SURGICALLY TREATED C1 FRACTURES: A POPULATION-BASED STUDY

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Abstrakti

Tarkoitus: Kuvata C1-murtumien leikkaushoitoa ja hoidon tuloksia väestöpohjaisessa tutkimusasetelmassa.

Menetelmät: Kuopion yliopistollisen sairaalan neurokirurgialla hoidetut C1-murtumapotilaat tunnistettiin retrospektiivisesti aikaväliltä tammikuu 1996 – kesäkuu 2017. C1-murtumat luokiteltiin AO Spine Upper Cervical- sekä Gehweiler-luokittelujärjestelmien mukaisesti. Potilaat jaettiin 4 ryhmään heidän saamansa hoidon mukaan: ryhmä 1 (C1-murtuman ensisijainen hoitolinja oli leikkaushoito), ryhmä 2 (C1-murtuman toissijainen hoitolinja oli leikkaushoito, kun ensisijainen konservatiivinen hoito oli ollut riittämätön), ryhmä 3 (muu samanaikainen kaularankamurtuma hoidettiin leikkaushoidolla, ja leikkaus ulottui C1-tasolle) ja ryhmä 4 (C1-murtuman hoitolinja oli konservatiivinen hoito).

Tulokset: Tunnistimme 47 C1-murtumapotilasta (ikäkeskiarvo 60,3 ± 18,2 vuotta; 83,0 % miehiä; American Society of Anesthesiologists -pistekeskiarvo 2,3 ± 0,8). Samanaikaisia kaularankamurtumia havaittiin 89,4 %:ssa tapauksista, yleisimmin C2-nikamassa (75,4 %). Ryhmään 2 kuului viisi murtumaa, ja näistä kolmen murtumatyyppi muuttui AO Spine -luokituksen tyypistä A tyypiksi B konservatiivisen hoidon jälkeisessä kontrollikuvauksessa viitaten instabiiliin murtumaan, ja näissä tapauksissa tarvittiin leikkaushoitoa toissijaisena hoitolinjana. C1-murtuma todettiin hyväasentoiseksi kaikilla 10:lla hoidon jälkeisen seurannan läpikäyneellä potilaalla ryhmissä 1 ja 2 sekä 10:lla 11 seuratusta potilaasta ryhmässä 3. Hoidon jälkeistä niskakipua ja -jäykkyyttä esiintyi kaikissa ryhmissä. Neurologiset jäännösoireet olivat harvinaisia ja lieviä.

Johtopäätökset: Instabiilien C1-murtumien leikkaushoito on turvallista ja johtaa hyviin lopputuloksiin. Alun perin stabiileiksi arvioidut murtumat saattavat vaatia leikkaushoitoa, jos niiden asento huononee seurantakuvantamisessa. Magneettikuvaus on suositeltava diagnostinen kuvantamismenetelmä instabiilien C1-murtumien parempaa havaitsemista varten.

Avainsanat: Atlasnikama; C1-murtuma; Kaularankamurtuma; Instabiilius; Kirurgia; Yläkaularanka

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Abstract

Objective: To characterize surgical treatment and outcomes of C1 fractures in a population-based setup.

Methods: Patients with C1 fracture treated at Kuopio University Hospital Neurosurgery were retrospectively identified from January 1996 to June 2017. C1 fractures were classified according to the AO Spine Upper Cervical and Gehweiler classification systems. Patients were divided into 4 groups based on their treatment: group 1 (underwent C1 surgery as a primary option), group 2 (underwent C1 surgery as a secondary option after initial nonoperative treatment), group 3 (underwent surgery involving the C1 level with main indication being a concomitant cervical spine fracture), and group 4 (C1 fracture treatment was nonoperative)

Results: We identified 47 patients with C1 fracture (mean age, 60.3 ± 18.2 years; 83.0% men; American Society of Anesthesiologists score, 2.3 ± 0.8). Concomitant cervical spine fractures were present in 89.4% of cases, most commonly in the C2 vertebra (75.4%). In group 2, 3 of 5 fractures changed from AO Spine type A to B in control imaging after nonoperative treatment, indicating fracture instability and requiring secondary surgery. Good C1 fracture alignment was achieved for 10 of 10 followed-up patients in groups 1 and 2, and for 10 of 11 followed-up patients in group 3. Residual neck pain and stiffness were present in all groups. Neurologic symptoms were rare and mild.

Conclusions: For unstable C1 fractures, surgery is safe treatment with good outcomes. Fractures initially determined as stable may require surgery if alignment is worsened in follow-up imaging. Magnetic resonance imaging is recommended to better detect unstable C1 fractures in diagnostic imaging.

