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Clinical Study

Surgical treatment improves survival of elderly with axis fracture—a national population-based multiregistry cohort study

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Abstract

BACKGROUND CONTEXT: Fractures of the axis (C2) are the most common cervical spinal injuries in the elderly population. Several authors have reported improved survival among elderly patients with C2 fractures when treated surgically.

PURPOSE: We aimed to analyze whether surgery improves survival of elderly with C2 fractures.

STUDY DESIGN/SETTING: An observational population-based longitudinal multi-registry study was carried out.

PATIENT SAMPLE: Swedish Patient Registry 1997 to 2014 and Swedish Cause of Death Registry 1997 to 2014 served as source of patient sample.

OUTCOME MEASURES: Survival after C2 fracture according to non-surgical and surgical treatment was the outcome measure.

METHODS: We included all patients treated for the primary diagnosis of C2 fracture (10th revision of the International Statistical Classification of Diseases and Related Health Problems or ICD-10: S12.1) at an age ≥70 years and receiving treatment at a health-care facility. Non-surgical treatment comprises cervical collar or halo-vest treatment. Surgical treatment was identified in the Swedish patient registry extract using the Swedish classification of procedural codes. Survival was determined using the Kaplan-Meier method. Comorbidity was determined using the Charlson Comorbidity Index.

RESULTS: Of the included 3,375 elderly patients with C2 fractures (43% men, aged 83±7 years), 22% were treated surgically. Surgical treatment was assigned based on age, gender, and year of treatment. The 1-year survival of 2,618 non-surgically treated patients was 72% (n=1,856), and 81% (n=614) for the 757 surgically treated (p<.001, relative risk reduction=11%). Adjusted for age, gender, comorbidity, and year of injury, surgically treated patients had greater survival than non-surgically treated patients (hazard ratio=0.88, 95% confidence interval: 0.79–0.97). Among those above 88 years of age (95% confidence interval: 85–92), surgical treatment lost its effect on survival.

CONCLUSIONS: Despite the frailty of elderly patients, the morbidity of cervical external immobilization with a rigid collar seemingly weighs greater than surgical morbidity, even in octogenarians. For those above 88 years of age, non-surgical treatment should be primarily attempted.

Keywords: Axis fractures; Elderly; Mortality; Odontoid fractures; Spinal fractures; Surgical treatment

FDA device/drug status: Not applicable.

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EVIDENCE & METHODS

Context

The authors assessed whether operative or nonoperative treatment afforded better one-year survival following C2 fractures in elderly patients.

Contribution

They found that, from age 70 to 88, surgery appeared to improve survival rates. Beyond that, survival rates were comparable.

Implications

The findings are of limited validity as the database used did not capture essential information in this setting; specifically, neurological status and specifics of co-morbidities. This is a common theme in the use of basic national databases—the questions asked are insufficient for the answers we seek. RCTs and prospective, well-thought-out spine-specific registries are key. Otherwise, we risk comparing "apples and oranges" wherein both "fruits" are poor quality case-series reports presented side by side.

Introduction

Fractures of the second cervical vertebra (C2) are the most common cervical spine injuries in the elderly population [1,2]. Because of surgical complications and the pulmonary hazards of external immobilization, recommendations for C2 fracture management in elderly are still inconclusive [3,4].

Most previously published studies on C2 fracture treatment for the elderly propose radiographic fracture healing as the primary end point, which seems counterintuitive, as radiographic non-union is not associated with a worse functional outcome [5,6]. A prospective study using the Neck Disability Index as end point reports better functioning if surgical treatment was applied [5,7].

Beyond that, a growing body of clinical studies indicates that surgical stabilization of C2 fractures is leading to improved fracture healing and survival [8]. Still, surgical complications outweigh the benefits of surgical treatment, according to some authors [9,10]. This is especially true for octogenarians and non-agenarians [11,12].

