# Cervical spine injuries in facial fracture patients - injury mechanism and fracture type matter

Puolakkainen, T

2021-05

Puolakkainen , T , Thoren , H , Vahasilta , L , Narjus-Sterba , M , Wilson , ML , Brinck , T &
Snall , J 2021 , ' Cervical spine injuries in facial fracture patients - injury mechanism and
fracture type matter ' , Journal of Cranio-Maxillofacial Surgery , vol. 49 , no. 5 , pp. 387-393 . https://doi.org/10.1016/j

http://hdl.handle.net/10138/344015
https://doi.org/10.1016/j.jcms.2021.01.025

publishedVersion

Journal of Cranio-Maxillo-Facial Surgery 49 (2021) 387–393

Contents lists available at ScienceDirect

Journal of Cranio-Maxillo-Facial Surgery

journal homepage: www.jcmfs.com

# Cervical spine injuries in facial fracture patients – injury mechanism and fracture type matter

Tero Puolakkainen [a, *], Hanna Thorén [b, c], Linda Vähäsilta [b, c], Matilda Narjus-Sterba [a], Michael Lowery Wilson [d, e], Tuomas Brinck [f], Johanna Snäll [a]

[a] Department of Oral and Maxillofacial Diseases, University of Helsinki and Helsinki University Hospital, PO BOX 100, FI-00029, HUS, Finland
[b] Department of Oral and Maxillofacial Surgery, Institute of Dentistry, University of Turku, Turku, FI-20014, Finland
[c] Department of Oral and Maxillofacial Diseases, Turku University Hospital, FI-20521, Turku, Finland
[d] Injury Epidemiology and Prevention (IEP), Turku Brain Injury Centre, Division of Clinical Neurosciences, Turku University Hospital and University of Turku, PO BOX 52, FI-20014, Finland
[e] Heidelberg Institute of Global Health (HIGH), Medical Faculty and University Hospital, Heidelberg University, 69120, Heidelberg, Germany
[f] Department of Orthopaedics and Traumatology, Helsinki University Hospital and University of Helsinki, PO BOX 100, FI-00029, HU, Finland

ARTICLE INFO

*Article history:*
Paper received 26 April 2020
Accepted 31 January 2021
Available online 5 February 2021

*Keywords:*
Cervical spine injury
Facial fracture
Mandibular fracture
Trauma

ABSTRACT

Evidence supports the notion that craniofacial fractures are significant predictors of cervical spine injuries (CSIs), but some debate remains on the injury mechanism of co-existing CSIs in craniofacial fractures and the relationship between CSI and specific facial fractures. In this retrospective study, we aim to assess the incidence rates of specific facial fracture types as well as other important variables and their relationship with CSIs. The primary outcome variable, CSI, and several predictor variables, including facial fracture type, were evaluated with logistic regression analyses. Of 2919 patients, the total CSI incidence rate was 3.0%. Rates of CSI in patients with isolated mandibular fractures (OR 0.26 CI 0.10, 0.63; $p = 0.006$) were lower than those previously reported, whereas isolated nasal fractures were strongly associated with CSI (OR 2.67 CI 1.36, 5.22; $p = 0.004$). Patients with concomitant cranial injuries were twice as likely to have CSI (OR 2.00, CI 1.22, 3.27; $p = 0.006$). Even though there is a strong occurrence rate of CSIs in patients with cranial injuries, clinicians should be aware that patients presenting with isolated facial fractures are at significant risk for sustaining CSIs also.



## 1. Introduction

Facial fractures can result from a wide array of etiological mechanisms ranging from isolated, direct forces to components of polytrauma. In addition to vital cranial and facial structures, surrounding tissues are also at high risk for concomitant injuries due to their anatomic proximity and lack of skeletal protection. Cervical spine injuries (CSIs) have been linked to cranial and maxillofacial fractures with incidence rates varying from 0% to 11% (Elahi et al., 2008; Mulligan et al., 2010; Hasler et al., 2012; Pietzka et al., 2020). CSIs provide a diagnostic challenge even to experienced surgeons, requiring clinical acumen and recognition of specific risk factors to suspect these injuries. Proper diagnosis is essential, as the presence or absence of these findings has fundamental implications regarding airway management as well as surgical timing and approach in these patients (Maull et al., 1977; Davidson et al., 1989; Mukherjee et al., 2015).