Keywords: Atlas; C1 fracture; Cervical spine fracture; Instability; Surgery; Upper cervical spine

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Introduction

Fractures of the C1 constitute 3–13% of all cervical spine injuries in adults.[1-3] They occur most frequently after motor vehicle accidents, falls, diving into shallow water, and sports injuries. At clinical presentation, patients often have neck pain and limited neck movement.[1-3] Neurologic impairment has also been reported; however, it is rare in isolated C1 fractures. In 40–44% of cases, there is also an axis fracture associated with the C1 fracture.[1-3]

The treatment of C1 fractures is often affected by a concomitant cervical spine fracture, most commonly the axis.[3] Most isolated C1 fractures are stable and can be treated nonoperatively with external immobilization, whereas evidence for management of unstable atlas fractures is still inadequate.[4,5] The integrity of the transverse atlantal ligament (TAL) is a commonly used distinctive factor between stable and unstable C1 injuries, with a ruptured ligament implicating an unstable fracture and a candidate for operative treatment.[3-6] Traditional surgical options for C1 fracture treatment are occiput-to-C2 fusion or C1-2 fusion.[3] However, they may reduce neck mobility and possibly increase the incidence of degenerative changes in the cervical spine because the adjacent levels are subjected to additional stress; therefore, several alternative surgical methods have been suggested in the literature.[6-9]

In this population-based retrospective study, we evaluated consecutive patients with C1 fracture treated at a tertiary center over a 21-year period. The purpose of the study was to assess the management of various C1 fracture types and evaluate outcomes of different treatment options.

Materials and methods

Study environment

This case series study was conducted at Kuopio University Hospital (KUH). KUH Neurosurgery is a tertiary center that exclusively provides surgical treatment of cervical spine fractures within its catchment area in Eastern Finland and has a specialized team dedicated to the evaluation and surgical treatment of cervical spine injuries. The catchment area is based on geographic location and includes 4 central hospitals, each with their own 24/7 emergency department and orthopedics/traumatology department: North Karelia

Central Hospital, Central Finland Central Hospital, Mikkeli Central Hospital, and Savonlinna Central Hospital. The central hospitals consult KUH Neurosurgery regarding the assessment, treatment, and follow-up of all cervical spine fractures. All patients requiring surgery for cervical spine fractures are referred to KUH Neurosurgery.

The population of the KUH catchment area was 844,510 at the start of the evaluation period (December 31, 1995) and 813,487 at the end of year 2016 (December 31, 2016).[10] Permission for this study was given by the Research Ethics Committee of the Northern Savo Hospital District. Research registry number was 236/2017. The study was register-based, and none of the included patients were contacted. Informed consent was not required.

Study population

All patients with cervical spine injury who underwent surgery at KUH Neurosurgery between January 1996 and June 2017 were identified from the KUH patient register using specific codes from NOMESCO Classification of Surgical Procedures (NCSP) and the Finnish version of the *International Statistical Classification of Diseases and Related Health Problems, 10th Revision*. The codes used were NAJ10, NAJ12, and NAG4x from NCSP and S12.x, S13.x, and S14.x from *International Statistical Classification of Diseases and Related Health Problems, 10th Revision*. For operations before 1998, operation codes were derived from an older procedure nomenclature. In total, 611 patients were found. From this population, only patients with C1 fracture were included in the study.

Imaging methods

During the study period, the applied imaging modalities varied between patients, and no standardized imaging protocol was used. C1 fractures were evaluated using magnetic resonance imaging (MRI), computed tomography (CT), anteroposterior plain radiograph, or a combination of these modalities. CT angiography was used whenever a vertebral canal injury was suspected. Dynamic imaging was not used. In this study, the available images were reviewed retrospectively.

Clinical data

The medical records, radiologic images, and radiology reports of the patients were reviewed. Demographic data, cause of injury, type of C1 fracture, concomitant cervical spine fractures, treatment type, and outcome were recorded. American Society of Anesthesiologists scores were obtained for each patient to classify the severity of possible comorbidities.[11] Collected data regarding C1 fracture treatment included the following items: nonoperative (Halo vest or cervical collar) or surgical, surgical technique, main indication for surgery, and whether surgery was the initial treatment plan or a secondary option after insufficient nonoperative treatment. Potential postoperative complications and treatment failures were also documented.

Patient groups

Patients were classified into 4 groups based on the treatment data (Figures 1 and 2). The groups are as follows: group 1 (patients who underwent C1 surgery as a primary option, with the main indication being an unstable C1 fracture), group 2 (patients who underwent C1 surgery after initial nonoperative treatment, with the main indication being an unstable C1 fracture), group 3 (patients who underwent surgery involving the C1 level, with the main indication being a concomitant cervical spine fracture, and group 4 (patients who did not receive surgical treatment at the C1 level and therefore C1 fracture treatment was considered nonoperative). Group 4 consisted of the patients whose C1 fracture was treated nonoperatively but who underwent cervical spine surgery at another level, or an application of external immobilization, or another minor operation without C1 surgery.

