Surgical Management of Acute Odontoid Fractures: surgery-related complications and long-term outcomes in a consecutive series of 97 patients

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Abstract

Background: The purpose of this study was to determine the incidence of surgery for odontoid fractures and to study surgical mortality, surgical morbidity and long-term outcome in a large, contemporary, consecutive, single institution, surgical series of odontoid fractures.

Methods: This is a retrospective study of all odontoid fractures treated by open surgery at our hospital during 2002–2009. The fractures were classified according to Grauer. Follow-up data, clinical examinations and cervical CTs were collected in 2010.

Results: This study included 97 consecutive patients with a median age of 73.0 years. The incidence of open fixation of odontoid fractures in this population was 0.45 per 100.000, and the incidence increased with age. The fractures were classified as type IIA in 3 patients, type IIB in 63 patients, type IIC in 8 patients and type III in 23 patients. Anterior fixation and posterior fixation were performed in 41 and 56 patients, respectively. Immediate postoperative neurological status was unchanged or improved in 97% of the patients. None of the patients developed postoperative hematoma, wound infection, deep venous thrombosis or pulmonary embolism. Eleven patients underwent resurgery during the follow-up period; five had suboptimal reposition after the first surgery, one had suboptimal position of an anterior odontoid screw, two had rupture of fixation materials, and three developed pseudarthrosis. Overall survival (OS) rates after 1, 12 and 24 months were 96%, 84% and 75%, respectively. Fifty-seven patients were available for follow-up evaluation with a mean time of 37 months. Radiological follow-up showed definite bony fusion in 82% of the patients and uncertain bony fusion in 18% of the patients. Flexion-extension radiographs were obtained in six of the ten patients with uncertain bony fusion; five of these were defined as stable (fibrous union), and one was unstable. Multivariate logistic regression demonstrated increased odds of non-bony fusion in more displaced fractures (OR 1.44, 95% CI (1.04-2.16), $p = 0.04$) and when using the anterior fusion technique (OR 0.17, 95% CI (0.03-0.75), $p = 0.02$). There was no significant association between neck pain and fusion method (Mann-Whitney test, $p = 0.86$). Patients treated with a posterior fusion approach had significantly more neck stiffness than patients who underwent fusion with an anterior odontoid screw (Fisher test, $p = 0.04$).

Conclusions: The annual incidence of open fixation of odontoid fractures was 0.45 per 100,000 inhabitants, and the incidence increased with age. Median age at time of surgery was 73.0 years, and the surgical mortality was 4%. Increased odds of non-bony fusion were observed in more displaced fractures and after anterior screw fixations. There were no significant differences between patients treated with anterior screw fixation versus posterior

wiring with respect to neck pain, but patients fused with a posterior approach reported significantly more neck stiffness.
Key words: Odontoid fracture, trauma, surgery, outcome, fusion rate.

Introduction

Odontoid fractures comprise 9–15% of all cervical spine fractures.[1,2] The incidence of odontoid fractures increases with age, and this is the most common cervical fracture in the elderly population.[2,3] The most common symptom in patients with an odontoid fracture is high cervical pain, as neurological deficits are infrequent.[1,4-6] Most likely, several patients die at the scene of an accident due to major dislocation of the odontoid fragment with fatal spinal cord compression.[7] In 1974, Anderson and D'Alonzo reported a classification system for odontoid fractures, which divided the fractures into type I, II and III;[8] type I fractures at the tip of the odontoid are rare and usually stable, type II fractures at the base of the odontoid process are the most common and are inherently unstable, and type III fractures occur through the body of the odontoid process and can be unstable. In 1988, Hadley and coworkers proposed a modification of the Anderson and D'Alonzo classification to distinguish comminuted fractures from free fragments at the base of the odontoid.[9] In 2005, Grauer and colleagues proposed a more treatment-oriented modification of the Anderson and D'Alonzo classification, especially for type II fractures, with the aim of helping to make decisions for the surgical approach: anterior odontoid screw versus posterior fixation.[10]

The best treatment strategy for unstable odontoid fractures remains controversial with regard to patient selection for conservative management (external stabilization) versus surgical treatment and choice of surgical method.[11-13] However, there exists a consensus to consider primary surgery for type II fractures, especially in patients >50 years, and to consider primary conservative management for type III fractures.[6,11,12,14] Surgical methods can be classified into two main groups based on the approach. The posterior approach includes posterior wire/cable bone techniques and rigid segmental techniques (C1-C2 transarticular screws and segmental fixation into the laminae, pars or pedicles of the axis and lateral mass screw fixation into the atlas), while the anterior approach includes anterior odontoid screw fixation.[15-31] The posterior approach aims at arthrodesis of C1-C2 resulting in major restriction of head and neck rotation, while the anterior approach preserves C1-C2 motion and head/neck rotation.[6,32] Isolated odontoid fracture fixations usually do not require incorporation of the occiput or lower cervical spine.