Mechanisms involving high-energy forces, such as motor vehicle accidents (MVAs), have been strongly linked to CSIs with corroborating evidence (Luce et al., 1979; Beirne et al., 1995; Pietzka et al., 2020). Other predictors include advanced age, low Glasgow Coma Scale (GCS) score, and concomitant thoracic injuries (Hasler et al., 2012; Chu et al., 2016). There is also evidence to support the notion that craniofacial fractures are significant predictors of CSIs (Luce et al., 1979; Beirne et al., 1995). Some debate remains regarding injury mechanism of co-existing CSIs in craniofacial fractures. Numerous publications have documented and convincingly shown that the transmitting of high-energy forces through skeletal structures to the neck region is the most plausible

* Corresponding author. Department of Oral and Maxillofacial Diseases, Helsinki University Hospital, PO BOX 100, FI-00029, HUS, Finland.
*E-mail address:* tlmpuo@utu.fi (T. Puolakkainen).

https://doi.org/10.1016/j.jcms.2021.01.025
1010-5182/

mechanism for patients with craniofacial fractures with concomitant CSI (Lewis et al., 1985; Mukherjee et al., 2015; Lalezari et al., 2018). However, uncertainty as to which craniofacial fractures are specifically associated with increased CSI risk exists (Gassner et al., 2003).

Several recent reports have described the relationship between specific facial fracture types and CSIs (Mourouzis et al., 2018; Farkkila et al., 2019; Xun et al., 2019). However, due to inconsistent observations and wide variations in study designs, conclusive remarks are insufficiently supported. We aim to clearly assess the incidence rates of specific facial fracture types as well as other important variables and their relationship with CSIs. We hypothesized that different facial injury and fracture types would vary from one to another in terms of CSI risk.

## 2. Materials and methods

### 2.1. Study design

This retrospective study was based on all patients with facial fractures admitted to a tertiary trauma center (Trauma Unit of Helsinki University Hospital, Helsinki, Finland) during 2013–2018. All fractures were diagnosed based on clinical examination and radiographic screening. Injuries to the cervical spine (C0 to C7) were identified by computed tomography (CT) imaging.

### 2.2. Inclusion and exclusion criteria

All patients with radiologically confirmed facial fractures and CSI were included in this study. Patients without comprehensive patient data were excluded from the analyses.

### 2.3. Study variables

The main outcome variable was CSI. The primary predictor variable was the type of facial fracture. The fracture types were classified as mandibular, nasal, combined midfacial, combination of facial thirds, upper facial third, and unilateral zygomatic-maxillary-orbital (ZMO) fractures. ZMO fractures included unilateral zygomatic, maxillary, and orbital fractures as well as their combinations.

Secondary predictor variables included intracranial injury, injury mechanism, high-energy trauma, and combined cranial fracture. Injury mechanism was classified as high-energy in road- and traffic-related injuries and in falls off over 3 m (Evans et al., 2010).

### 2.4. Explanatory variables were patient age and sex

The anatomical distributions of CSIs were described and analyzed according to trauma energy and facial fracture type. In addition, a retrospective review of CSI patients was conducted, and specificity of screening according to the National Emergency X-ray Utilization Study (NEXUS) and the Canadian C-spine criteria was evaluated.

### 2.5. Statistical analyses

Absolute numbers and percentages were used for the descriptive statistics for patients with and without CSI. The Pearson $\chi^2$ test was used for categorical variables or the Fisher exact test if any cell had five or fewer observations. Median and interquartile range were reported for age as a continuous variable because they were not normally distributed. Categorical predictor variables were coded dichotomously as yes/no. Univariate logistic regression analysis was conducted to determine the association between CSI and each predictor variable. Variables that were significant in the univariate analysis were used to fit the multivariable logistic regression model. The variables included in the multivariable model were selected based on those found to be statistically significant at $p < 0.05$ or clinically significant in the univariate analysis. Significant variables were retained in the final model. Unadjusted and adjusted odds ratios (ORs) were reported with the confidence interval (CIs) at 95% and statistical significance at $p < 0.05$. The Hosmer–Lemeshow statistic was used to test the fit of multivariable models. The multivariable models had a good fit based on resulting p-values all being greater than 0.05. Multicollinearity was determined using the Variance Inflation Factor (VIF) estimate. Within in each final model, the VIF estimate for each covariate was less than 2.0. Data analysis was done using Stata 11 (StataCorp, College Station, TX, USA) and R (RStudio 3.5.0).

### Ethics approval

The study was approved by the Internal Review Board of the Head and Neck Center, Helsinki University Hospital, Helsinki, Finland (HUS/54/2019).

## 3. Results

A total of 2919 patients with radiologically confirmed facial fractures during the study period were included in the analysis. Comprehensive data of injuries and findings were available for all of these patients. The majority of patients (n = 2090, 71.6%) were male. ZMO-fractures (n = 1188, 38.8%) and mandibular fractures (n = 868, 29.7%) were the most frequent fracture types. Concomitant cranial fractures were diagnosed in 287 patients (9.8%). Altogether 88 (3.0%) of the 2919 patients were diagnosed with CSI. According to the hospital's imaging protocol, all CSIs were diagnosed with computed tomography (CT) imaging during primary examination. Patients with CSI were significantly older than patients without CSI ($p < 0.001$). CSIs were more common in patients with concomitant cranial fractures, combined midfacial fractures, nasal fractures and combined fractures of the facial thirds as well as in high-energy injuries than in patients with other facial fracture types and injury mechanisms. Patients' descriptive statistics are shown in Table 1.

