid fractures represent nearly 20% of all cervical fractures [5, 13, 17, 29, 30]. Among these, a majority (65–74%) are type II fractures according to Anderson and D'Alonzo, which is concordant with the results presented herein.

In the present study, the mean age of patients treated by orthotic devices (cervical collar, cervico-thoracic brace, etc.) was 66.1 years, and for patients treated by surgical treatment this was 68.5 years; age therefore does not seem to be the main determining factor in the choice between surgical and conservative treatment. The optimal treatment for C1-C2 injuries is still controversial [31–36]. In order to choose the most appropriate treatment for these patients, surgeons must consider a multitude of criteria including age, co-morbidities, injury pattern, neurological status, previous autonomy, and overall life expectancy [31–35]. An analysis of the literature found that 57% of the patients received surgical management and 43% conservative treatment [22], whereas herein a majority of patients underwent conservative treatment (61.1%). Surgery is usually indicated for displaced or unstable fractures with the aim to decompress the neurological structures and restore the correct alignment and stability of the cervical spine [16]. In case of surgical treatment, anterior screw fixation of the dens is chosen most frequently [22] as found herein (> 80% of cases). In case of conservative treatment, a rigid or semi-rigid neck brace was the most frequently prescribed type of immobilisation in the present study (84%). The same review found that external immobilisation with a rigid cervical collar was used in most cases (65%) of conservative treatment [22].

Regarding the treatment options, typically, stable injuries were treated conservatively whereas displaced and unstable lesions were treated surgically, but the treatment strategy took also into consideration the age and overall condition of the patient. This is consistent with the treatment algorithm proposed by Joaquim et al. (review reported in 2014) to help the surgeon in the decision-making process—operative versus non-operative treatment; the authors propose

