Clinical Study

Epidemiology of atlas fractures—a national registry–based cohort study of 1,537 cases

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Abstract

BACKGROUND CONTEXT: The epidemiology of fractures of the first cervical vertebra—the atlas—has not been well documented. Previous studies concerning atlas fractures focus on treatment and form a weak platform for epidemiologic study.

PURPOSE: This study aims to provide reliable epidemiologic data on atlas fractures.

STUDY DESIGN: This was a national registry–based cohort study.

PATIENT SAMPLE: A total of 1,537 cases of atlas fractures between 1997 and 2011 from the Swedish National Patient Registry (NPR).

OUTCOME MEASURES: The outcome measures were annual incidence and mortality.

METHODS: Data from the NPR and the Swedish Cause of Death Registry were extracted, including age, gender, diagnosis, comorbidity, treatment codes, and date of death. The Charlson Comorbidity Index was calculated and a survival analysis performed.

RESULTS: A total of 869 (56.5%) cases were men, and 668 (43.5%) were women. The mean age of the entire population was 64 years. The proportion of atlas fractures of all registered cervical fractures was 10.6%. In 19% of all cases, there was an additional fracture of the axis, and 7% of all cases had additional subaxial cervical fractures. Patients with fractures of the axis were older than patients with isolated atlas fractures. The annual incidence almost doubled during the study period, and in 2011, it was 17 per million inhabitants. The greatest increase in incidence occurred in the elderly population.

CONCLUSIONS: Atlas fractures occurred predominantly in the elderly population. Further study is needed to determine the cause of the increasing incidence.

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Keywords: Atlas fractures; Axis fractures; Elderly; Epidemiology; Mortality; Incidence

Background

Despite being a relatively common cervical fracture, the epidemiology of fractures of the first cervical vertebra—atlases—has not yet been properly documented. Since Jefferson first described them in 1920 [1,2], several case studies regarding atlas fractures have been published [2–9]. All these have in common that they focus on management and treatment of atlas fractures in general [2–6], or even only the so-called Jefferson burst fracture, a special type of atlas fracture [7–9]. They present small case series of up to 57 patients collected from either a single hospital or a specialized spine trauma unit.

In previous studies, atlas fractures account for about 5% of all cervical fractures (Table 1). These data are based on retrospective case series and not on national health-care data.

Similar to C2 fractures, atlas fractures are in most cases caused by either high-energy trauma in the young or minor trauma in the osteoporotic elderly [10]. The two most common events leading to atlas fractures in the published literature are motor vehicle accidents and falls. Together, they account for 80% to 85% of all cases [11]. It would be
valuable to see whether these two proposed injury mechanisms are reflected in the age distribution of atlas fractures by two peaks: one for the younger population and one for the elderly.

About 60% of the previously described cases are male, and the mean ages in these studies range from 30 to 52 years (Table 1). Assuming that the mean population age increased during the last decades, a greater proportion of elderly among atlas fractures is expected. This would influence the observed mortality of atlas fractures. On the one hand, with increasing mean age, a greater comorbidity will be seen, and expectedly, a greater mortality. On the other hand, the improved medical care and better diagnostics will improve patient survival, despite age and comorbidity. Because of the mostly benign nature of the atlas fracture, it is unclear whether the atlas fracture itself is associated with increased mortality.

Until now, no true incidence data regarding atlas fractures are available, and the scientific basis for conclusions regarding the epidemiology of atlas fractures is relatively scarce. This study presents epidemiologic data from more than 1,500 cases of atlas fractures from a national Swedish registry. The purpose of this study was to improve the scientific knowledge regarding the epidemiology of atlas fractures, identify future areas of research, and allow for more effective preventive measures.

Materials and methods

Since 1987, all inpatients in Sweden are registered in the National Patient Registry (NPR) with personal identification number, gender, age, date of admission, discharge date, primary and secondary diagnosis, as well as treatment codes [12]. Participation in the registry is mandatory for all Swedish county councils. The county councils report these data to the Swedish National Board for Health and Welfare (Socialstyrelsen), which maintains the registry. Diagnosis codes are coded using International Classification of Diseases (ICD)-9 until 1997 when ICD-10 is implemented [13]. The Swedish Cause of Death Registry registers the date of death and the personal identification number for every fatality nationwide. The Swedish National Board for Health and Welfare provides cross-linked anonymized extracts without personal identification numbers from these registries for research purposes. International Classification of Diseases-10 classifies fractures and other injuries under the letter S. The first digit shows which part of the body is involved, and the second digit classifies the type of injury. The third digit further specifies the place of injury. Atlas fractures have the ICD-10 code S12.0, axis fractures have the code S12.1, and subaxial fractures are classified as S12.2.