In the univariate analysis (Table 2), patients with concomitant cranial fractures were at least four times more likely to have a CSI than those with isolated facial fractures (OR 4.38, 95% CI 2.73, 7.01; $p < 0.001$). Among facial fracture subtypes, patients with nasal fractures had the highest associated risk of sustaining CSI (OR 3.52, 95% CI 1.98, 6.28; $p < 0.001$). There was a reduced likelihood associated with CSI for patients with mandibular fractures (OR 0.17, 95% CI 0.07, 0.38; $p < 0.001$) and unilateral ZMO fractures (OR 0.52, 95% CI 0.32, 0.84; $p = 0.008$) compared to other facial fracture types. There was also a three-fold risk for CSIs occurring as a result of high-energy impact (OR 3.52, 95% CI 2.23, 5.54; $p < 0.001$) and roughly a four-fold risk for CSI in patients with intracranial injuries (OR 4.24, 95% CI 2.74, 6.58; $p < 0.001$). Falls from height or stairs, motor vehicle crash–related injuries, and bicycle crash–related injuries were the injury mechanisms that conferred a statistically significantly increased risk of CSIs compared to other mechanisms.

In the adjusted model (Table 3), only unilateral ZMO fractures, nasal fractures, mandibular fractures, age, injuries due to falls from heights or stairs, motor vehicle crashes, bicycle crashes, and intracranial injuries remained statistically significant. There was a 3% increase in the risk of CSIs for every yearly increase in age (OR 1.03, 95% CI 1.02, 1.04; $p < 0.001$). There was roughly a four-fold increase in risk for CSIs with falls from heights (OR 4.34, CI 2.05, 9.16; $p < 0.001$) and falls down stairs (OR 3.85, CI 1.83, 8.10;

**Table 1**
Descriptive statistics for patients with and without cervical spine injury.

| | With CSI n (%) | No CSI n (%) | p-Value |
|---|---|---|---|
| Age | | | |
| Median (IQR) | 63.1 (41.9, 75.0) | 41.0 (26.7, 60.0) | <0.001 |
| Sex | | | 0.812 |
| Male | 64 (3.06) | 2026 (96.94) | |
| Female | 24 (2.90) | 805 (97.10) | |
| Mechanism of injury | | | |
| Ground-level fall | 23 (2.76) | 810 (97.24) | 0.613 |
| Yes | 65 (3.12) | 2021 (96.88) | |
| No | | | |
| Fall from height | 14 (8.05) | 160 (91.95) | <0.001 |
| Yes | 72 (2.70) | 2671 (97.30) | |
| No | | | |
| Fall from stairs | 12 (10.08) | 107 (89.92) | <0.001 |
| Yes | 76 (2.71) | 2724 (97.29) | |
| No | | | |
| Motor vehicle accident | 16 (7.31) | 203 (92.69) | <0.001 |
| Yes | 72 (2.67) | 2628 (97.33) | |
| No | | | |
| Bicycle accident | 19 (5.18) | 348 (94.82) | 0.010 |
| Yes | 69 (2.70) | 2483 (97.30) | |
| No | | | |
| Assault | 1 (0.12) | 840 (99.88) | <0.001 |
| Yes | 87 (4.19) | 1991 (95.81) | |
| No | | | |
| Other/unknown | 3 (0.82) | 363 (99.18) | 0.005 |
| Yes | 85 (3.33) | 2468 (96.67) | |
| No | | | |
| High-energy | | | <0.001 |
| Yes | 30 (7.63) | 363 (92.37) | |
| No | 58 (2.30) | 2468 (97.70) | |
| Intracranial injury | | | <0.001 |
| Yes | 36 (8.31) | 397 (91.69) | |
| No | 52 (2.09) | 2434 (97.91) | |
| Cranial fracture | | | <0.001 |
| Yes (concomitant cranial fracture) | 27 (9.41) | 260 (90.59) | |
| No (only facial fracture) | 61 (2.32) | 2571 (97.68) | |
| Facial fracture types | | | |
| Unilateral zygomatic-maxillary-orbital | 22 (1.94) | 1111 (98.06) | 0.007 |
| Yes | 66 (3.70) | 1720 (96.30) | |
| No | | | |
| Combination of facial thirds | 20 (6.62) | 282 (93.38) | <0.001 |
| Yes | 66 (3.70) | 2549 (97.40) | |
| No | | | |
| Combined midfacial | 17 (5.20) | 310 (94.80) | 0.014 |
| Yes | 71 (2.74) | 2521 (97.26) | |
| No | | | |
| Nasal | 15 (8.77) | 156 (91.23) | <0.001 |
| Yes | 73 (2.66) | 2675 (97.34) | |
| No | | | |
| Upper third | 7 (7.37) | 88 (92.63) | 0.012 |
| Yes | 81 (2.87) | 2743 (97.13) | |
| No | | | |
| Mandible | 6 (0.69) | 862 (99.31) | <0.001 |
| Yes | 82 (4.00) | 1969 (96.00) | |
| No | | | |
| Other | 1 (4.35) | 22 (95.65) | 0.507 |
| Yes | 87 (3.00) | 2809 (97.00) | |
| No | | | |
| CSI level | | | |
| C0–C2 | 26 (29.55) | | |
| C3–C5 | 7 (7.95) | | |
| C6–C7 | 23 (26.14) | | |