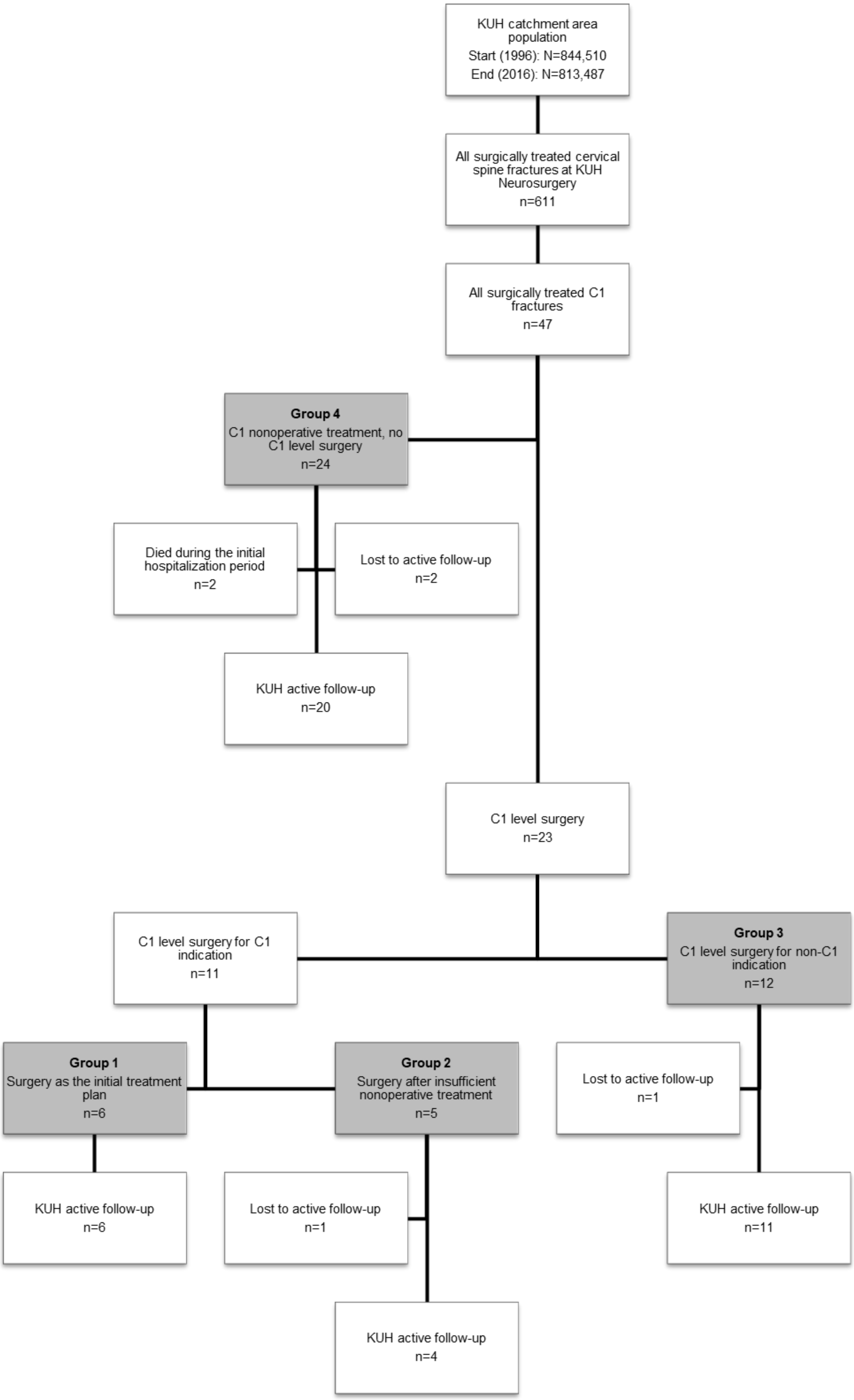

Figure 1: A flowchart showing all surgically treated patients with C1 fracture at Kuopio University Hospital Neurosurgery between January 1996 and June 2017 and division into 4 groups based on C1 fracture treatment. KUH, Kuopio University Hospital.