This national multiregistry study was designed to analyze the effect of surgical treatment on survival in the elderly with a C2 fracture.

Methods

Study design

This national multiregistry study investigates a nationwide cohort of patients with C2 fractures, followed prospectively with the date of death as the end point. The regional ethical review board of Uppsala approved this study (no. 2010/131/1). The study protocol is registered at ClinicalTrials.gov (NCT02839057) and follows STROBE and RECORD statements [13,14].

Setting

The Swedish National Patient Registry (NPR) is hosted by the Swedish Agency of Health and Welfare and contains all patient contacts within Sweden with a coverage of >90% for orthopedic diagnoses [15]. Registered are main diagnoses and comorbidity using the 9th and 10th revisions of the International Statistical Classification of Diseases and Related Health Problems until 1996 (ICD-9 codes) and from 1997 (ICD-10 codes) onward [16], respectively. Treatment has been coded since 1997 using the Swedish classification of surgical procedures [17]. Furthermore, information on hospitalization time is available from the registry. In the Swedish Cause of Death Registry (CDR), all deaths in Sweden are registered with the date and cause of death. Although the date of death coverage is complete, the cause of death has only 46% agreement with the final hospital diagnosis [18].

Participants

All patients with a main diagnosis of a C2 fracture (ICD-10: S12.1), treated between January 1, 1997 and December 31, 2014, were extracted from the NPR and merged with the Swedish Cause of Death Registry for death incidents. Before data transmission, the Swedish Agency of Health and Welfare anonymized the individual personal identification numbers using a key, which remained with the Agency. Included in the study were patients ≥70 years of age.

Multiple admissions (cases with the same identification number but more than 12 months between admissions) and duplicate entries (cases with the same identification number) were removed from the data set, once valuable comorbidity data from the duplicate entries were stored in the original record. Duplicate entries originated from separate recordings from each hospital if the patient had been referred to a specialized hospital. Furthermore, primarily non-surgically treated patients with a change of treatment modality to surgery within 12 months were registered as surgical patients. Multiply traumatized patients with unspecified multiple injuries (ICD-10: T07) were excluded from the study. The registered hospitalization time for these patients was the combined non-surgical and surgical in-hospital treatment period.

Variables

Treatment allocation

Using Swedish surgical procedure codes for spinal fusion ("NAG") and spinal osteosynthesis ("NAJ"), patients receiving surgical treatment were identified in the NPR, with the cohort divided into two groups in terms of those receiving non-surgical and those receiving surgical treatment.

Survival

Patient survival was calculated from the date of injury or first fracture registration with end point death or censored on December 31, 2014.

Spinal cord injury

With the ICD-10 codes S14, S24, S34.0, and S34.1, patients with spinal cord injury were identified.

Charlson Comorbidity Index

From each record in the NPR, the Charlson Comorbidity Index (CCI) was calculated using a previously validated algorithm based on ICD-10 codes [19]. The factor "CCI score" categorized the level of comorbidity in low (1–3), moderate (4–5), high (6–7), and very high comorbidity (≥8) [20].

Statistical methods

Mean values were presented ±the standard deviation. Groups were compared with the *t* test for normally distributed variables; otherwise, the Wilcoxon test was applied. A probability of p<.05 was regarded as statistically significant.

Logistic regression analysis, which identified covariates of surgical treatment assignment, resulted in 95% confidence intervals (CI) and statistical probability p [21].

The Kaplan-Meier method was used to determine mean and median survival for non-surgical and surgical treatment. Absolute survival rates among non-surgical and surgical treatment groups and relative risk reduction (RRR) at 3 months, 1 year, and 2 years were determined, while the survival curve was visualized using a Kaplan-Meier plot. A semiparametric G-rho test was applied to test differences of survival curves [22]. Proportional survival differences according to treatment were tested with the chi-squared test. Using the Cox proportional hazards regression method, the contribution of multiple covariates to survival was analyzed and presented as hazard ratio (HR) with 95% CI and probability p. Besides surgical treatment, age, gender [23], spinal cord injury [24,25], and CCI score [26] were identified as relevant covariates for survival. Because we assumed that medical advancement had improved patient survival in general in recent decades, every year of admission was included as a covariate in the model. Covariates were treated as categorical variables and entered or excluded in stepwise fashion. The adjusted HR for a certain age and above was plotted over the age range with a 95% CI to identify a cutoff age where a treatment modality is no longer associated with greater survival.