$p < 0.001$). Additionally, patients with intracranial injuries had a two-fold risk of sustaining CSI (OR 2.00 CI 1.22, 3,27; $p = 0.006$). Patients with nasal fractures were at least twice as likely to have CSIs (OR 2.67, CI 1.36, 5.22; $p = 0.004$). There was a reduced risk of sustaining CSI for patients with unilateral ZMO fractures (OR 0.40, CI 0.23, 0.69; $p = 0.001$) and mandibular fractures (OR 0.26, CI 0.10, 0.63; $p = 0.003$) compared to other facial fracture types. Among the mechanisms of injury, only assault carried a reduced associated risk of CSI (OR 0.11, CI 0.01, 0.80; $p = 0.029$), while patients with injuries due to motor vehicle crashes, bicycle crashes, and falls from stairs or height had significantly increased risks. Injuries as a result of high-energy forces were not included in the final model due to multicollinearity.

Retrospective evaluation and comparison of CSI patients with NEXUS and Canadian C-spine criteria were also conducted. All CSI patients fulfilled the imaging indications in relation to the C-spine

**Table 2**
Univariate logistic regression for cervical spine injuries.

| Variable | Unadjusted odds ratio | 95% Confidence interval | p-Value |
|---|---|---|---|
| Age | 1.03 | 1.02, 1.04 | <0.001 |
| Sex (Female) | 0.94 | 0.59, 1.52 | 0.812 |
| Mechanism of injury | | | |
| Ground-level fall | 0.88 | 0.54, 1.43 | 0.613 |
| Fall from height | 3.16 | 1.75, 5.72 | <0.001 |
| Fall from stairs | 4.02 | 2.12, 7.61 | <0.001 |
| Motor vehicle crash | 2.88 | 1.64, 5.04 | <0.001 |
| Bicycle crash | 1.96 | 1.17, 3.30 | 0.011 |
| Assault | 0.03 | 0.001, 0.16 | <0.001 |
| Other/Unknown | 0.24 | 0.05, 0.73 | 0.006 |
| High-energy | 3.52 | 2.23, 5.54 | <0.001 |
| Intracranial injury | 4.24 | 2.74, 6.58 | <0.001 |
| Cranial fracture (ref: only facial) | | | |
| Yes (concomitant) | 4.38 | 2.73, 7.01 | <0.001 |
| Facial fractures | | | |
| Unilateral zygomatic-maxillary-orbital | 0.52 | 0.32, 0.84 | 0.008 |
| Mandible | 0.17 | 0.07, 0.38 | <0.001 |
| Combined midfacial | 1.95 | 1.13, 3.35 | 0.016 |
| Combination of facial thirds | 2.66 | 1.59, 4.44 | <0.001 |
| Nasal | 3.52 | 1.98, 6.28 | <0.001 |
| Upper third | 2.69 | 1.21, 6.00 | 0.015 |
| Other | 1.47 | 0.04, 9.29 | 1.000 |

**Table 3**
Multivariable logistic regression analysis.

| Variable | Adjusted odds ratio | 95% Confidence interval | p-Value |
|---|---|---|---|
| Age | 1.03 | 1.02, 1.04 | <0.001 |
| Mechanism of injury | | | |
| Fall from height | 4.34 | 2.05, 9.16 | <0.001 |
| Fall from stairs | 3.85 | 1.83, 8.10 | <0.001 |
| Motor vehicle crash | 3.39 | 1.68, 6.85 | 0.001 |
| Bicycle crash | 3.40 | 1.78, 6.49 | <0.001 |
| Assault | 0.11 | 0.01, 0.80 | 0.029 |
| Intracranial injury | 2.00 | 1.22, 3.27 | 0.006 |
| Facial fractures | | | |
| Unilateral zygomatic-maxillary-orbital | 0.40 | 0.23, 0.69 | 0.001 |
| Mandibular | 0.26 | 0.10, 0.63 | 0.003 |
| Nasal | 2.67 | 1.36, 5.22 | 0.004 |

protocol. Two (2.3%) of the 88 patients did not meet the NEXUS criteria.