The aims of the present study were to determine the incidence of surgery for odontoid fractures and study surgical mortality, surgical morbidity and long-term outcome in a large, contemporary (2002–2009), consecutive, single-institution, surgical series of odontoid fractures. In 2005, we added anterior odontoid screw fixation to our surgical armamentarium. Previously, almost all fractures were fixed with posterior wire/cable bone techniques. Thus, this series gave us the opportunity to compare the outcomes between anterior odontoid screw and posterior fixation.

Materials and methods

Hospital

Oslo University Hospital, Ullevål (OUS-U), is the largest trauma center in Norway with a defined catchment area of 2.7 million people, and the hospital performs >95% of open fixations for cervical fractures within this patient population.

Inclusion criteria

- Trauma patients admitted to OUS-U between January 2002 and December 2009
- Diagnosed odontoid fractures on cervical CT with 3-D reconstruction
- Odontoid fractures treated with open surgery

Exclusion criteria

- Odontoid fractures treated only with external fixation

Variables registered based on chart review

The following variables were recorded based on chart review: sex, age, trauma mechanism according to ICD-10,[33] Head Injury Severity Scale (HISS),[34] preoperative impairment scale according to the American Spinal Injury Assosiation (ASIA),[35] classification of odontoid fractures by Grauer,[10] fracture displacement in millimeters,[36] odontoid fracture angulation in degrees,[36] other cervicothoracolumbar fractures caused by current trauma (yes/no), primary surgery or primary conservative treatment that led to surgery due to progressive dislocation or symptomatic pseudarthrosis, time from injury to surgery (days), surgical method (posterior wiring, posterior wiring with bone graft, anterior screw, transarticular screw, occipitocervical fusion or lateral mass/pedicle screws), bone from hip (yes/no), surgery for other spine injuries (yes/no), neurological deterioration after surgery (yes/no), postoperative ASIA impairment scale, surgery for postoperative hematoma (yes/no), surgery for postoperative infection (yes/no), resurgery (no, yes; suboptimal reposition, yes; suboptimal placement of fixation material, yes; breakage of fixation material, yes; pseudarthrosis), deep venous thrombosis or pulmonary embolism (yes/no), and surgical mortality within 30 days.

Surgery and postoperative management

In each case, the choice of surgical method was decided by the treating surgeon. The two most utilized techniques have been posterior wiring of C1-C2 with a bone graft from the hip[20-22] and anterior odontoid screw fixation using one screw.[18,19] The latter technique was introduced in our department in 2005, and since then, it has been the recommended method in our department, especially for Grauer IIB fractures (fractures that pass from anterior superior to posterior inferior or displaced transverse fractures). Posterior fixation has been the recommended method for Grauer IIC fractures (fractures that pass from anterior inferior to posterior superior or fractures with significant communition), also after 2005. A small group of patients were operated on with transarticular screw fixation,[27] lateral mass/pedicle screws[23,26] or with occipitocervical fusion.[16,25,28,29] The latter techniques have been used in patients with additional morphology to odontoid fractures and/or extreme dislocations.

As an antibiotic prophylaxis, we routinely used a single dose of cephalotine (2 g) 15-30 minutes before the skin incision. Alternatively, clindamycine (600 mg) was used in cases of allergies. Thrombosis prophylaxis included compression stockings and early mobilization. Low-molecular-weight heparine was administered to patients who could not be mobilized within 24 hours. All patients who were operated on with posterior fusion techniques and most patients with anterior screw fixation recieved a stiff collar for 12 weeks.

Long-term clinical follow-up

Vital status (dead or alive) and time of death were obtained from the Norwegian Population Registry (Folkeregisteret) on 31st January 2010. At this time, 68 patients were alive, 26 were dead and 3 were not found in the Norwegian Population Registry (they were living outside Norway and not available for follow-up). Of the 68 alive patients living in Norway, 8 rejected the invitation to participate in follow-up examinations and 3 did not respond. Thus, 57 patients were available for follow-up evaluations during 2010 (clinical examination and cervical CT).