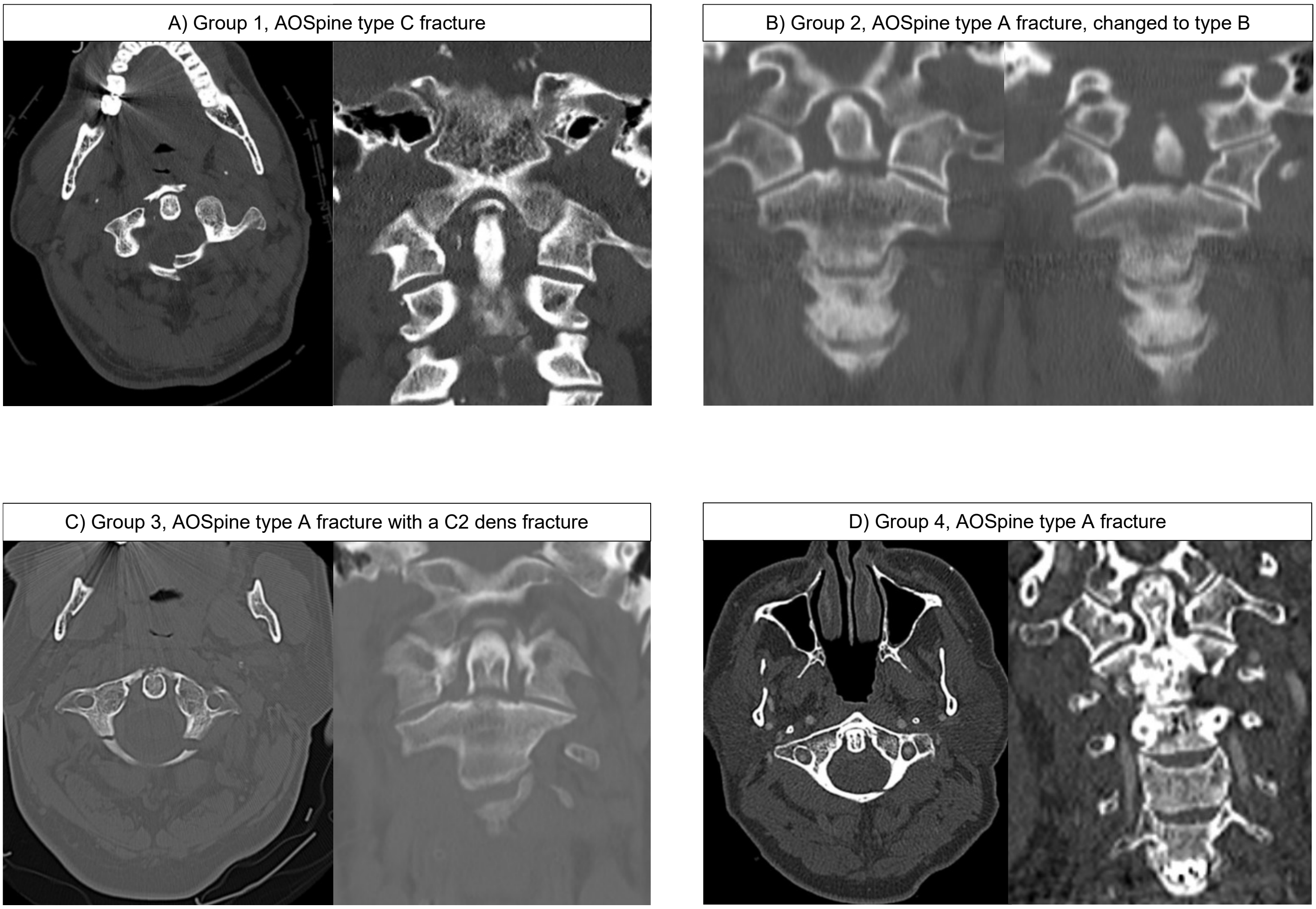

Figure 2: Example fractures from each of the 4 study groups. (A) Group 1: AO Spine type C fracture before surgical treatment. (B) Group 2: fracture type was changed from AO Spine type A in diagnostic imaging (left) to type B in follow-up imaging after nonoperative treatment (right) because of increased lateral mass displacement, suggesting instability and requiring secondary surgery. (C) Group 3: AO Spine type A fracture with a concomitant C2 dens fracture before surgical treatment. (D) Group 4: isolated AO Spine type A fracture before nonoperative treatment.

Injury classification

C1 fractures were classified according to both AO Spine Upper Cervical Classification[12] and Gehweiler[13] classification systems based on radiology reports and diagnostic imaging.

Gehweiler types were defined as follows: type I (isolated anterior arch fracture), type II (isolated posterior arch fracture), type III (fractures in both anterior and posterior arch), type IV (isolated fracture of the lateral mass), and type V (isolated fracture of the transverse process).

AO Spine types were categorized as follows: type A (bony injury with intact TAL and no atlantoaxial rotation or displacement), type B (injury of the TAL based on direct MRI assessment or significant lateral mass displacement in radiographs or CT images), and type C (marked atlantoaxial instability or translation in any plane).

Integrity of the TAL was evaluated directly using MRI whenever possible. If no MRI was available for a patient, the status of the TAL was evaluated indirectly using CT images and/or anteroposterior plain radiographs. Significant lateral mass displacement was considered to be an indication of a TAL rupture.

Outcome measures

A routine active follow-up protocol of 2–3 months is applied for all cervical spine fracture patients at KUH Neurosurgery and is prolonged on an individual basis if required. The length of the active follow-up time was determined in months from initial hospitalization to the last documented follow-up contact regarding the C1 fracture at KUH Neurosurgery. The total follow-up time was determined in months from initial hospitalization to the end of the study period or, alternatively, to death if a patient died before the end of the study period.

The outcome was evaluated at the last active follow-up visit. Residual symptoms were recorded, and C1 fracture alignment was defined as either good or suboptimal. Fracture alignment was evaluated either directly by using follow-up CT/MRI images when available, or indirectly from follow-up radiographs by comparing fracture alignment and/or the position of the fixation material to previous imaging.

Statistical methods

Statistical analyses were conducted using IBM SPSS Statistics 25 (IBM Corp., Armonk, New York, USA). The Mann-Whitney U test was used for nonparametric data. For analysis of categorical variables (e.g., injury classifications), the $\chi 2$ and Fisher exact tests were used. $P < 0.05$ was considered statistically significant. Missing data were excluded from the analysis and separately addressed in the tables. Patients lost to active follow-up were excluded from the outcome analysis.