Fig. 1 illustrates the relation of different facial fracture patterns and injury mechanism energy to the anatomical distribution of CSIs. Isolated CSIs occurred most often at the upper and lower cervical levels. Isolated CSIs located in the C0 to C2 region were mostly associated with nasal fractures compared with other facial fractures, whereas unilateral ZMO fractures were the most prevalent in patients with isolated CSI located in the C3 to C5 and the C6 to C7 planes. Patients with multiple CSI were mostly seen in fractures sustained in different combinations of facial thirds.

## 4. Discussion

The purpose of this study was to analyze our findings of CSI incidence rates in patients with different types of facial fractures. We also compared the fracture patterns with the corresponding superior–inferior planes of the cervical spine to determine whether some fracture types predispose to certain injuries of the cervical spine. We hypothesized that different facial injuries and fracture types would vary from one to another in terms of risk of CSI. Our hypothesis was confirmed, and the wide range of incidence rates pertaining to different facial fractures and their relationships with CSIs are presented. Interestingly, assault-related CSIs in facial fracture patients were rare. Our findings of the association between CSI and mandibular fractures also differ from those of previous studies.

Our results show a CSI incidence rate of 2.3% in CSI for patients who suffered facial fractures without cranial fractures, and a high incidence rate of 9.4% in patients sustaining combined craniofacial fractures. The total CSI incidence rate was 3.0% for the entire patient population, which is in concordance with previous reports with similar cohorts (Haug et al., 1991; Hackl et al., 2001). Significant disparities in incidence rates of CSI in cranial and facial fracture patients are known, suggesting that these fracture types are not necessarily significant, independent risk factors for CSI (McCabe et al., 1984; Williams et al., 1992). These differences are most likely due to the non-descriptive nature of registry studies, the varying methods of classifying facial fractures, and the heterogeneity of trauma mechanisms. Our results indicate that intracranial injuries are significant risk factors that strongly support the supposition that patients with cranial fractures are at higher risk for having concomitant CSI compared to patients with facial fractures alone.

Mandibular fractures are of particular significance in patients with CSI, as this patient group requires special caution regarding neck manipulation. The mandible has been conceived to form an anatomical ring, which is posteriorly constructed of the cervical spine. Therefore, findings linking mandibular fractures to injuries of C1 and C2 are not implausible (Bertolami et al., 1982; Halsey et al.,