The following variables were recorded: time from injury to clinical follow-up (months), neurological status (normal/weakened without relation to injury/weakened with relation to injury), ASIA impairment scale,[35] neck stiffness (none/mild/severe),[37] neck pain (scored with the visual analogue scale [VAS scale])[38] and bony fusion on follow-up CT (certain/uncertain). Flexion-extension radiographs were performed in patients with uncertain bony fusion on follow-up CT scans. Postoperative fusion status was categorized into bone union (trabeculation across the fracture site and/or trabeculation connecting the posterior part of C1-C2), fibrous union (trabeculation was absent, but movement of the odontoid fragment was absent on flexion-extension radiographs) and nonunion. Quality of life (QoL) was measured with the Short Form-12 Health Survey (SF-12).[39] QoL was expressed in terms of two metascores: the physical component summary (PCS) and the mental component summary (MCS). A higher SF-12 score indicated better functioning. The PCS and MCS scores had a range of 0–100 and were designed to have a mean score of 50 and a standard deviation of 10. The PCS decreases with age, and the mean value is 39 for people ≥75 years old.[39]

Ethics

The study was appoved by the data protection official at Oslo University Hospital.

Database and statistical analysis

Data were described with medians and interquartile ranges (IQR) if the distribution was non-normal based on quantile-quantile plotting and Kolmogorov-Smirnov testing. Furthermore, in non-normally distributed data, the Mann-Whitney test was used for two independent samples, while the paired Wilcoxon rank sum test was used for paired data. In cases of normally distributed data, robust t-tests and means were presented.

Overall survival (OS) analyses were conducted using Kaplan-Meier curves, which measured survival from the time from surgery to the time of death. A p value < 0.05 was considered statistically significant. The statistical analyses were performed using SPSS v16.0 (SPSS Inc., Chicago, IL, USA).

Results

Demographics

This study included 97 consecutive patients who underwent surgery for odontoid fracture at OUS-U during 2002-2009. OUS-U has a defined catchment area of 2.7 million people. Thus, the annual incidence of open fixation of odontoid fractures in this population has been estimated to be 0.45 per 100.000 inhabitants.

Patient characteristics

Patient characteristics are given in Table 1; there were 64 (66.0%) males, median age at the time of surgery was 73.0 years (range 20-94 years), 78.4% of the patients were ≥60 years and 34.0% were ≥80 years. There was a significant correlation between mechanism of injury and age. The median age of patients injured due to falling was significantly higher than the median age of patients injured in a transportation accident (78 years versus 55 years; Mann-Whitney test; $p < 0.001$).

Classification of fractures

At the time of surgery, fractures were classified according to Grauer and co-workers[10] as follows: type IIA, 3/97; type IIB, 63/97; type IIC, 8/97 and type III, 23/97 (Table 1). An overview of direction (anterior/posterior), magnitudes of translation (mm) and angulation of the odontoid fragment (°) are given in Tables 2 and 3. The mean translation and angulation at the time of surgery for all patients were 4.7 mm (range 0–14 mm) and 16.8º (range 0–55º), respectively.

The rather large fraction of type III fractures (23/97) in this study was explored; five of the patients underwent surgery after failed conservative treatment, and nine patients underwent primary surgery due to a ≥4 mm translation of the odontoid fragment. In the remaining nine cases, we were uncertain why a descision of primary surgery was made, but during the chart review and reexamination of the CT scans, we got the impression that some type III fractures at the time of surgery had been mistakenly classified as type II fractures. However, it was impossible to calculate an exact number of misclassifications due to insufficient operative notes and CT descriptions.

Multiple spine fractures were diagnosed in 28 patients, 17 patients had one or more fractures at the C2 level in addition to the odontoid fractures, 18 patients had C1 fractures, 9 had C3-C7 fractures, and 10 had thoracolumbar fractures. Two patients required additional surgical fixation at the cervical level for non-odontoid fractures, and one patient was treated surgically for a thoracolumbar fracture.