All statistical calculations were programmed in R Version 3.4.1 (R Foundation for Statistical Computing, Vienna, Austria) [27].

Results

Inclusion and baseline data

The inclusion flow diagram is presented in Fig. 1. Of the included 3,375 elderly patients (≥70 years), 43% were men. The mean age was 83±7 years. Of patients with C2 fractures, 3.7% had a concomitant C1 fracture, and 3.7% had a subaxial cervical fracture. Acute spinal cord injury was present in 0.9% of all included patients. The baseline data are summarized in Table 1.

Treatment selection

Of the included patients ≥70 years of age, 22% (n=757) were treated surgically. Appendix 1 summarizes the group differences regarding baseline comorbidities.

Surgical treatment assignment was based on younger age (odds ratio [OR]=0.93, CI: 0.92–0.95, p<.001), male gender (OR=1.28, CI: 1.07–1.53, p=.006), and earlier years of treatment (OR=0.91, CI: 0.89–0.92, p<.001). Overall comorbidity as determined by the CCI did not play a role in treatment assignment (OR=1.00, CI: 0.94–1.06, p=.99).

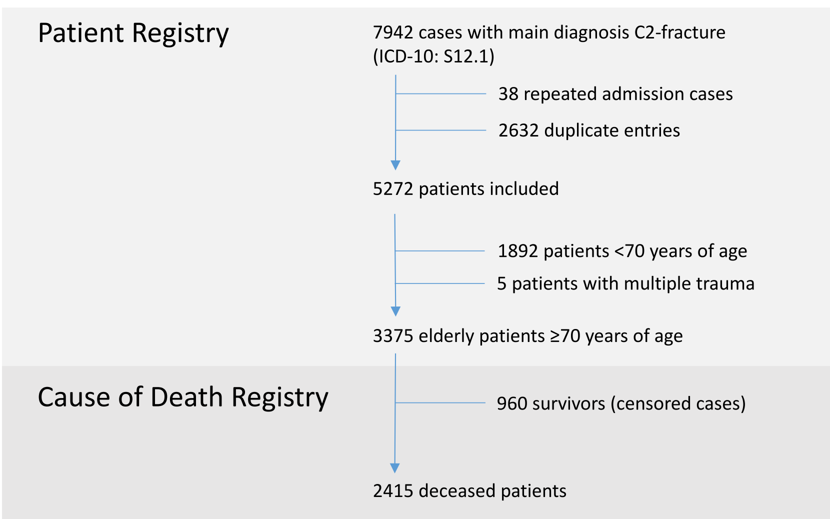

Fig. 1. Inclusion flow diagram. ICD, International Classification of Diseases.

Table 1
Baseline data of elderly patients ≥70 years with C2 fractures according to treatment (count no. or mean±standard deviation)

		Age	Gender		Hospitalization	Comorbidity	Concomitant spinal injuries		
Treatment	No. of subjects	Years	No. of male	No. of female	Days	CCI	No. of C1 fx	No. of subaxial fx	No. of SCI
Non-surgical	2,618	83.4±6.9	1,073	1,545	12±14	6.2±1.7	73	95	16
Surgical	757	79.9±6.3	386	371	16±16	5.7±1.6	52	29	15
All	3,375	82.6±6.9	1,459	1,916	13±15	6.1±1.6	125	124	31

CCI, Charlson Comorbidity Index; SCI, spinal cord injury; fx, fracture.