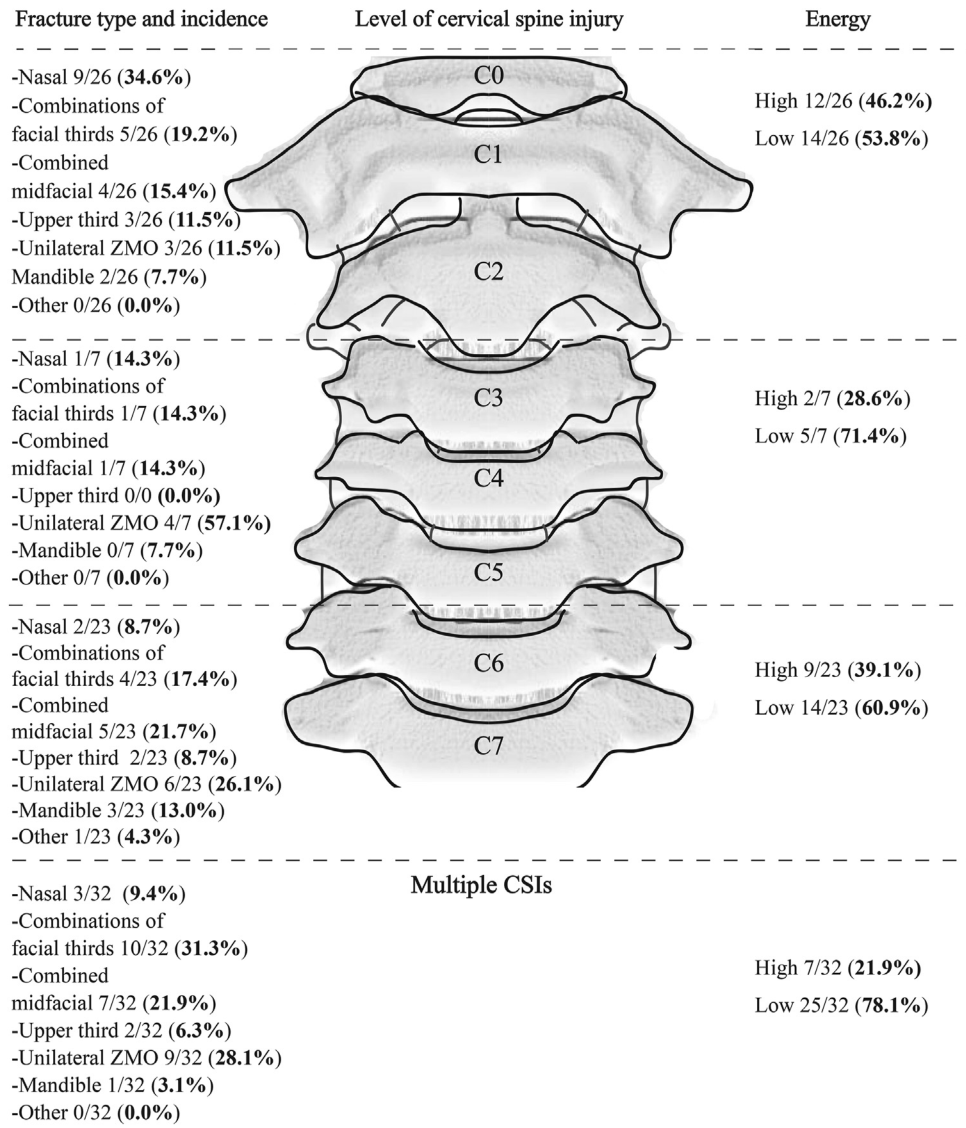


**Fig. 1.** Illustrative and descriptive data of cervical spine injury (CSI) incidence rates, anatomic location, and energy of the trauma mechanism. Locations of cervical spine injuries were not noticeably related to facial fracture type. Only isolated nasal fractures seemed to occur more prominently in the upper cervical spine than in other cervical levels. In addition, the middle cervical level was injured slightly more often in low-energy injuries than in high-energy accidents. ZMO = zygomatico-maxillary-orbital.

2016). In the present study, only six of the 868 patients with mandibular fractures sustained concomitant CSI, for an incidence rate of 0.69%, which is substantially lower than that reported by other authors (Elahi et al., 2008; Jamal et al., 2009; Chu et al., 2016; Farkkila et al., 2019). It is possible that the significance of CSI occurring in patients with isolated mandibular fractures is lower than previously believed. The movement of the mandible is based on its articular structure in relation to the glenoid fossa, so, typically, forces exerted on the mandible are not transmitted directly to the head and neck areas, unlike in middle and upper face fractures. This speculation could support the idea that the mandible diminishes energy from forces and protects the head and neck from energy transmission. Interestingly, and even conversely, Chu et al. reported that patients sustaining multiple mandibular fractures had fewer CSIs than patients with isolated mandibular fractures. The authors considered this to be due to the facial skeleton absorbing the transmitted energy, causing the energy to spread throughout the facial bones, targeting a lesser force towards the cervical spine (Chu et al., 2016). Clayton et al. on the other hand, suggested that the cervical spine may be more commonly associated with inertial differences between the head and torso, as opposed to transmitted compression forces from head or facial trauma (Clayton et al., 2012). Both of these explanations are plausible, and case-by-case differences are indeed highly dependent on the corresponding trauma mechanism.

Recently, Färkkilä et al. reported that isolated fractures of the mandibular ramus–condyle unit are risk factors for increased CSI risk (Farkkila et al., 2019). However, the presence of a concomitant midface fracture significantly increased this risk. The important study by Chu et al. proposed fractures of the mandibular body to be associated with CSIs (Chu et al., 2016). However, in their study, they did not specify whether the exclusion criteria covered patients with concomitant facial fractures other than mandibular fractures. Based on these discrepancies, we propose that even though mandibular fractures are of significant value when assessing concomitant head and neck injuries, as isolated facial fractures their relationship with CSIs might be less consequential than previously hypothesized.

Our somewhat capricious result of nasal fractures being independent risk factors for increased CSI risk is worth addressing, despite it being in agreement with the recent, descriptive publication by Färkkilä et al. (Farkkila et al., 2020). Numerous publications have suggested midfacial fractures to be strongly associated with CSI (Mukherjee et al., 2015; Reich et al., 2016; Mourouzis et al., 2018; Xun et al., 2019). One plausible explanation is that instead of differentiating nasal fractures from the surrounding skeletal structures, their classification can easily overlap with other groups of midfacial fractures, or they may simply be classified as non-mandibular fractures. This vague approach can result in inaccurate and misleading interpretations of the true nature of specific facial fractures.