Surgery

Primary surgery versus primary conservative group: In 74/97 patients, primary surgery was decided to be the treatment of choice based on the initial observation. In 23/97 patients, primary conservative treatment with external fixation was decided but was later changed to open surgical fixation (due to increased displacement of the odontoid fragment in 17 patients and non-union/pseudarthrosis in 6 patients). On the initial CT scans, the primary surgery group had significantly larger angulation (median 15°, IQR (5.25-24.75) versus median 0°, IQR (0-4)) and translation (median 4 mm, IQR (2-6 mm) versus median 1 mm, IQR (0-3 mm)) compared to the primary conservative group (Mann-Whitney test; $p < 0.001$ for angulation and $p < 0.001$ for translation). Angulation and translation in the primary conservative group increased significantly before conversion to surgery (paired sample Wilcoxon rank sum test; $p < 0.001$ for both angulation and translation). There was no difference between the primary surgery group and the primary conservative group with respect to fracture classification (chi-square, $p = 0.78$). Overall, the conservative group tended to be younger with a median age of 70 years (IQR (55.5-76.0)) versus 76.5 years (IQR (62.3-83.0)), but the difference was not significant (Wilcoxon rank sum test, $p = 0.09$).
Type of open surgical fixation: Surgery involved anterior odontoid screw fixation in 40 patients (41.2%), posterior wiring with autologous bone graft in 45 patients (46.4%) and without bone graft in 7 patients (7.2%), posterior screw osteosynthesis in 1 patient (1.0%), occipitocervical fusion in 2 patients (2.1%), combined odontoid screw fixation and anterior C1-C2 plate fixation in 1 patient and combined surgery with posterior wiring with bone graft and posterior screw osteosynthesis in 1 patient. Fifty patients had cervical bone grafts from

the hip during the primary surgery. Table 4 shows the surgical techniques used versus the type of fracture. As outlined in the Materials and Methods section, the anterior odontoid screw technique was introduced in our department in 2005. Since this time, most Type IIB fractures have been fixated with the anterior odontoid screw technique. For Grauer IIA, IIC and III fractures, a posterior technique was typically used.

Timing of open surgical fixation: The median time from trauma to open surgical fixation was 6.0 days (range 1–423 days). The median time to surgery was significantly different between patients when surgery was the primary treatment of choice (5 days, IQR (2-8)) versus patients primary treated conservatively with external orthosis; later converted to open surgical fixation (45 days, IQR (26.5-120)) (Wilcoxon rank sum test, $p < 0.001$).

Surgical mortality and morbidity after primary surgery

The surgical mortality, defined as death within 30 days after surgery, was 4/98 (4.1 %). Two patients, an 87-year-old female and an 86-year-old male, died of postoperative pneumonia/heart failure. A 68-year-old female and a 69-year-old male had multiple injuries, and the cause of death in these patients was not directly related to the odontoid fracture or odontoid surgery.

Immediate postoperative neurological status evaluated with the ASIA impairment scale was unchanged or better in 95 (96.9%) patients, one patient's status declined and one patient was unable to be evaluated after surgery due to a severe head injury. In addition, two patients had minor deterioration within the same ASIA class.

None of the patients developed postoperative hematoma, wound infection, deep venous thrombosis or pulmonary embolism.

Eleven patients underwent resurgery during the follow-up period (Table 5). Five patients had suboptimal reposition after the first surgery, one had suboptimal position of the anterior odontoid screw, two had rupture of the fixation materials, and three developed pseudarthrosis.

There was no statistically significant difference between anterior screw fixation and posterior wiring techniques with respect to the rate of resurgery (7/40 versus 4/53, respectively; Fisher's exact test, $p = 0.197$). There was no surgical mortality after resurgery, and none of the patients developed neurological deterioration, postoperative hematoma, wound infection, deep venous thrombosis or pulmonary embolism.

Survival

OS rates after 1, 12 and 24 months were 96%, 84 % and 75 %, respectively (Figure 1). Age was inversely correlated with OS (log rank test, $p = 0.001$).

Long-term follow-up examination

As outlined in the Materials and Methods section, 57 patients were available for follow-up evaluation, and the mean follow-up time was 37 months (range 6–93 months).

Fusion rate: Radiological follow-up with CT showed definite bony fusion (bony union) in 47 patients and uncertain bony fusion in 10 patients. We managed to obtain flexion-extension radiographs in 6 of the 10 patients with uncertain bony fusion confirmed by CT; five were defined as stable (fibrous union), and one was defined as unstable (Table 6). The single patient classified as unstable was reoperated on and fixed through a posterior approach. Four patients did not show up for flexion-extension radiographs despite several invitations. The definite bony fusion rate was higher for posterior fusion techniques (34/37) than for anterior odontoid screws (13/20; Fisher's exact test, p = 0.02). A multivariate logistic regression model was developed, demonstrating insignificant associations between bony fusion and the following variables; fracture type according to Grauer, time from injury to surgery and the magnitude and direction of angulation. The model showed increased odds of non-bony fusion in more displaced fractures (OR 1.44, 95% CI (1.04-2.16), $p = 0.04$), retaining the sigificance of the approach (OR 0.17, 95% CI (0.03-0.75), $p = 0.02$).