There was a strong linear trend toward less surgical treatment for patients with the main ICD-10 code S12.1, fracture of the second vertebrae, from 34% surgically treated in 1997 to 11% in 2014 (r=–0.93, p<.001).

Survival

The mean survival of 2,618 non-surgically treated patients was 4.6 years (median: 3.1 years, 95% CI: 2.8–3.2), and 6.1 years (median: 4.9 years, 95% CI: 4.3–5.6) for 757 patients treated surgically.

The 3-month survival rate was 82% (n=2,150) for non-surgically treated patients and 89% (n=671) for surgically treated patients (p<.001, RRR=8%). The 1-year survival of non-surgically treated patients was 72% (n=1,856), and 81% (n=614) for the surgically treated (p<.001, RRR=11%). The 2-year survival rate for non-surgically treated patients was 59% (n=1,401), whereas 73% (n=525) of surgically treated patients survived (p<.001, RRR=19%). Adjusted survival curves of non-surgically and surgically treated patients ≥70 years of age with a C2 fracture is presented in Fig. 2 (G-rho test, p<.001).

The lowest mortality was found among surgically treated patients. Non-surgically treated patients experienced a higher risk of dying during follow-up than surgically treated patients (HR=1.37, 95% CI: 1.25–1.51). When we further adjusted for age (decades), gender (male, female), the CCI (moderate, high, very high), and the decade of treatment, we again found the lowest mortality among surgically treated patients (Table 2). Increased mortality risk among non-surgically treated patients was reduced to some extent (HR=1.14, 95% CI: 1.03–1.26). The detailed multivariate-adjusted HR for surgery for every year of age and above indicated improved survival with regard to those who received surgical therapy below 88 years of age. Surgical treatment was not associated with improved survival above 88 years of age (95% CI: 85–92) (Fig. 3).

Hospitalization

Non-surgical treatment was associated with a shorter mean hospitalization time of 12 days (median: 8 days, 95% CI: 11–13) compared with surgical treatment with 16 days (median: 11 days, 95% CI: 15–17) (p<.001). Hospitalization time was not correlated with patient age or the CCI. During the last 2 decades, the mean total hospitalization time for C2 fracture treatment decreased from 16 days (median: 12 days, 95% CI: 12–20) for non-surgically treated patients and 28 days (median: 21 days, 95% CI: 18–38) for surgically treated patients in 1997 (p=.03) to 9 days (median: 11 days, 95% CI: 8–10) and 13

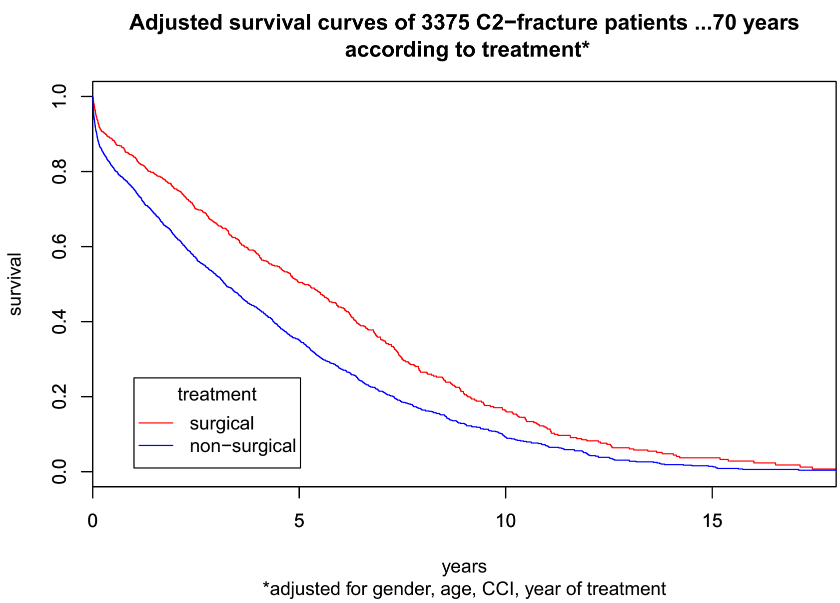

Fig. 2. Adjusted survival curves of C2 fracture patients ≥70 years with and without surgical treatment. CCI, Charlson Comorbidity Index.