Results

Baseline data

We identified 47 patients with C1 fracture. Baseline data for the population are presented in Table 1. From group 4, 2 patients died during initial hospitalization, both because of injury-related severe respiratory failure. In addition, 2 patients were otherwise lost to active follow-up (Figure 1). Additionally, 1 patient was lost from both groups 2 and 3, totaling 6 patients lost to active follow-up.

Table 1. Baseline Data for All Surgically Treated Patients with C1 Fracture (N = 47)

Variable	Value
Sex	
Female	8 (17.0)
Male	39 (83.0)
Age (years)	60.3 ± 18.2
Age range (years)	19–90
BMI (kg/m^2)	25.7 ± 4.1
Number of patients with BMI data missing	5
ASA score	2.3 ± 0.8
Number of patients with ASA data missing	1
Mechanism of injury	
Ground level fall	20 (42.6)
Fall from height	9 (19.1)
Motor vehicle collision	6 (12.8)
Blunt head trauma	5 (10.7)
Bicycle accident	2 (4.3)
Diving accident	2 (4.3)
Backflip neck injury	1 (2.1)
Downhill skiing fall	1 (2.1)
Vehicle-pedestrian collision	1 (2.1)
AO Spine fracture type	
Type A	34 (72.3)
Type B	2 (4.3)
Type C	10 (21.3)
Data missing	1 (2.1)
Gehweiler fracture type	
Type I	5 (10.6)
Type II	14 (29.8)
Type III	22 (46.8)
Type IV	5 (10.6)
Type V	0 (0.0)
Data missing	1 (2.1)
Concomitant cervical spine fractures	42 (89.4)
C2 only	27 (64.3)
C2 + subaxial	6 (12.8)
Subaxial only	5 (10.6)
C0 + subaxial	2 (4.3)
C0 + C2	1 (2.1)
C0 + C2 + subaxial	1 (2.1)
None	5 (10.6)
Active follow-up at KUH	41 (87.2)
Follow-up months	5.8 ± 4.8

Values are number of patients (%), mean ± SD, or as otherwise indicated.

BMI, body mass index; ASA, American Society of Anesthesiologists; KUH, Kuopio University Hospital

Surgical treatment of C1 fractures

Out of all 47 patients with C1 fracture, 23 received surgical treatment at the C1 level. In 11 of 23 cases, primary indication for surgery was an unstable C1 fracture. The 11 patients who were operated for C1 indication were further divided into 2 groups based on the timing of surgery: 6 patients who were operated as the initial treatment plan (group 1) and 5 patients who were operated after insufficient nonoperative treatment (group 2). In group 2, 3 of the type A fractures showed such worsening of fracture alignment in control imaging that the fracture type was changed from A to B, indicating an unstable fracture and being an indication for surgery. Other indications for secondary surgery were nonunion of the C1 ring and worsened fracture alignment of a type C fracture. The baseline data and the comparison of groups 1 and 2 are shown in Table 2. The data regarding C1 fracture types, concomitant fractures, and surgical treatment are presented in Table 3.

Table 2. Baseline Data for Patients in Groups 1 and 2

Variable	Group 1 (n = 6)	Group 2 (n = 5)	p value
Sex			0.99
Female	2	2	
Male	4	3	
Age (years)	68.5 ± 7.7	62.8 ± 5.4	0.20
Age range (years)	32–75	30–83	
BMI (kg/m^2)	26.4 ± 0.7	26.7 ± 4.7	0.87
BMI data missing	1	0	
ASA score	2.2 ± 1.0	2.6 ± 0.5	0.41
Mechanism of injury			0.99
Fall on the same level	3	3	
Fall from height	2	1	
Motor vehicle collision	1	0	
Blunt head trauma	0	1	
AO Spine fracture type			0.08
Type A	1	4	
Type B	0	0	
Type C	5	1	
Gehweiler fracture type			0.46
Type I	0	0	
Type II	2	0	
Type III	4	4	
Type IV	0	1	
Concomitant spine fractures	6	2	0.99
C2 only	4	2	
Subaxial only	1	0	
C2 + subaxial	1	0	
None	0	3	

Values are number of patients, mean ± SD, or as otherwise indicated.

Group 1, C1 indication with surgery as the initial treatment plan; Group 2, C1 indication with surgery after insufficient nonoperative treatment; ASA, American Society of Anesthesiologists.