All entries in the NPR with atlas fractures, from 1997 to 2011, were identified, and date of death was added from the Cause of Death Registry. Duplicate cases were omitted. Statistical analysis was performed using R Studio (Free Software Foundation Inc., Boston, MA, USA). Population data for Sweden during the years 1997 to 2011 were provided by Statistics Sweden (Statistiska centralbyran). Charlson Comorbidity Index (CCI) was calculated for each case using the secondary diagnoses registered in the NPR [14]. The Kaplan-Meier method was used to estimate mean survival, and 95% confidence intervals (CIs) are presented. For comparison, the entire cohort of spinal fractures in the NPR from 1997 to 2011 was included in

<table>
<thead>
<tr>
<th>Author</th>
<th>Years included</th>
<th>N</th>
<th>Age (range), y</th>
<th>Gender</th>
<th>Proportion of C1 fx % (cervical fx)</th>
<th>Additional C2 fracture (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gehweiler et al. [4]</td>
<td>1967 to 1975</td>
<td>21</td>
<td>30 (15–63)</td>
<td>63% male</td>
<td>5.3 (400)</td>
<td>24</td>
</tr>
<tr>
<td>Hadley et al. [2]</td>
<td>1976 to 1986</td>
<td>57</td>
<td>41(14–86)</td>
<td>60% male</td>
<td>6.6 (860)</td>
<td>44</td>
</tr>
<tr>
<td>Landells and Van Peteghem [5]</td>
<td>1975 to 1985</td>
<td>35</td>
<td>n/a</td>
<td>n/a</td>
<td>4.7 (750)</td>
<td>46</td>
</tr>
<tr>
<td>Fowler et al. [3]</td>
<td>1976 to 1988</td>
<td>48</td>
<td>(15–93)</td>
<td>69% male</td>
<td>5.5 (867)</td>
<td>46</td>
</tr>
<tr>
<td>Kontautas et al. [6]</td>
<td>1998 to 2004</td>
<td>29</td>
<td>52 (17–80)</td>
<td>62% male</td>
<td>n/a</td>
<td>41</td>
</tr>
</tbody>
</table>

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**Context**

The authors report on the epidemiology of atlas fractures as documented in a Swedish registry.

**Contribution**

The authors document 1,537 cases over a 15-year period. The authors maintain that these types of fracture are increasing among the elderly in Sweden. The annual incidence nearly doubled over the course of the study period and in 2011 was nearly 17 per million.

**Implications**

This study adds to the literature, reinforcing many previous findings documented regarding the incidence and epidemiology of atlas fractures in the US and elsewhere. The sociodemographic context of Sweden and factors unique to its population may limit the translation of these study findings to patients from other nations, be they in Europe or in other countries across the globe.

— The Editors

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the analysis. The log-rank test (Mantel-Cox) was used to compare mean survival between cohorts. The hazard ratio (HR) of covariates in the survival curve was determined by Cox regression analysis. This study was approved by the regional ethical review board of Uppsala (Dnr 2014/228).

Results

After exclusion of duplicate cases, a total of 14,700 cases of admissions for cervical fractures (ICD-10: S12-) were identified in the NPR between 1997 and 2011 (Fig. 1). C1 fractures accounted for 1,553 of these and thus represented 10.6% of all cervical fractures. Sixteen pediatric cases aged below 15 were excluded. The coincidence with C2 fractures was 19% (n=287), and in 7% (n=113) of all cases, there was a fracture of a cervical vertebra other than C2.

The study group consisted of 868 male (56.5%) and 668 female (43.5%) patients (Table 2). The overall male-to-female ratio was 1.3:1. The mean age of the entire study population was 64 years (range 15–101 years). A total of 1,250 (710M:540F) patients had isolated C1 fractures, and 287 (159M:128F) had combined C1–C2 fractures. These two groups showed similar gender distributions with male-to-female ratios of 1.3:1 and 1.2:1, respectively.

The mean age among male patients was 59 compared with 70 among female patients. A bimodal curve for the age distribution was found with a first peak at the age of 24 years and the second peak at 80 to 84 years (Fig. 3). The age distribution showed a clear imbalance toward older age, and 74% of all cases occurred in patients over the age of 50. Furthermore, in younger ages, a large majority (70%) of all cases were male. This imbalance was reduced in the elderly where 52% of all cases were female.

The mean age among patients with combined C1–C2 fractures was 73 compared with 62 years in patients without C2 fractures (U test, p<.001; Table 2). The mean CCI for the whole group was 3.75. The group of isolated atlas fractures had a mean CCI of 3.56, and the group of combined fractures had a mean CCI of 4.61 (U test p<.001; Table 2).