Table 2
Survival after C2 fracture in elderly according to covariate category

Covariate	Categories	No. of deaths/no. of subjects	No. of person-years	Univariate		Multivariate*	
				HR (95% CI)	p	HR (95% CI)	p
Treatment	Non-surgical	1,856/2,618	10,212	1.00 (Ref)		1.00 (Ref)	
	Surgical	559/757	4,178	0.73 (0.66–0.80)	<.001	0.88 (0.79–0.97)	.008
Age (decade)	70–79 y	657/1,154	6,744	1.00 (Ref)		1.00 (Ref)	
	80–89 y	1,239/1,627	6,102	2.43 (2.20–2.68)	<.001	1.89 (1.69–2.11)	<.001
	90–99 y	510/585	1,525	4.51 (3.99–5.10)	<.001	2.86 (2.48–3.31)	<.001
	100+ y	9/9	19	6.77 (3.50–13.10)	<.001	3.36 (1.72–6.56)	<.001
Gender	Female	1,345/1,916	8,423	1.00 (Ref)		1.00 (Ref)	
	Male	1,070/1,459	5,967	1.14 (1.05–1.23)	.002	1.41 (1.30–1.53)	<.001
Charlson Comorbidity Index	Moderate (4–5)	807/1,364	8,059	1.00 (Ref)		1.00 (Ref)	
	High (6–7)	1,182/1,517	5,170	1.52 (1.41–1.65)	<.001	1.89 (1.70–2.10)	<.001
	Very high (≥8)	426/494	1,161	2.85 (2.64–3.08)	<.001	3.34 (2.91–3.83)	<.001
Year of fracture (decade)	1990s	334/349	2,246	1.00 (Ref)		1.00 (Ref)	
	2000s	1,441/1,751	8,778	1.13 (1.02–1.25)	.016	0.94 (0.83–1.07)	.351
	2010s	640/1275	3,366	0.98 (0.91–1.05)	.531	0.85 (0.73–0.98)	.026

HR, hazard ratio; CI, confidence interval; Ref, reference category.
Results of univariate and multivariate Cox proportional hazards regressions are presented with 95% CI.
* r^2=0.255 (Likelihood ratio test p<.001, Wald test p<.001, Score (log-rank) test p<.001).

