Factors associated with nonunion in conservatively-treated type-II fractures of the odontoid process

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In type-II fractures of the odontoid process, the treatment is either conservative in a halo vest or primary surgical stabilisation. Since nonunion, requiring prolonged immobilisation or late surgery, is common in patients treated in a halo vest, the identification of those in whom this treatment is likely to fail is important.

We reviewed the data of 69 patients with acute type-II fractures of the odontoid process treated in a halo vest. The mean follow-up was 12 months. Conservative treatment was successful, resulting in bony union in 32 (46%) patients. Anterior dislocation, gender and age were unrelated to nonunion. However, nonunion did correlate with a fracture gap (>1 mm), posterior displacement (> 5 mm), delayed start of treatment (> 4 days) and posterior redisplacement (> 2 mm).

We conclude that patients presenting with these risk factors are unlikely to achieve bony union by treatment in a halo vest. They deserve careful attention during the follow-up period and should also be considered as candidates for primary surgical stabilisation.

Fracture of the odontoid process is the most common fracture of the upper cervical spine, accounting for 10% to 16% of all fractures of the cervical spine.[1-3] Anderson and D'Alanzo[4] classified fractures of the odontoid into three subtypes, based on level. This has proved to be useful for predicting outcomes and as a guideline for deciding on the method of treatment. Type-I fractures are uncommon,[4-13] and are usually stable and clinically straightforward avulsion fractures of the tip of the odontoid process.[4] Type-II fractures occur at the base of the odontoid process. Type-III fractures run lower, through the vertebral body. In type-III fractures, excellent rates of union after conservative treatment have been reported.[4,6-9,11-13] A cervical collar may provide insufficient immobilisation for this subtype.[5]

Type-II fractures are challenging. Nonunion after conservative treatment is common, although the incidence varies considerably (Table I). Possible causes of nonunion include relatively small fracture surfaces, lack of periosteum, the synovial environment of the fracture, and high degrees of instability in conjunction with inadequacy of methods of external immobilisation.[14,15] The role of avascular necrosis, once believed to be an important cause of nonunion, is doubtful since the blood supply to the odontoid fragment is not disrupted.[16] Advanced age[12,16-18] and delay before treatment[6,16,17] are also considered to cause nonunion and several studies have also found the extent of displacement to be related to it.[5,7,8,13,16] The significance of the direction of displacement is uncertain, but there is evidence which suggests that posteriorly-displaced type-II fractures are particularly prone to nonunion.[6,11,16]

The optimal treatment for type-II fractures – external fixation or primary surgical stabilisation – is controversial.[3,6,11,15,19-21] The indications for early surgery remain under debate, with opinions, in many instances based upon thin evidence. This makes it difficult to decide whether a patient with a type-II fracture should undergo primary surgical stabilisation or whether there is a reasonable chance of bony union by the use of conservative methods. We therefore performed this study in order to determine the factors associated with failure of treatment by a halo vest.

Patients and Methods

We reviewed the data on 69 patients treated by a halo vest for acute type-II fractures of the odontoid at the Helsinki University Central Hospital, between 1982 and 2002. Patients with known malignancy, rheumatoid disease or other disease which might have affected the outcome were excluded as were those lost to follow-up during primary treatment and those

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Table I. Studies on conservatively-treated type-II fractures of the odontoid process

	Nonunion/numbers of patients treated conservatively					
Author/s	**Total**	**Collar**	**Minerva or SOMI***	**Skull traction**	**Halo vest**	**Factors associated with nonunion in type-II fractures**
Anderson and D'Alonzo[4]	8/24	-	-	8/24	-	-
Clark and White[5]	11/41	3/3	-	1/3	7/35	> 5 mm displacement in any direction > 10° of angulation
Dunn and Seljeskog[6]	19/59	-	-	NR†	NR	> 2 mm of posterior displacement Age > 65 years Delay > 7 days
Govender et al[16]	50/109	-	50/109	-	-	Age > 40 years > 4 mm anterior displacement Posterior displacement Delay > 7 days
Greene et al[7]	25/88	NR/5‡	NR/9‡	-	NR/81‡	> 6 mm displacement in any direction‡
Hadley et al[8]	8/31	1/2	2/6	-	5/23	-
Hadley et al[9]	19/68§	NR/2	NR/8	-	NR/65	> 6 mm displacement in any direction
Hanigan et al[10]	3/6¶	2/5	-	-	1/1	-
Hanssen and Cabanela[11]	3/15	1/2	0/3	-	2/10	Posterior displacement
Lennarson et al[18]	11/33	-	-	-	11/33	Age > 50 years
Lind et al[3]	1/9	-	-	-	1/9	-
Maiman and Larson[21]	15/15	-	8/8	6/6	1/1	-
Pepin et al[12]	7/13	NR	-	NR	1/3	-
Polin et al[28]	12/34	7/15	-	-	5/19	Age > 40 years
Schweigel[13]	7/42	NR	NR	NR	3/20**	> 4 mm displacement in any direction
Seljeskog[24]	2/27	-	-	1/12	1/15	-
Stoney et al[26]	4/22	-	-	-	4/22	> 3 mm posterior displacement > 20° angulation Delay > 3 days