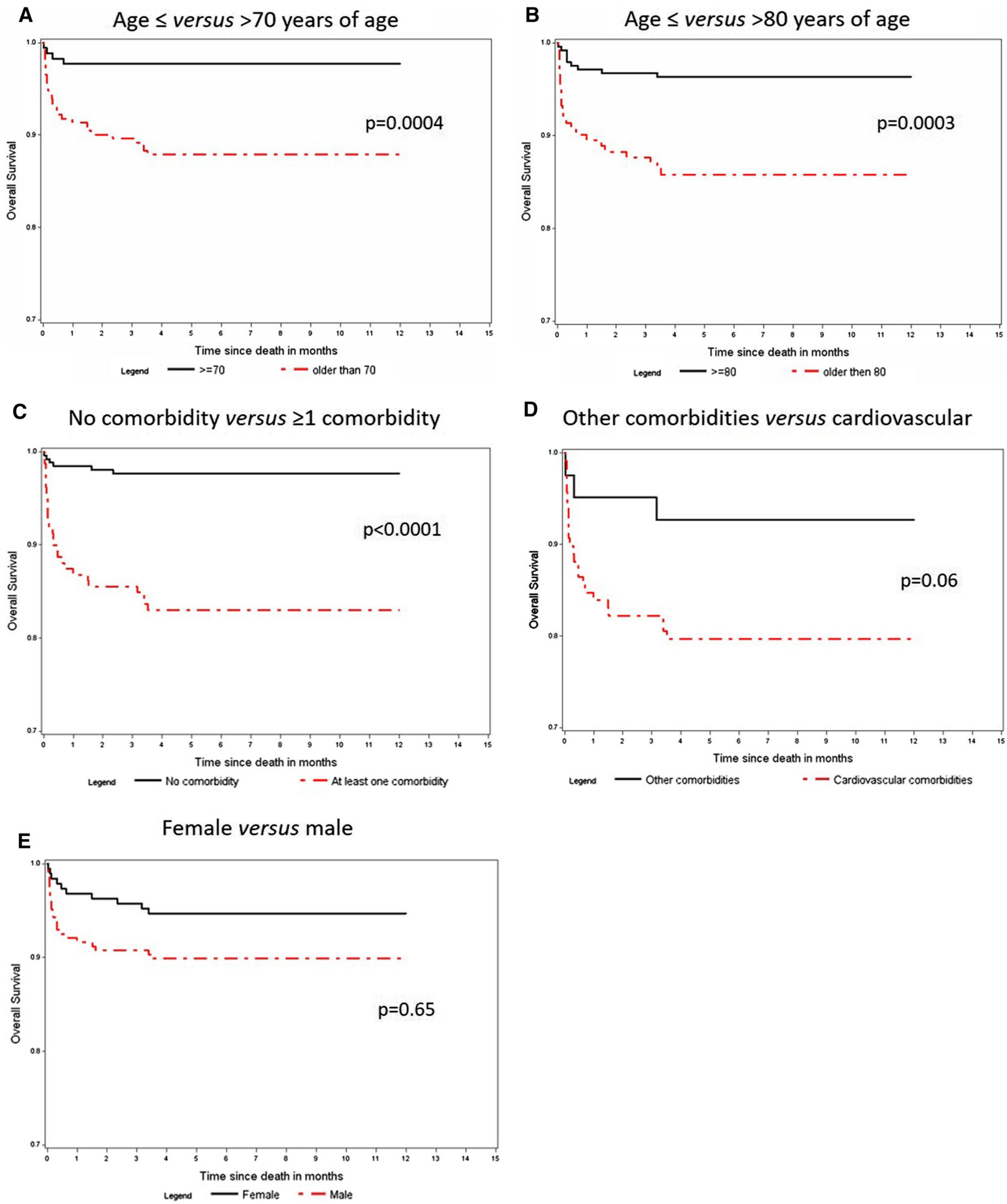

Figure 2 Kaplan–Meier survival curves investigating the impact of age ≤ or >70 years (2A), age ≤ or >80 years-old (2B), presence of comorbidity (2C), nature of comorbidity (2D), and sex (2E) on mortality.

Table 4 Univariate analysis—prognostic factors for death at 12-months

	Total population, $n = 417$		p
Age[#], n (%)	≤ 70 y-old, $n = 185$	> 70 y-old, $n = 223$	
Alive	180 (97.3)[a]	194 (87.0)[b]	–
Dead	5 (2.7)[a]	29 (13.0)[b]	–
HR [95%CI]	1 [-]	4.7 [1.8–12.2]	0.002
Age[§], n (%)	≤ 80 y-old, $n = 245$	> 80 y-old, $n = 162$	
Alive	236 (96.3)[c]	138 (85.2)[d]	–
Dead	9 (3.7)[c]	24 (14.8)[d]	–
HR [95%CI]	1 [-]	4.1 [1.9–8.9]	0.0003
Sex, n (%)	Female, n = 189	Male, n = 227	
Alive	179 (94.7)[e]	203 (89.4)[f]	–
Dead	10 (5.3)[e]	24 (10.6)[f]	–
HR [95%CI]	1 [-]	2 [0.9–4.2]	0.07
Presence of ≥ 1 comorbidity, n (%)	No, $n = 257$	Yes, $n = 159$	
Alive	251 (97.7)[g]	131 (82.4)[h]	–
Dead	6 (2.3)[g]	28 (17.6)[h]	–
HR [95%CI]	1 [-]	7.8 [3.2–19.0]	< 0.0001
Type of comorbidity (CM), n(%)	Other CM, $n = 41$	Cardio-vascular CM, $n = 118$	
Alive	38 (92.7)[i]	93 (78.8)[j]	–
Dead	3 (7.3)[i]	25 (21.2)[j]	–
HR [95%CI]	1 [-]	3 [0.9–9.9]	0.08

[#]age ≤ or > 70 years; [§]age ≤ or > 80 years

[a]percentages among $n = 185$; [b]among $n = 223$; [c]among $n = 245$; [d]among $n = 162$; [e]among n = 189; [f]among $n = 227$; [g]among $n = 257$; [h]among $n = 159$; [i]among $n = 41$; [j]among $n = 118$

Table 5 Multivariate analysis – prognostic factors for death at 12-months

	Total population, $n = 417$		p
Age, n (%)	< = 80 y-old, $n = 245$	> 80 y-old, $n = 162$	
Alive	236 (96.3)[a]	138 (85.2)[b]	–
Dead	9 (3.7)[a]	24 (14.8)[b]	–
HR [95%CI]	1 [-]	3.2 [1.4–7.1]	0.005
Presence of ≥ 1 comorbidity, n (%)	No, $n = 248$	Yes, $n = 159$	
Alive	243 (98.0)[c]	131 (82.4)[d]	–
Dead	5 (2.0)[c]	28 (17.6)[d]	–
HR [95%CI]	1 [-]	6.9 [2.6–18.2]	0.0001

[a]percentages among $n = 245$; [b]among $n = 162$; [c]among $n = 248$; [d]among $n = 159$

Adjusted on age, sex and presence of ≥ 1 comorbidity

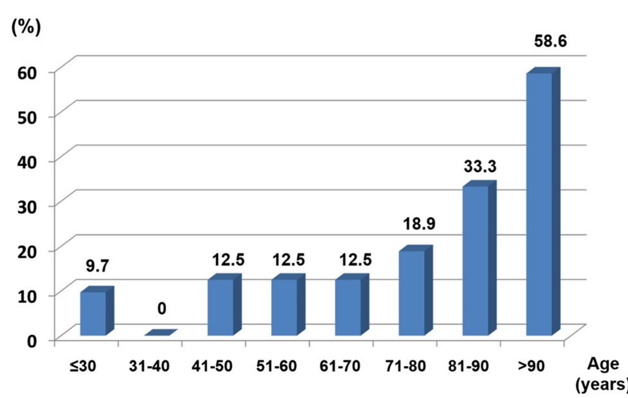

Figure 3 Distribution of non-union rates according to age

surgical treatment for patients with ligamentous injuries and for patients with fractures at the base of the dens (type II) with risk factors for non-union (> 50 years of age, severe displacement between bone fractures and comminution) [31].