The Kaplan-Meier analysis revealed a greater mean survival for all patients with spinal fractures of 159 months (95% CI: 156–158) than for patients with atlas fractures 117 months (95% CI: 112–122; log-rank test, p=.007). Still, the Cox regression analysis compensating for multiple covariates (age, gender, cervical fracture, thoracic fracture, lumbar fracture, CCI, year of hospitalization) found no significant effect of an atlas fracture on survival (HR=1.04, p=.454). Within the atlas fracture, cohort multiple covariates had a significant influence on patient survival (Table 3). Higher age and increasing CCI were associated with slightly increased mortality (HR=1.04 and 1.25, both p<.001). A concomitant C2 fracture (HR=0.80, p=.037) and a later year of injury were associated with greater survival (HR=0.95, p<.001).

The number of cases per year increased from 64 cases in 1997 to 164 cases in 2011. Compensating for population

Table 2
Summary of included C1-fractures, subdivided into isolated C1-fractures and concomitant C1 and C2-fractures.

<table>
<thead>
<tr>
<th></th>
<th>Isolated C1 fractures</th>
<th>C1+C2 fractures</th>
<th>All C1 fractures</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of cases</td>
<td>1,250</td>
<td>287</td>
<td>1,537</td>
</tr>
<tr>
<td>Male</td>
<td>710</td>
<td>159</td>
<td>869</td>
</tr>
<tr>
<td>Female</td>
<td>540</td>
<td>128</td>
<td>668</td>
</tr>
<tr>
<td>Mean age (range)</td>
<td>62 (15–101)</td>
<td>73 (16–99)</td>
<td>64 (15–101)</td>
</tr>
<tr>
<td>Mean CCI (range)</td>
<td>3.56 (0–15)</td>
<td>4.61 (0–14)</td>
<td>3.75 (0–15)</td>
</tr>
</tbody>
</table>

CCI, Charlson Comorbidity Index.

Table 3
Hazard ratio covariates in the Cox regression analysis of survival after atlas fracture (n=1,553) presented with 95% confidence interval and significance (p).

<table>
<thead>
<tr>
<th>Covariate</th>
<th>HR</th>
<th>95% CI Lower</th>
<th>95% CI Upper</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1.04</td>
<td>1.03</td>
<td>1.05</td>
<td>.000</td>
</tr>
<tr>
<td>Sex</td>
<td>1.18</td>
<td>1.00</td>
<td>1.40</td>
<td>.055</td>
</tr>
<tr>
<td>Charlson Comorbidity Index</td>
<td>1.25</td>
<td>1.19</td>
<td>1.31</td>
<td>.000</td>
</tr>
<tr>
<td>Concomitant axis fracture</td>
<td>0.80</td>
<td>0.65</td>
<td>0.99</td>
<td>.037</td>
</tr>
<tr>
<td>Concomitant subaxial fracture</td>
<td>1.06</td>
<td>0.72</td>
<td>1.56</td>
<td>.760</td>
</tr>
<tr>
<td>Year of injury</td>
<td>0.95</td>
<td>0.93</td>
<td>0.97</td>
<td>.000</td>
</tr>
</tbody>
</table>

HR, hazard ratio; CI, confidence interval.
growth yielded an increasing incidence from seven admissions per million inhabitants in 1997 to 17 admissions per million inhabitants in 2011 (Fig. 2).

This increase in incidence followed a clear linear trend ($r=0.94$).

**Discussion**

This study presented nationwide collected epidemiologic data on C1 fractures for the first time. The main findings were an increasing incidence of atlas fractures, a bimodal age distribution of atlas fracture incidence, and the coincidence of C1 and C2 fractures.

**Increasing incidence of atlas fractures**

In the investigated population, the incidence of admissions for atlas fractures more than doubled from 7 per million inhabitants in 1997 to 17 per million inhabitants in 2011, and linear regression analysis showed a clear linear trend. The greatest increase occurred in the elderly (>50 years) were the incidence almost tripled. The incidence in the younger age groups (0–49 years) remained unchanged. This result is in accordance with the findings of Brolin and von Holst [15]. They use data from the NPR in a study on cervical fractures between 1987 and 1999 and find a decreasing incidence of cervical fractures in younger age groups and an increasing incidence in the elderly population particularly among elderly women. Our findings documented that this trend has continued in the case of atlas fractures. Several studies find that simple falls are the most common causes of cervical fractures in the elderly [15–19]. One possible explanation for the increased incidence could be an increase in the number of falls in the elderly population. Another possible explanation could be that falls among the elderly perhaps have resulted in more fractures because of an increased vulnerability (osteoporosis) among the elderly. Furthermore, a greater incidence of injuries due to a greater level of activity of the elderly may be assumed, which could be explained by an improved general health status in the elderly is necessary to determine what role falls among the elderly play in the increasing incidence. One possible confounder of the incidence data is better diagnostics. Because of the greater availability of computed tomography units even in rural regions, atlas fractures are more likely to be diagnosed. Interestingly, the increasing trend in the elderly population is continuing although computed tomography scans are available throughout the country for more than 10 years. Furthermore, the increase is not impressive in the younger population, implicating that this diagnostic bias alone cannot account for the dramatic trend.