Table 3. C1 Fracture Types, Concomitant Spine Fractures, Indications for Surgery, and Surgical Treatment in Groups 1 and 2

Patient Sex, Age (years)	C1 Fracture Type		Concomitant Spine Fracture(s)	Indication(s) for C1 Surgery and Days from Injury to Surgery in Group 2	Surgical Treatment for C1 Fracture
	AO Spine	Gehweiler			
Group 1					
Male, 75	C	III	C2	Unstable C1 fracture	Posterior occipitocervical fixation
Female, 75	C	III	C2	Unstable C1 fracture	C1-2 fixation with Harms technique
Male, 73	A	III	C2, C6	Unstable C1 fracture	C1-2 fixation with Harms technique
Male, 61	C	II	C2	Unstable C1 fracture	Posterior occipitocervical fixation
Female, 70	C	II	C2	Unstable C1 fracture	C1-2 fixation with Harms technique
Male, 57	C	III	C7, Th3-4, Th7	Unstable C1 fracture	Posterior occipitocervical fixation
Group 2					
Male, 68	A*	III	C2	Worsened C1 fracture alignment (AO Spine type changed from A to B), dizziness, numbness in both arms (793 days)	Posterior occipitocervical fixation
Male, 57	A*	IV	None	Worsened C1 fracture alignment (AO Spine type changed from A to B) (28 days)	C1-2 fixation with Harms technique
Female, 61	A*	III	C2	Worsened C1 fracture alignment (AO Spine type changed from A to B); worsened C2 fracture alignment (87 days)	C1-2 fixation with Harms technique
Female, 59	A	III	None	Non-union of the C1 fractures (122 days)	Posterior occipitocervical fixation
Male, 69	C	III	None	Worsened C1 fracture alignment (109 days)	C1-2 transarticular screw fixation

Group 1, C1 indication with surgery as the initial treatment plan; Group 2, C1 indication with surgery after insufficient nonoperative treatment.

*C1 fracture type changed from A to B in control imaging.

In group 3, 11 of 12 patients had AO Spine type A fractures. In 1 case, fracture type was indeterminate because of missing data (Table 4).

Table 4. C1 Fracture Types, Concomitant Spine Fractures, Timing of Surgery, Indications for Surgery, and Surgical Treatment in Group 3 (n = 12)

Patient Sex, Age (years)	C1 Fracture Type		Concomitant Fracture(s)	Timing of Surgery	Indication(s) for Surgery	Surgical Treatment for C1 Fracture
	AO Spine	Gehweiler				
Male, 65	A	II	C2	Secondary	Worsened C2 fracture position	C1-2 transarticular screw fixation
Male, 69	A	III	C2	Secondary	Non-union of the unstable C2 fracture	Posterior occipitocervical fixation
Male, 78	A	III	C2	Secondary	Non-union of the C2 fracture	Posterior C1-2 screw and hook fixation
Male, 72	A	III	C2	Secondary	Worsened C2 fracture position	Posterior occipitocervical fixation
Male, 79	A	II	C2	Secondary	Worsened C2 fracture position	Posterior occipitocervical fixation
Male, 64	A	II	C2	Secondary	Non-union of the C2 fracture	Posterior C1-subaxial fixation
Male, 32	A	II	C2	Primary	Unstable C2 fracture	C1-2 transarticular screw fixation
Male, 71	A	II	C2	Secondary	Non-union of the C2 fracture	Posterior occipitocervical fixation
Male, 83	A	III	C0, C2	Secondary	Non-union of the C2 fracture	C1-2 fixation with Harms technique
Female, 66	Data missing	Data missing	C2	Secondary	Worsened C2 fracture position	Posterior occipitocervical fixation
Male, 53	A	IV	C2-3	Primary	Unstable C2 fracture	Posterior C1-subaxial fixation
Male, 30	A	I	C2	Secondary	Non-union of the C2 fracture	Posterior C1-2 screw and hook fixation

Group 3, C1 surgery for non-C1 indication.

Reoperations after C1 surgery were needed in 2 cases in group 3: one was performed after a transarticular screw failure using occipitocervical fixation and another was a removal of occipitocervical fixation material 15 months after initial surgery because of persistent neck pain (Table 5). One operation in group 3 was a reoperation in itself: occipitocervical fixation was required because of nonunion of a C2 fracture after dens screw fixation. Postoperative immobilization with cervical collar was used for all 23 patients who underwent an operation at the C1 level.

Table 5. Overview of Outcomes in Groups 1–3

	Group 1 (n = 6)	Group 2 (n = 5)	Group 3 (n = 12)	Total (n = 23)
Surgery was successful	6	5	11	22
Treatment failure	0	0	1*	1*
Reoperation needed	0	0	2	2
Postoperative immobilization				
Cervical collar only	6	5	12	23
Duration (months)	2.3 ± 0.4	1.8 ± 0.8	1.9 ± 0.7	2.0 ± 0.7
Follow-up at KUH	6	4	11	21
Good C1 fracture alignment	6	4	10	20
Suboptimal C1 fracture alignment	0	0	1	1
Neck pain	3	1	6	10
No neck pain	3	3	5	11
Neck stiffness	4	2	6	12
No neck stiffness	2	2	5	9
Neurologic symptoms	2†	0	1‡	3†, ‡
No neurologic symptoms	4	4	10	18

Values are number of patients or mean ± SD.

Group 1, C1 indication with surgery as the initial treatment plan; Group 2, C1 indication with surgery after insufficient nonoperative treatment; Group 3, C1 surgery for non-C1 indication; KUH, Kuopio University Hospital.

*Failure of the right-side C1-2 transarticular screw.
†Slight sensory deficit in fingers (n=1) and ulnar pain in right arm and hand (n=1).
‡Transient numbness of thumb in right hand (n=1).