Two widely implemented protocols for evaluating the need for cervical spine imaging are the NEXUS (National Emergency X-radiography Utilization Study) and the Canadian C-spine criteria (Hoffman et al., 2000; Stiell et al., 2001). While both of these protocols are well accepted, their guidelines have somewhat different approaches to ruling out the need for cervical imaging. The NEXUS criteria involve the state of alertness as well as the presence or absence of intoxicity, neurological deficits, neck tenderness, and distracting injuries, whereas the Canadian C-spine criteria include the capability of the patient to perform neck rotation, the trauma mechanism, and the patient's age. When comparing our patients by using these guidelines, all CSI patients fulfilled the indications for cervical spine imaging based on the Canadian C-spine criteria, but two patients (2.3%), both over 60 years of age, did not meet the requirements based on NEXUS criteria. One of these patients sustained multiple midfacial fractures and was also diagnosed with a blunt cerebrovascular injury. A recent study presented challenges in NEXUS criteria sensitivity in older patients subjected to blunt trauma (Paykin et al., 2017). Clinicians should be aware of the drawbacks of using NEXUS criteria especially in elderly patients with suspected facial fractures.

The retrospective nature of our study can be listed as its main limitation. Another significant limitation was the fact that not all patients in our study were appropriately imaged for cervical spine injuries. This might suggest that the actual incidence rate for CSI could be even higher. However, compared with previous registry trials and studies focusing on specific facial fracture types, our study with detailed patient description provides an important and comprehensive overview of the key findings regarding the relationship between facial fractures and CSIs.

## 5. Conclusion

Patients with high-energy accidents, advanced age, and polytrauma are at the highest risk for cervical spine injuries (CSI) in the facial fracture population. CSI must be considered in patients presenting with even minor facial fractures such as nasal fractures. Thus, even though CSI are strongly associated with cranial injuries, careful clinical examination and further imaging according to trauma patient guidelines are warranted in isolated facial fracture patients as well.

## Declaration of competing interest

The authors have no conflicts of interest to declare.

## Acknowledgements

Anne Abio is acknowledged for cross-validating the statistical tests.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jcms.2021.01.025.

## Funding

This study was funded by a grant from Alexander von Humboldt-Stiftung, Bonn, Germany.was funded by the Paulo Foundation and the Helsinki University Hospital Fund.