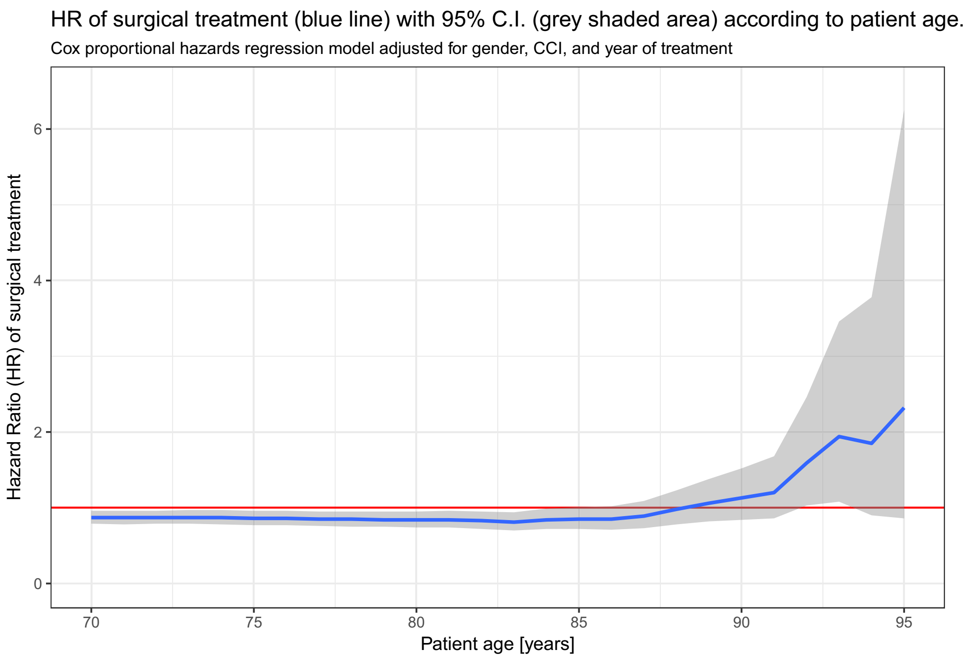

Fig. 3. Adjusted hazard ratio curve of surgical C2 fracture treatment according to patient age (gray area depicts 95% CI). The red line depicts HR=1.00, below which mortality is reduced. CI, confidence interval; CCI, Charlson Comorbidity Index; HR, hazard ratio.

days (median: 7 days, 95% CI: 10–16) in 2014 (p<.001) (r=–0.20), respectively.

Discussion

This study documents the benefit of surgical treatment on the short-, mid-, and long-term survival of elderly patients with C2 fractures in a comprehensive national patient cohort. A cutoff age of 88 years could be determined where surgical treatment lost its beneficial effect on survival.

Strengths and weaknesses of this study

The national population-based cohort design of this study is superior to most previously published studies, as it minimizes the selection bias of highly specialized trauma centers, which often attract odd and unusual case referrals, thus distorting the disease panorama. Instead of creating a sample of the population, as is done in randomized controlled trials, national cohort studies include the whole population.

Even though we could previously demonstrate that 89% of C2 fractures are odontoid fractures in elderly patients, the odontoid type 3 fracture (about 26% of all C2 fractures) is, in virtually all cases, treated non-surgically [1]. Therefore, in the present study, we compared the cohort of all odontoid type 3 fractures and non-surgically treated type 2 fractures with the cohort of surgically treated odontoid type 2 fractures. A recent study has identified odontoid type 3 fractures as a predictor of 1-year mortality [25]. Unfortunately, the detail in ICD-10: S12.1 does not allow us to adjust for C2 fracture subtypes.

Beyond that, the identification of patients with neurologic compromise in the NPR is limited. Patients with spinal cord injury were identified and adjusted for in the multivariate model, but it remains unclear at which dermatome level the injury occurred, and whether it is a partial or complete spinal cord injury. With regard to the surgical technique of C2 fracture stabilization, we have no satisfactory data whether anterior or posterior or circumferential accesses were used, which levels were included, which devices were implanted, and whether bone graft was used. These questions were previously answered using a retrospective study design [1].

Treatment of C2 fractures

The trend of C2 fracture treatment among the elderly aged ≥70 years in Sweden has been toward non-surgical treatment in the last 2 decades [2]. This trend contrasts with the findings from our recent cohort study on odontoid fracture treatment in two Swedish tertiary referral centers, where an increased surgical treatment trend was identified [1].

In a North American retrospective cohort, in the last 2 decades, the treatment trend for odontoid type 2 fractures favored surgery [28]. Obviously, regional differences exist in the interpretation of current treatment evidence.

The ICD-10 used in the NPR does not allow distinguishing between different types of C2 fractures [2]. Therefore, an analysis of survival related to a certain surgical technique (ie, anterior vs. posterior access) is currently impossible. The more important question whether a cervical collar was provided postoperatively or not, is not available in the NPR.

Survival

A prospectively collected cohort of 159 patients >64 years with an odontoid type 2 fracture reports a 1-year mortality of 26% among the non-surgically treated and 14% among the surgically treated (p=.059) [7]. A meta-analysis of 1,284 retrospectively collected cases with odontoid type 2 fractures finds a 1-year mortality rate of 23% among non-surgically treated patients and 11% among surgically treated patients (p<.001) [8].