C1 fracture alignment was good in 20 of 21 cases after follow-up. Good C1 fracture alignment was achieved for all 10 followed-up patients in groups 1 and 2; 1 patient from group 2 was lost to follow-up (Table 5). Neck pain (P = 0.57) and stiffness (P = 0.99) were present in both groups 1 and 2. Neurologic symptoms were seen in 2 of 6 patients in group 1, whereas in group 2 they were nonexistent (P = 0.47) (Table 5). In group 3, good fracture alignment was achieved for 10 of 11 followed-up patients and 1 patient was lost to follow-up (Table 5).

Nonoperative treatment of concomitant C1 fractures in cervical fracture surgery

In group 4, C1 fracture was treated nonoperatively, and the treatment and outcome data of the patients in group 4 are presented in Table 6. Of the patients, 18 of 24 had AO Spine type A fractures. Seventeen of the 24 patients underwent other cervical spine surgery not involving the C1 level. Good C1 fracture alignment was achieved in 17 of 20 followed-up cases, whereas in 2 patients, both type A fractures, alignment was considered suboptimal but both patients were symptomless. No follow-up control images were found for 1 patient.

Table 6. Overview of Treatment and Outcomes in Group 4 (n = 24)	
Variable	**Value**
AO Spine fracture type	
Type A	18
Type B	2
Type C	4
Gehweiler fracture type	
Type I	3
Type II	8
Type III	10
Type IV	3
Underwent nonoperative treatment period for C1 fracture	22
Died before treatment during the initial hospitalization	2
Duration of nonoperative treatment (months)	2.6 ± 1.0
Type of C1 nonoperative treatment	
Cervical collar only	14
Halo vest only	2
Halo vest + cervical collar	6
Underwent cervical spine surgery other than C1	17
C2 dens screw fixation	10
Subaxial spine surgery	7
Surgery was successful with no complications	15
Treatment failure	1*
Postoperative complications	1†
Follow-up at KUH	20
Died during the initial hospitalization	2
Lost to follow-up	2
Good fracture alignment	17
Suboptimal alignment	2
Data missing	1
Neck pain	4
No neck pain	16
Neck stiffness	10
No neck stiffness	10
Neurologic symptoms	1†
No neurologic symptoms	19

Values are number of patients or mean ± SD.

Group 4, nonoperative treatment for C1 fracture, underwent other surgery not involving the C1; KUH, Kuopio University Hospital.

*Dens screw was misplaced on the right side of the C2 (n=1).
†Recurrent laryngeal nerve paresis after anterior C7-Th1 fixation (n=1).

Discussion

Overall, 23 patients with C1 fracture underwent surgery where the C1 level was involved between January 1996 and June 2017 in a tertiary center that exclusively provides surgical treatment of cervical spine fractures within its catchment area in Eastern Finland. Good fracture alignment was achieved in 20 of 21 followed-up cases. In addition, good fracture alignment was achieved in all 10 cases where the C1 fracture was the main indication for surgery. Postoperative neurologic symptoms were rare and were only mild sensory or radicular symptoms. At the outpatient clinic follow-up, patients commonly reported neck pain and stiffness during the early phase after surgery. However, neck mobility is inevitably reduced after an upper cervical fixation and does not indicate an unsatisfactory result per se. C1-2 fixation causes limitation to neck rotation but preserves extension and flexion at the occipitocervical level. In contrast, occipitocervical fixation eliminates all movement from the occiput to the C2, reducing both rotation and flexion-extension in the cervical spine.[6] Moreover, neck pain and stiffness were also present in group 4, suggesting that they are natural consequences of upper cervical spine trauma rather than adverse postoperative symptoms.

Our study population consisted predominantly of elderly patients (mean age, 60.3 ± 18.2 years; age range, 19–90 years), and most were men, which is in accordance with the literature.[14,15] Only 9 of 47 patients were under 50 years of age. Therefore, we did not divide patients into different age groups. The most common injury mechanisms were falls and motor vehicle collisions, also in line with previous literature.[3]

AO Spine type A fractures were most common, representing 35 of 47 cases. In addition, 4 of 35 patients underwent C1 surgery after initial nonoperative treatment, 3 of them because of a change of fracture type from A to B in control imaging. With initial MRI, these potentially unstable fracture types might be recognized more efficiently, which might improve the treatment decision-making. Twelve of 35 type A fractures were operated at the C1 level because of a concomitant C2 fracture.

AO Spine type B fractures were present in diagnostic imaging in only 2 of 47 cases. Both were treated with a combination of Halo vest for 8–10 weeks followed by cervical collar immobilization for 8 weeks. This seems to be in line with the literature; however, surgery is regarded as a good option because of potential complications associated with Halo vest.[4,5]

AO Spine type C fractures were seen in 10 of 47 patients. C1 surgery was indicated in 6 of 10 cases, 5 of whom were operated initially and 1 after cervical collar immobilization because of worsened C1 fracture alignment. The other 4 of 10 patients were successfully treated nonoperatively. However, all 4 had a concomitant C2 dens fracture, which was treated with anterior screw fixation.