## References

Beirne, J.C., Butler, P.E., Brady, F.A., 1995. Cervical spine injuries in patients with facial fractures: a 1-year prospective study. Int J Oral Maxillofac Surg 24, 26–29.
Bertolami, C.N., Kaban, L.B., 1982. Chin trauma: a clue to associated mandibular and cervical spine injury. Oral Surg Oral Med Oral Pathol 53, 122–126.
Chu, M.W., Soleimani, T., Evans, T.A., Fernandez, S.I., Spera, L., Klene, C., Zarzaur, B.L., Tholpady, S.S., 2016. C-spine injury and mandibular fractures: lifesaver broken in two spots. J Surg Res 206, 386–390.
Clayton, J.L., Harris, M.B., Weintraub, S.L., Marr, A.B., Timmer, J., Stuke, L.E., McSwain, N.E., Duchesne, J.C., Hunt, J.P., 2012. Risk factors for cervical spine injury. Injury 43, 431–435.
Davidson, J.S., Birdsell, D.C., 1989. Cervical spine injury in patients with facial skeletal trauma. J Trauma 29, 1276–1278.
Elahi, M.M., Brar, M.S., Ahmed, N., Howley, D.B., Nishtar, S., Mahoney, J.L., 2008. Cervical spine injury in association with craniomaxillofacial fractures. Plast Reconstr Surg 121, 201–208.
Evans, J.A., van Wessem, K.J., McDougall, D., Lee, K.A., Lyons, T., Balogh, Z.J., 2010. Epidemiology of traumatic deaths: comprehensive population-based assessment. World J Surg 34, 158–163.
Farkkila, E.M., Peacock, Z.S., Tannyhill, R.J., Petrovick, L., Gervasini, A., Velmahos, G.C., Kaban, L.B., 2019. Risk factors for cervical spine injury in patients with mandibular fractures. J Oral Maxillofac Surg 77, 109–117.
Farkkila, E.M., Peacock, Z.S., Tannyhill, R.J., Petrovick, L., Gervasini, A., Velmahos, G.C., Kaban, L.B., 2020. Frequency of cervical spine injuries in patients with midface fractures. Int J Oral Maxillofac Surg 49, 75–81.
Gassner, R., Tuli, T., Hachl, O., Rudisch, A., Ulmer, H., 2003. Cranio-maxillofacial trauma: a 10 year review of 9,543 cases with 21,067 injuries. J Craniomaxillofac Surg 31, 51–61.
Hackl, W., Hausberger, K., Sailer, R., Ulmer, H., Gassner, R., 2001. Prevalence of cervical spine injuries in patients with facial trauma. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 92, 370–376.
Halsey, J.N., Hoppe, I.C., Marano, A.A., Kordahi, A.M., Lee, E.S., Granick, M.S., 2016. Characteristics of cervical spine injury in pediatric patients with facial fractures. J Craniofac Surg 27, 109–111.
Hasler, R.M., Exadaktylos, A.K., Bouamra, O., Benneker, L.M., Clancy, M., Sieber, R., Zimmermann, H., Lecky, F., 2012. Epidemiology and predictors of cervical spine injury in adult major trauma patients: a multicenter cohort study. J Trauma Acute Care Surg 72, 975–981.
Haug, R.H., Wible, R.T., Likavec, M.J., Conforti, P.J., 1991. Cervical spine fractures and maxillofacial trauma. J Oral Maxillofac Surg 49, 725–729.
Hoffman, J.R., Mower, W.R., Wolfson, A.B., Todd, K.H., Zucker, M.I., 2000. Validity of a set of clinical criteria to rule out injury to the cervical spine in patients with blunt trauma. National Emergency X-Radiography Utilization Study Group. N Engl J Med 343, 94–99.
Jamal, B.T., Diecidue, R., Qutob, A., Cohen, M., 2009. The pattern of combined maxillofacial and cervical spine fractures. J Oral Maxillofac Surg 67, 559–562.
Lalezari, S., Lee, C., Paydar, K.Z., Shaterian, A., 2018. Age and number of surgeries increase risk for complications in polytrauma patients with operative maxillofacial fractures. World J Plast Surg 7, 307–313.
Lewis Jr., V.L., Manson, P.N., Morgan, R.F., Cerullo, L.J., Meyer Jr., P.R., 1985. Facial injuries associated with cervical fractures: recognition, patterns, and management. J Trauma 25, 90–93.
Luce, E.A., Tubb, T.D., Moore, A.M., 1979. Review of 1,000 major facial fractures and associated injuries. Plast Reconstr Surg 63, 26–30.
Maull, K.I., Sachatello, C.R., 1977. Avoiding a pitfall in resuscitation: the painless cervical fracture. South Med J 70, 477–478.
McCabe, J.B., Angelos, M.G., 1984. Injury to the head and face in patients with cervical spine injury. Am J Emerg Med 2, 333–335.
Mourouzis, C., Schoinohoriti, O., Krasadakis, C., Rallis, G., 2018. Cervical spine fractures associated with maxillofacial trauma: a 3-year-long study in the Greek population. J Craniomaxillofac Surg 46, 1712–1718.
Mukherjee, S., Abhinav, K., Revington, P.J., 2015. A review of cervical spine injury associated with maxillofacial trauma at a UK tertiary referral centre. Ann R Coll Surg Engl 97, 66–72.
Mulligan, R.P., Mahabir, R.C., 2010. The prevalence of cervical spine injury, head injury, or both with isolated and multiple craniomaxillofacial fractures. Plast Reconstr Surg 126, 1647–1651.

Paykin, G., O'Reilly, G., Ackland, H.M., Mitra, B., 2017. The NEXUS criteria are insufficient to exclude cervical spine fractures in older blunt trauma patients. Injury 48, 1020–1024.
Pietzka, S., Kammerer, P.W., Pietzka, S., Schramm, A., Lampl, L., Lefering, R., Bieler, D., Kulla, M., 2020. Maxillofacial injuries in severely injured patients after road traffic accidents—a retrospective evaluation of the TraumaRegister DGU(R) 1993-2014. Clin Oral Investig 24 (1), 503–513.
Reich, W., Surov, A., Eckert, A.W., 2016. Maxillofacial trauma—underestimation of cervical spine injury. J Craniomaxillofac Surg 44, 1469–1478.
Stiell, I.G., Wells, G.A., Vandemheen, K.L., Clement, C.M., Lesiuk, H., De Maio, V.J., Laupacis, A., Schull, M., McKnight, R.D., Verbeek, R., Brison, R., Cass, D., Dreyer, J., Eisenhauer, M.A., Greenberg, G.H., MacPhail, I., Morrison, L., Reardon, M., Worthington, J., 2001. The Canadian C-spine rule for radiography in alert and stable trauma patients. JAMA 286, 1841–1848.
Williams, J., Jehle, D., Cottington, E., Shufflebarger, C., 1992. Head, facial, and clavicular trauma as a predictor of cervical-spine injury. Ann Emerg Med 21, 719–722.
Xun, H., Lopez, J., Darrach, H., Redett, R.J., Manson, P.N., Dorafshar, A.H., 2019. Frequency of cervical spine injuries in pediatric craniomaxillofacial trauma. J Oral Maxillofac Surg 77, 1423–1432.