Neurological function: Forty out of 57 (70.2%) patients had normal function in both upper and lower extremities at the follow-up examinations, 8/57 (21%) had reduced function related to trauma, and 9/57 (8.8%) had reduced function unrelated to trauma.

Neck pain: The median VAS score for neck pain was 2 (IQR (0-5)). Thirty-six patients had VAS scores ≤3, 16 had VAS scores between 4-6, and 5 had VAS scores ≥7. There was no significant association between neck pain and fusion method (Mann-Whitney test, $p = 0.86$), or between neck pain and fusion (Mann-Whitney test, $p = 0.363$).

Neck stiffness: Eighteen patients reported severe neck stiffness, 29 reported mild neck stiffness, and 10 reported no neck stiffness. Patients fused with a posterior approach had significantly more neck stiffness than patients fused with an anterior odontoid screw (Fisher's exact test, $p = 0.04$).

QoL was scored with the SF-12. PCS was scored as 38.0 (range 15.2–58.0), and MCS was scored as 48.5 (range 22.5–67.5). The scores showed no significant correlation to age or fusion. Age was dichotomized into <75 or ≥ 75 years (Mann-Whitney test, $p = 0.829$ for PCS and $p = 0.523$ for MCS), and fusion was dichotomized into bony fusion or fibrous union (Mann-Whitney test, $p = 0.593$ for PCS and $p = 0.180$ for MCS).

Discussion

Epidemiology

The incidence of open surgery for odontoid fractures in our defined population was estimated to be 0.45 per 100,000 inhabitants. To the best of our knowledge, this is the first study attempting to estimate the incidence of open surgery for odontoid fractures in a defined population. There were 64 (66.0 %) males, and the median age at the time of surgery was 73.0 years (range 20-94). A total of 78.4% of the patients were ≥ 60 years, and 34.0% were ≥ 80 years. Odontoid fractures are the most common isolated spine fracture in the elderly,[2] and there has been a steady increase in the rate of odontoid fracture presentations during the last two decades, mostly due to the increasing number of elderly people in the population.[40] There was a significant correlation between mechanism of injury and patient age. Falls were more frequent in the elderly and transportation accidents in the younger. This association between age and injury mechanism has also been reported by others.[40]

Surgical or conservative management

There is no level I evidence to determine when odontoid fractures should be managed by open surgery or conservative measures (external stabilization only).[13] However, treatment flow charts have evolved and have been published during the last few decades.[6,11,12,14] Odontoid type III fractures have had high fusion rates with conservative measures, and it has been accepted that most type III fractures should be treated by conservative measures.[6] The rather high percentage of type III fractures in our study was explained by failed conservative management, translation ≥ 4 mm and misclassification of fractures (type II instead of type III) at the time of surgery.

In 2009, Nourbakhsh et al.[14] published a meta-analysis discussing operative versus nonoperative management of acute odontoid type II fractures. They concluded that operative treatment provides a better fusion rate than external immobilization, although in certain situations, such as anterior displacement of the fracture and for younger patients, conservative management can be as effective as surgery. Nourbakhsh et al. recommended operative management in older patients, cases of posterior displacement of fractures, and displacements >4-6 mm. Vaccaro and coworkers recently presented a prospective study of geriatric odontoid-type fractures where they questioned the superiority of surgical treatment over conservative management for this patient group.[41]

Unfortunately, our group does not have a complete database of odontoid fractures treated conservatively from the same time period. Thus, we cannot evaluate whether we have followed the mentioned recommendations. In 23/97 patients included in our study, a decision was made for primary conservative treatment with external fixation but was later changed to open surgical fixation (due to increased displacement of odontoid fragments in 17 patients and non-union/pseudarthrosis in 6 patients). There were no differences between the primary surgery group and the primary conservative group with respect to fracture classification and age. However, on initial CT scan, the primary surgery group had significantly larger angulation and translation compared to the primary conservative group. Furthermore, the angulation and translation in the primary conservative group increased significantly before conversion to surgery. It remains an open question whether some of these patients should have been treated with surgery from the start.