**Bimodal age distribution**

A bimodal age distribution with a small first peak at 24 years and a larger second peak at 81 years was found in

![Fig. 3. Age distribution for all atlas fractures with and without concomitant axis fracture.](image-url)
the study population. This distribution suggests that C1 fractures differ according to age group. The age distribution was heavily imbalanced, and a large majority of cases occurred in the elderly population. This is in accordance with the findings of Brolin [16] and Lomoschitz et al. [18] who previously report that atlas fractures are more common in the elderly population. This is further supported by the fact that the mean age of the study population, 64 years, was much older than the mean age of previously published series of atlas fractures, between 30 and 52 years (Table 1). One explanation for this disparity could be differences in the study populations. The cases in the previous studies [2–9] are collected from singular caregivers, often a highly specialized hospital or institution, such as specialized spine trauma units and university hospitals, whereas the cases in this study were collected nationwide from admissions to all emergency hospitals in Sweden. It is reasonable that a greater number of cases referred to specialized care are caused by high-energy trauma. Low-energy trauma is the dominant cause of cervical fractures in the elderly [15–19]. Because these data in this study were collected nationwide from all Swedish hospitals, it is likely to include a greater amount of uncomplicated cases resulting from low-energy trauma among the elderly who will not have been referred to highly specialized care.

Coincidence of C1 and C2 fractures

In previously published studies on atlas fractures, the coincidence of C1 and C2 fractures is 24% to 46% [2–7,9]. The coincidence found in this study was lower compared with the previously published data (19%). One reason for this could be the differences in the aforementioned study populations. Because the cases in the previous studies have been collected from highly specialized hospitals, it is possible that they include a greater number of complicated cases and that therefore, some of them will present higher rates of combined C1–C2 fractures.

Mortality

The mortality analysis using the Kaplan-Meier method revealed a shorter mean survival for patients with atlas fractures compared with a cohort of patients with spinal fractures. However, Cox regression analysis, where multiple covariates were accounted for, did not identify atlas fractures as an independent risk factor. The shorter mean survival seen in the atlas fracture group is therefore most likely confounded by a selection bias of differences in the age distribution and comorbidities of the cohorts. Cox regression analysis within the atlas fracture cohort revealed no unexpected results. High age and high CCI were associated with slightly increased HRs. Later year of injury was associated with a slight decrease in HR, possibly an effect of improved management of C1 fractures or comorbidities. The coincidence of a C2 fracture reduced the mortality significantly. Because C1 fractures have a higher coincidence with C2 fractures in the elderly population (Fig. 4), a low-energy trauma on osteoporotic bone mechanism could be assumed. As the mortality of low-energy trauma is lower than that of high-energy trauma, the “protective” effect of concomitant C2 fractures was rather caused by a selection bias.

Because this study is based on registry data, it is important to consider possible flaws in the data set. The Swedish National Board for Health and Welfare performs quality control on the registry and corrects obvious errors, but of course, there are still possibilities for faults in the registry [20]. One such possibility is misdiagnosis due to coding errors, that the wrong ICD code was coded for a diagnosis. Another possibility is omission of one or more diagnoses in cases with several diagnoses. The NPR has shown both internal and external validity for orthopedic diagnoses [20]. Diagnoses as hip fractures were in more than 95% correctly identified. Additionally, the increasing incidence occurring only in the elderly age group can hardly be caused by an improved coding practice, which would be evident even in the younger age group. Beyond that, the Swedish reimbursement policy requires complete diagnosis registration, an effective incitement to proper coding.

Conclusions

Atlas fractures occurred predominantly in the elderly population. Still, this injury was not associated with greater mortality in an adjusted model. Both the age distribution and the coincidence with axis fractures suggested prevalent osteoporosis as a contributing factor. Therefore, preventative measures should be directed toward the oldest age group by osteoporosis prevention, and by physiotherapeutic instructions reducing the risk of falls.

Acknowledgments

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References