In the study population, there were 35 deaths; this represented an overall mortality rate of 8.4% and 16% in those aged over 80 years; fracture in the upper spine therefore represents a significant Event in the elderly, similarly to that observed for hip fracture in the elderly. As for the complications, it is important to note that 64.6% of patients who had had ≥ 1 complication were ≥ 70 years, and a clear and significant increase in complications and mortality according to age. The nature of complications differed according to the treatment; in surgical group, there were more frequently general or infectious complications, whereas in the non-surgical group mechanical complications, such as pseudoarthrosis, were much more frequent.

Jubert et al. in their review of upper cervical spine trauma in elderly subjects found that the median mortality rate was 9.2% for all types of treatment combined and that deaths were more frequent in the conservative treatment group than in the surgical treatment group (21% versus 8.9%) [22]. Although the main late stage complication was non-union, which was also the case herein, the overall frequency was approximately half of that observed in the present study (19.9%); the authors found that non-union occurred in 12.4% of surgically treated patients while this occurred in only 10.8% of patients receiving conservative treatment [22]. Yang et al. in their meta-analysis of type II odontoid fractures in the elderly found that conservative treatment and surgical treatment were both effective procedures for treating type II odontoid fractures in the elderly; compared with surgical treatment, there was no significant difference in mortality with those treated conservatively, but non-union occurred more frequently among the latter [32], which is consistent with the findings reported herein. Similarly, in a recent systematic review on the treatment of geriatric type II odontoid fractures, Schroeder et al. reported lower short-term and long-term mortality with no significant difference in complication rate between operative versus non-operative treatment [33]. Mitchell et al. in their cases series also found that there was a higher mortality among the elderly (11.8% versus 0.7%) [34]. In addition, Harris et al. [7] compared the mortality rates based on the treatment protocol (surgical or non-surgical) in a retrospective study including 640 elderly with cervical spine fractures; 1-year mortality rate increased with patient age, 18.3% for those aged between 65 and 74 years rising to 38.9% for the patients aged > 85 years, but was similar according to treatment groups, 27% (surgery) versus 28% (non-surgery). Taken together, and as found in the present study, age appears to have more impact on mortality than treatment modality. Therefore, in the elderly (≥ 80 years), as surgical treatment leads to higher frequency complication and mortality rates compared to conservative treatment, surgery should be reserved for patients in good/excellent general condition only. After 90 years of age, the probability of fracture healing is very low (< 50%) irrespective of treatment option and therefore the value of the surgery and/or orthotic device should be questioned.

Study limitations

Although of prospective and multicentre design, and with a large number of patients included, this study presents some limitations. First, the series included many different types of C1-C2 injury and concerned adult patients of all ages, which are potential sources of heterogeneity. Secondly, this was an observational study and therefore there was a selection of patients for a particular treatment; for instance, in the surgical group, the lesions were more severe and more unstable. Also, patients in very bad general condition should have not been operated. Finally, more detailed sub-groups analysis could have been conducted, according to the type of comorbidities for instance or according to the level of the spine centre expertise.

Conclusion

After C1-C2 injury, overall mortality is significant and quite high for patients aged > 80 years. Age and comorbidities affected mortality and complication rates most, and irrespective of the fracture and treatment type. The choice of treatment remains controversial; in order to choose the most appropriate treatment for these patients, surgeons must consider certain criteria such as age, comorbidities, previous patient autonomy, and overall life expectancy. In the elderly population, the results suggest that surgery seems to be appropriate in a limited group of patients with displaced or unstable fractures and only for those with limited comorbidities. Surgical treatment leads to a lower rate of non-union but higher complication and mortality rates compared to conservative treatment. Finally, irrespective of the treatment option, pseudarthrosis was quite high after 80 years.

Acknowledgment We thank Philippe Roussouly (SMAIO, Lyon, France) for his invaluable assistance in customizing Keops website for the study, and Philip Robinson (DRCI, Hospices Civils de Lyon, Lyon, France) for help in manuscript preparation.

Funding The study was supported by the French Spine Surgery Society (payment fees for Keops licences, statistical analysis and legal declaration to CNIL and Ethical committee).

Compliance with ethical standards

Conflict of interest Pr Cédric Y. Barrey is consultant for Noraker™, Medicrea/Medtronic™, Implanet™, Seaspine™ and Global'S™ company; member of CSRS board and member of advisory board for European Spine Journal.

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