Surgical method

In our study, the main surgical fixation techniques used were posterior wire/cable bone techniques and single anterior odontoid screw fixations. Both techniques are well known and accepted.[18-22] Regarding anterior odontoid screw fixation, a single screw has been regarded as better than the two-screw technique.[42,43] For posterior fixation tecniques, Patel et al. have suggested that rigid segmental techniques (C1-C2 transarticular screws and segmental fixation into the laminae, pars, or pedicles of the axis and lateral mass screw fixation into the atlas) are better than the "old-fashioned" posterior wire/cable-bone techniques due to less dependence on postoperative external stabilization.[12] There has been no level I evidence to support decision making when chosing surgical approaches/techniques.[11-13]

Surgical mortality and morbidity

A surgical mortality of 4.1% in this patient population has been acceptable and comparable to rates reported by others.[3,11,12,17,41,44,45] No patients in our study were reoperated on for postoperative hematoma or infection, two parameters regarded as quality indicators for surgery. Three patients (3/97) experienced neurological decline after surgery; two cases were minor, and one resulted in a drop in ASIA impairment scale class. The morbidity rate presented in this work was comparatively low. Surgical mortality and morbidity after odontoid fracture surgery in elderly patients are reported in the range 0–13% and 0–66%, respectively.[11] White et al. recently published a systematic mortality and morbidity analysis of odontoid fractures in the elderly and reported an overall mortality rate after surgery of 10.1%.[45] They reported similar mortality rates following anterior surgery and posterior surgery. Furthermore, there were no differences in the rates of major airway complications between these groups (anterior: 17%; posterior: 18%). However, there was a higher rate of site-specific complications (nonunion, technical failure, and the need for revision surgery) following anterior surgery compared to posterior surgery.[45]

If morbidity data in our series had been collected prospectively, the numbers would probably have been higher. Yadla and coworkers recently published a prospective study on early complications in spine surgeries, including trauma surgery, showing higher complication rates.[46] Their interpretation was that many studies contain lower complication rates due to incomplete records and recall bias, and these results seem reasonable. Our results from the current study coincide with this interpretation. In a review on complications of spine surgery, Nasser et al. highlighted a lack of standardized reporting of these complications.[47] For future standardized reporting on complications of spine surgery, decisions must be made as to whether resurgery for suboptimal reposition, pseudarthrosis, and hardware problems, such as fracture or screw pullouts, should be regarded as complications. In our series, 11% (11 patients) underwent resurgery during the follow-up period (5 patients had suboptimal reposition after the first surgery, 1 had suboptimal position of an anterior odontoid screw, 2 had rupture of fixation materials, and 3 had developed pseudarthrosis). Apfelbaum et al. reported hardware-related complications in 9% of the 147 patients treated with anterior screw fixation (mainly screw pullouts).[17]

Long-term outcome

Survival: In our study, OS rates after 1, 12 and 24 months were 96%, 84 % and 75 %, respectively, and age was inversely correlated with OS. The high death rate during the years after trauma has been a common observation in this patient population with a high mean age (median age at the time of surgery was 73.0 years and 34.0% of the patients were ≥ 80 years). The survival rate determined from our study is comparable to published rates of OS for eldery patients with acute odontoid fractures.[41,48]

Fusion rate: Radiological follow-up with CT showed definite bony fusion in 82% (47/57) and uncertain bony fusion in 18% (10/57) of patients. The definite bony fusion rate was higher for posterior fusion techniques than for anterior odontoid screws. We obtained flexion-extension radiographs in 6 of the 10 patients with uncertain bony fusion on CT; five had no pathological movement of the odontoid fragment. One patient with pathological movement was reoperated and fixed through a posterior approach. Four patients did not show up for flexion-extension radiographs despite several invitations. Patients with uncertain bony fusion and no pathological movement as evidenced by flexion-extension radiographs did not have increased neck pain compared to patients with bony fusion. We have defined these patients as “stable” and not requiring further internal or external stabilization (fibrous union). Thus, it seemed reasonable to categorize fusion status into stable with bone union, stable with fibrous union and unstable. Using this terminology, our long-term results with regard to fusion can be expressed as follows: 82% bony fusion, 9% fibrous union, 2% unstable and 7% not categorized due to lack of follow-up flexion-extension radiographs. Other researchers have reported higher bony fusion rates after anterior odontoid screw fixations.[3,6,11,17,45] However, in their multicenter study of the surgical treatment of C2 fractures in the eldery, Omeis et al.

reported bony fusion rates of 38 and 29% after anterior odontoid screw fixation and posterior fixation, respectively.[44] All patients, with the exclusion of one without radiographic bony fusion, appeared to be stabilized based on flexion-extension radiographs. In our study, the fusion rate was not significantly correlated to the time from injury to surgery, the magnitude of translation, angulation or anterior versus posterior translation or angulation of the odontoid fragment. Grauer IIB fractures appeared to have the lowest fusion rate; however, these results were not significant. The safety of stable fibrous unions has been questioned by Crockard et al.[49] and Kirankumar et al.[50] According to these authors, a fibrous union carries an inherent risk of instability with eventual myelopathy. However, recent studies indicated that late-onset myelopathy may be a relatively rare event.[51]

Neurological function: More than 70% of the patients had normal neurological function at the time of follow-up examination, indicating a good neurological outcome in this older patient population.