* sterno-occiputomandibular immobiliser
† not reported
‡ includes exclusions because of deaths and loss to follow-up. Distribution of exclusions by treatment category not reported. Whether direction of displacement was recorded and considered is not stated
§ includes exclusions because of deaths and loss to follow-up. Distribution of exclusions by treatment category not reported
¶ excluding five patients who died during treatment
** includes seven patients treated surgically, four after failed treatment in a halo vest not included in number of nonunions

subjected to primary surgical fusion without an attempt at conservative treatment. Information on accompanying injuries, neurological status, delay in relation to diagnosis or treatment, treatment and clinical outcomes was noted.

Displacement, angulation, and fracture gaps of fragments of the odontoid process were measured from radiographs taken on admission. We repeated the measurements from radiographs taken before discharge after a mean period of 6.1 days (SD 3.5) in a halo vest. For patients hospitalised for more than two weeks, repeated measurements were made from radiographs taken approximately one week after application of the halo vest. In order to assess union of the fracture, radiographs at the end of follow-up were studied using the criteria described by Schatzker et al.[14] For patients who underwent late surgical stabilisation, the pre-operative radiographs were studied instead.

Lateral flexion-extension radiographs were compared in the following manner. The borders of the vertebral body of the axis and the spinous and odontoid processes were drawn on transparent film placed on a radiograph taken in flexion. The same transparent film was then placed on the corresponding radiograph in extension and, with the vertebral body and spinous markings merging with the anatomical structures of the radiograph in extension, the margins of the odontoid process were drawn on the transparent film for a second time. By this means even the slightest tilting and movement of a nonunited odontoid process became apparent. In a fibrous nonunion, that is a fracture in which fibrous tissue filled the fracture gap and which may have been clinically considered to be acceptably stable, the movement was not always evident when radiographs were only examined side by side. When there was a pseudarthrosis, the movement was easier to detect.

The follow-up ceased when the fracture was considered to be clinically and radiologically sufficiently stable. There were 42 men and 27 women with a mean age of 57.5 years (SD 19; 13 to 94). Seven (10.1%) had been followed for more than 24 months, ten (14.5%) for 12 to 24 months, 25 (36.2%) for 6 to 12 months and 23 (33.3%) for three to six months. Four patients (5.8%) had a shorter follow-up, within the two- to three-month range. In three of these the fracture proceeded to bony union and in one to a pseudarthrosis. The mean follow-up of these 69 patients was 12.2 months (2 to 82).

Statistical analysis. This was performed with SPSS 9.0 software (SPSS Inc, Chicago, Illinois). Differences between continuous variables were assessed by Mann-Whitney rank-sum test, and between ratios by the chi-squared or Fisher's exact test. Two-sided probability testing was used. The log likelihood test statistic (backward method) was used in logistic regression analysis. Values of $p < 0.05$ were regarded as significant.