Compared with previously published data, the NPR cohort in this study had a higher 1-year mortality rate of 28% versus 19% for non-surgical and surgical treatment cases (p<.001). One possible reason is that the comprehensive nationwide coverage of patients with C2 fractures minimized dropout and loss to follow-up, even among the worst patients who died a few days after admission. Furthermore, patients registered in national databases could not opt out of study inclusion, which eliminated a significant selection bias. Beyond that, dementia and language problems, being common exclusion criteria for clinical study participation, cannot cause a selection bias in a national registry study.

Reasons for greater survival of surgical treatment of C2 fractures are as follows:

1. Non-surgical treatment with halo vests and cervical collars restrict upper thoracic mobility, thereby impairing respiratory function [29]. This increases the susceptibility of our patients to pneumonia or respiratory distress [30].
2. Soft tissue complications associated with pressure sores during collar treatment, as well as intracranial pin migration and pin tract infections involving halo vests, may complicate the course of non-surgical treatment [31].
3. Early rehabilitation is facilitated if patients are not stigmatized with a cervical collar or halo vest. This maintains a high level of function and greater quality of life.
4. Cervical collars and halo vests cause dysphagia, which may lead to aspiration [32–34]. If the swallowing function is impaired, dehydration and malnutrition commonly occur [35,36].

Implications for clinicians and policymakers

After 1 year, surgical stabilization improved survival with a RRR of 11%, which increased after 2 years to 19%. Of relevance to health economic decision-making was a 1.5-year longer survival period with surgical treatment, at a cost of 4 more days of hospitalization. A recent cost-effectiveness analysis of surgical versus non-surgical treatment of odontoid C2 fractures came to the conclusion that surgery is cost-effective up to the age of 85 years [37]. This is consistent with our finding that surgery lost its effectiveness on the survival of C2 fractured patients above the age of 88 years (95% CI: 85–92), when surgery rather reduced the number of life years gained.

Future areas of research

Although surgical stabilization was found to have a beneficial effect on survival after C2 fractures, the implications of this invasive treatment on patients' health-related quality of life is relatively unknown. Prospective studies, preferably with a randomized controlled design, investigating function and quality of life in non-surgical and surgical treatment contexts are necessary, if we want to be able to make strong evidence-based treatment recommendations.

Data sharing statement

Patient registry dataset and technical appendix are available at the Swedish National Board of Health and Welfare (http://www.socialstyrelsen.se/statistics). Patient consent was not obtained, but the data are anonymized and risk of identification is low.

Acknowledgment

Dr. Johan Willander's statistical expertise on tables and graphs improved the quality of this manuscript dramatically. We thank Ms. Pernilla Fagerström from the Swedish Agency of Health and Welfare for excellent assistance with the registry extracts.

Appendix

Appendix 1Baseline comorbidities according to surgical and non-surgical treatment groups.

	Non-surgical treatment		Surgical treatment	
Comorbidity	n	Proportion	n	Proportion
Coronary heart disease	354	9%	112	8%
Congestive heart disease	288	8%	67	5%
Peripheral vascular disease	21	1%	3	0%
Cerebrovascular disease	161	4%	68	5%
Dementia	225	6%	38	3%
Chronic pulmonary disease	125	3%	47	3%
Connective tissue disorder	74	2%	29	2%
Peptic ulcer	12	0%	8	1%
Mild liver disease	9	0%	6	0%
Diabetes mellitus	304	8%	96	7%
Hemiplegia	40	1%	30	2%
Renal disease	72	2%	21	1%
Diabetes mellitus with complications	37	1%	12	1%
Cancer	187	5%	44	3%
Severe liver disease	22	1%	15	1%
Metastatic disease	42	1%	13	1%

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