Neck pain and stiffness: Persistent neck pain was less of a concern than expected for our patients at the time of follow-up, and intensity of neck pain showed no significant correlation with fusion methods. Neck stiffness, on the other hand, was a major concern for many patients, and patients fused with a posterior approach reported significantly more neck stiffness than patients fused with an anterior odontoid screw. The rarity of neck pain after surgery for odontoid fractures has previously been reported.[3] Neck stiffness, on the other hand, has been a well-recognized result after posterior arthrodesis of C1-C2.[6]

QoL was scored with SF-12. PCS was lower in our patients than in the general population, while MCS was very close to that of the general population. These results were similar to QoL data (measured with SF-36) reported by Vaccaro et al. for patients treated for geriatric odontoid fractures.[41] It has been reported in several studies that PCS and MCS scores calculated from SF-36 and SF-12 are nearly identical.[52]

Limitations of the study

The major limitations of this study were the retrospective design and lack of a defined treatment algorithm throughout the study period.

Strengths of the study

The data were restricted to only one health center (OUS-Ullevål), thereby reducing the possible confounding effects of differences in access to health care services between health centers. Thus, we have avoided the selection bias inherently present in large multi-center studies, as there was only one neurosurgical unit performing these surgeries in a geographically well-defined area. The study was contemporary, thereby reflecting our current neurosurgical practice, and it was performed within a relatively short period, thereby reducing confounding factors. Recently, updated follow-up data were available for most of the patients with a mean follow-up time of 37 months.

Conclusions

The annual incidence of open fixation of odontoid fractures was 0.45 per 100,000 inhabitants, and the incidence increased with age. Median age at time of surgery was 73.0 years, and the surgical mortality was 4%. An increased likelihood of non-bony fusion was seen for more displaced fractures and after anterior screw fixations. There were no significant differences in treatment outcome between patients treated with anterior screw fixation versus posterior wiring with respect to neck pain, but patients fused with a posterior approach reported significantly more neck stiffness.

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Table 1. Patient characteristics (n = 97).

	n	%
Sex		
Male	64	66.0
Female	33	34.0
Age (years)		
<19.9	0	0
20–39.9	10	10.3
40–9.9	11	11.3
60–79.9	43	44.3
≥80	33	34.0
Injury mechanism - ICD-10		
Falls	71	73.2
Pedestrian injured in transport	1	1.0
Pedal cyclist injured in transport accidents	5	5.2
Car occupant injured in transport accident	14	14.4
Exposure to unspecified factor	3	3.1
Assault	1	1.0
Drowning and submersion	1	1.0
Exposure to inanimate mechanical forces	1	1.0
Head Injury Severity Scale		
None	1	1.0
Minimal	49	50.5
Mild	38	39.2
Moderate	4	4.1
Severe	5	5.2
Preoperative ASIA impairment scale		
Not possible to score due to severe head injury	2	2.1
A	0	0.0
B	1	1.0
C	3	3.1
D	6	6.2
E	85	87.6
Fracture type according to Grauer et al.		
Type IIA	3	3.1
Type IIB	63	64.9
Type IIC	8	8.3
Type III	23	23.7

Table 2. Direction of translation (anterior/posterior) and angulation (anterior/posterior) at the time of surgery as measured by CT scan.

		Translation		
		None	**Anterior**	**Posterior**
Angulation	None	5	8	3
	Anterior	0	15	3
	Posterior	2	7	54

Table 3. Magnitude of translation (mm) and angulation (°) of the odontoid fragment as measured by CT scan in all patients in both the "conservative group" and the "surgery group." The "conservative group" was measured at two time points: the start of conservative treatment and at the time of surgery.

	Start of conservative treatment		Time of surgery	
Group (n)	**Translation (mm)**	**Angulation (°)**	**Translation (mm)**	**Angulation (°)**
All patients (97)			4.7 (0-14)	16.8 (0–55)
Surgery group (75)			4.7 (0–14)	16.7 (0–55)
Conservative group (22)	1.6 (0–9)	2.7 (0–5)	4.4 (0–11)	17.1 (0–36)

Table 4. Surgical technique used versus type of odontoid fracture.