Concomitant occipital condyle (C0) fractures were present in 4 of 47 cases, with 1 in group 3 and 3 in group 4. The patient in group 3 underwent C1-2 fixation with Harms technique, 2 of 3 patients in group 4 underwent surgery at the C5-7 level, and 1 of 3 patients was treated with a combination of Halo vest and cervical collar immobilization without surgery. Therefore, for these condyle fractures in the population, nonoperative treatment was sufficient.

KUH Neurosurgery exclusively provides surgical treatment of cervical spine fractures within its catchment area. Therefore, all patients with C1 fracture who require treatment are referred to KUH Neurosurgery also after the active follow-up period in case the recovery is not uneventful. Therefore, even though the mean active follow-up period was 5.7 months, the indirect follow-up period lasted until the end of June 2017 or death.

Atlas fractures are frequently accompanied by other cervical spine fractures, most commonly axis fractures, which are present in 40%–44% of cases.[3] Isolated C1 fractures can usually be treated nonoperatively, whereas in combined C1-2 fractures or unstable C1 fractures, treatment is primarily based on the nature of the C2 fracture and/or TAL injury.[3-5] As for Gehweiler fracture types, primary surgery is recommended for type III fractures with concomitant TAL disruption and sagittal split type IV fractures, whereas other types (types I, II, and V; type III without TAL disruption; other type IV fractures) may be treated conservatively.[4,5]

In our study, concomitant cervical spine fractures were present in 42 of 47 cases (89.4%), and C2 fractures were present in 36 of 47 cases (76.6%). A probable factor for this higher incidence is the selection criteria of the study population, consisting of patients with either cervical spine operation or application of external immobilization and therefore was potentially biased toward patients who had concomitant cervical spine fractures that more often require operative treatment. In accordance with the literature, C1 fracture treatment was often guided by a concomitant C2 fracture. Out of the 23 patients who underwent C1 surgery, in only 11 cases, surgery was performed because of the C1 fracture itself (Table 3), whereas in 12 cases the main indication for surgery was a concomitant C2 fracture. Moreover, out of the 24 patients whose C1 fracture was treated nonoperatively, 17 received surgical treatment for either C2 or subaxial fracture.

The stability of atlas fractures is traditionally determined based on the integrity of the TAL.[3] Several methods for evaluating this have been suggested in the literature. The rule of Spence suggests that total displacement of >6.9 mm of the lateral masses after a C1 fracture in plain radiographic imaging is a probable sign of a TAL rupture and atlantoaxial instability and therefore surgical stabilization would be indicated.[16] However, this rule has later been deemed inaccurate. Dickman et al[17,18] showed that 61% of TAL disruptions were missed using the rule of Spence and suggested that MRI is the recommended imaging modality for direct assessment of the TAL.

In our study, AO Spine type B fractures represent injuries involving the TAL based on either direct MRI assessment or indirect assessment using radiographic or CT imaging. MRI is contemporarily the criterion standard to define ligament injuries, but prior to its routine use, the ligament status was evaluated indirectly. Worsened fracture alignment in consecutive images and significant lateral mass displacement were suggestive of instability and a potential TAL rupture.[16-18] Because of limited availability of MRI in the beginning of the study period, some unstable type B injuries were initially deemed as stable type A, and instability was only revealed as the fracture alignment had worsened in control imaging (Table 3).

A limitation of this study is its retrospective nature. The applied imaging modalities varied between patients with the application of CT and MRI becoming routine practice in the diagnostics of upper cervical injuries during the study period. Especially in patients treated at the beginning of the study period, the status of the TAL had to be determined mostly indirectly from plain radiographic or CT images. This may have impacted the low incidence of type B fractures in the population. Contemporarily, MRI is routinely used in C1 fracture stability evaluation at KUH Neurosurgery. In some cases, fracture classifications had to be made indirectly based on radiology reports because of missing diagnostic images. In addition, because no standardized imaging protocol was applied during the long study period, there were no comparable images for all patients to use specific radiologic metrics to define the upper cervical alignment. The sample was small especially for the patients whose main indication for surgery was an unstable C1 fracture. Because of the usage of NCSP codes in patient selection, most C1 fractures treated nonoperatively over the study period were not included, and the incidence of C1 fractures that can be treated nonoperatively is likely substantially larger than in group 4.

Conclusions

C1 fractures that require surgical treatment are rare. AO Spine type A fractures are generally stable and can be treated with cervical collar immobilization if surgery is not required for a concomitant C2 fracture. For AO Spine type B fractures, nonoperative treatment may be possible, but surgery should be considered, especially if fracture alignment is worsened in control imaging, suggesting instability. For unstable AO Spine type C fractures with atlantoaxial instability, early surgery is safe and yields good results. MRI is recommended to directly evaluate the integrity of the transverse ligament and to improve the detection of potentially unstable fractures. For unstable C1 fractures, we prefer C1-2 fixation with Harms technique, which preserves extension and flexion at the occipitocervical level. If the C1 fracture is stable in the presence of concomitant unstable C2 or subaxial fractures, we prefer to not add the C1 to the fixation.

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