Fracture type	Ant. odontoid screw	Posterior wiring	Other methods
Type II			
Grauer A	1	2	0
Grauer B	33	27	3
Grauer C	1	7	0
Type III	5	16	2
Total	**40**	**52**	**5**

Table 5. Resurgery during the follow-up period was done in 11/97 (11%) of the patients.

		Primary surgery		Re-surgery		
Sex	**Age (year)**	**Fracture**	**Method**	**Indication**	**Method**	**Time (days)***
M	50	Type 2	Posterior wiring with bone graft	Wire breakage	Posterior wiring with bone graft	97
M	72	Type 2	Posterior wiring with bone graft	Pseudarthrosis	Odontoid screw	179
F	72	Type 2	Odontoid screw	Screw pullout	Odontoid screw	25
F	81	Type 2	Odontoid screw	Suboptimal reposition	Posterior wiring with bone graft	99
F	65	Type 3	Odontoid screw	Suboptimal reposition	Posterior wiring with bone graft	57
M	26	Type 2	Posterior wiring with bone graft	Suboptimal reposition	Posterior wiring with bone graft	109
M	70	Type 3	Odontoid screw	Suboptimal position of odontoid screw	Odontoid screw	5
M	77	Type 2	Posterior wiring with bone graft	Suboptimal reposition	Posterior wiring with bone graft + posterior screw osteosynthesis	13
M	69	Type 2	Odontoid screw	Suboptimal reposition	Odontoid screw	0
M	70	Type 2	Odontoid screw	Pseudarthrosis	Posterior wiring with bone graft	258
M	74	Type 2	Odontoid screw	Pseudarthrosis	Posterior screw osteosynthesis	410

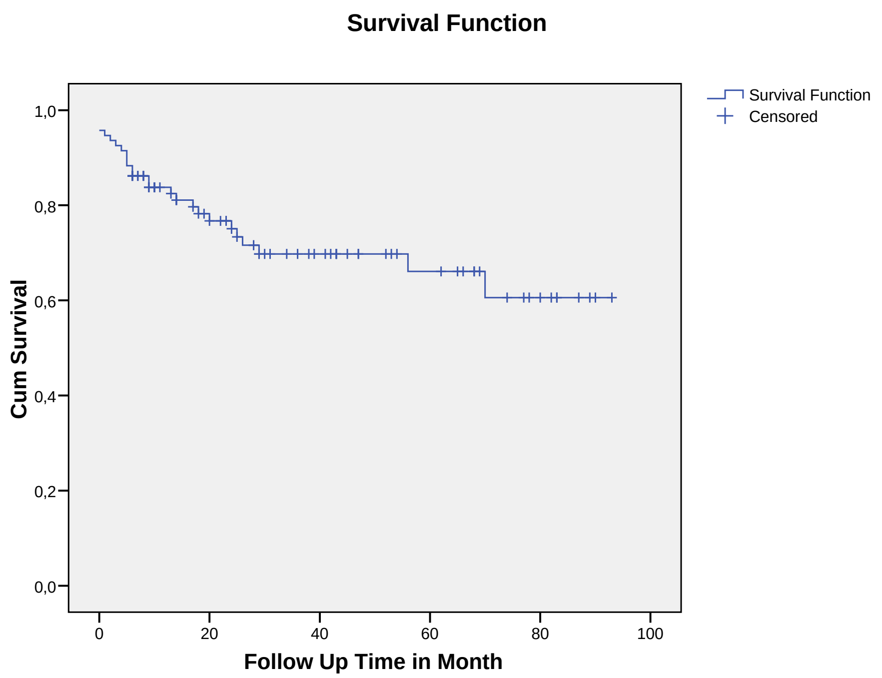
*Time in days from primary surgery to resurgery

Table 6. Fusion status at the time of follow-up.

Fusion status	All N (%)	Posterior approach N (%)	Anterior approach N (%)
Bony union	47 (82)	34 (92)	13 (65)
Fibrous union	5 (9)	2 (5)	3 (15)
Unstable	1 (2)	0	1 (5)
Incomplete data	4 (7)	1 (3)	3 (15)

Figure 1. Kaplan-Meier curves showing overall survival in all patients (A) and in age groups dichotomized into <75 years or ≥75 years (B).

A



B