Table II. Clinical details and risk factors in 69 patients treated by a halo vest (SD)

	Union after halo vest (n = 32)	Halo vest failed (n = 37)	p value
Gender	9 F, 23 M	18 F, 19 M	0.091*
Delay > 4 days	2/32	8/37	0.093†
Mean displacement on admission	1.2 mm (5.5 mm) in anterior direction	3.1 mm (6.4 mm) in posterior direction	0.0058‡
> 5 mm of posterior displacement on admission	4/32	15/37	0.014†
Mean tilting of the odontoid peg on admission	9.9° (13.5) posteriorly	17.7° (16.7) posteriorly	0.027‡
> 20° of posterior tilting on admission	7/32	19/37	0.014*
Mean displacement on discharge	1.1 mm (3.3) in anterior direction	1.9 mm (3.8) in posterior direction	0.00049‡
> 2 mm of posterior displacement on discharge	2/32	19/37	0.000049†
> 1 mm fracture gap on admission or discharge	1/32	14/37	0.00039†
Mean tilting of the odontoid peg on discharge	11.6° (10.5) posteriorly	19.2° (14.8) posteriorly	0.010‡
Mean age (yrs)	49.8 (18.6)	64.2 (16.4)	0.0029‡
Age > 65 years	6/32	19/37	0.0061*

* Pearson chi-squared test
† Fisher's exact test
‡ Mann-Whitney rank-sum test

Results

Displaced fractures (n = 41) had been repositioned using skull traction for a mean period of four days (0 to 22) before the application of a halo vest. This was worn for a mean of 66 days (SD 20; 20 to 122). Treatment in a halo vest was followed by the wearing of a cervical collar for a mean of 51 days (SD 35; 14 to 172).

Treatment in a vest resulted in bony union in 32 of the 69 fractures (46%). Union was sufficiently stable for removal of the halo vest after a mean of 64 days. In the other 37 patients, conservative treatment had failed and nine underwent surgical stabilisation. In two this took place five weeks after injury and in seven between three months and three years after injury (Table II). The remaining 28 patients with nonunion were considered to be sufficiently stable clinically and not to require surgery.

Treatment in hospital had been started more than one day after injury in 38 patients, 20 of whom had fractures which did not unite. If the treatment was delayed for more than four days, the proportion of nonunions increased although this was not statistically significant in univariate analysis. Nonunion was significantly associated with the size of the fracture gap (> 1 mm) and posterior displacement of the odontoid fragment. Thresholds beyond which the incidence of nonunion increased markedly were at 5 mm of posterior displacement on admission and at 2 mm of posterior displacement on discharge. For anteriorly-displaced fractures, the extent of displacement did not correlate with nonunion. Union occurred in nine of 19 fractures which were undisplaced on admission, compared with 23 of 50 displaced (> 2 mm) fractures (p = 0.91). Even after perfect reduction by the use of skull traction and external stabilisation in a halo vest, 37 of the fractures had redisplaced more than 2 mm by the time the patients were discharged from hospital (Fig. 1). Although further attempts at repositioning took place, those fractures which had redisplaced more than 2 mm posteriorly almost uniformly resulted in nonunion. Posterior tilting of the odontoid peg was significantly associated with failure of conservative treatment, although with considerable overlap. Patients

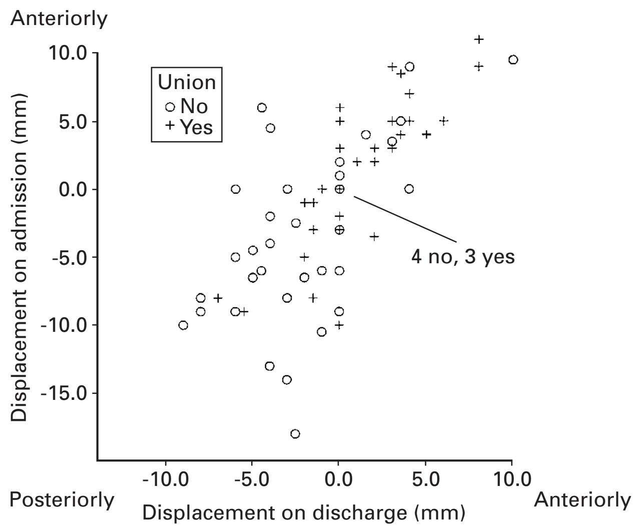

Fig. 1

Displacement of the odontoid process fragment on admission and discharge.

with more than 20° of posterior tilting were especially prone to have nonunion; 19 of 26 patients with posterior tilting greater than 20° had nonunion.

Neither the duration of skull traction, the use of a halo vest, or immobilisation with a collar correlated with nonunion, a result which may be confounded, since patients with nonunion are more likely to have their immobilisation prolonged. Simultaneous fractures of the atlas (nine of the patients with nonunion and seven of the patients with union of the odontoid), injury to the spinal cord (two with nonunion and four with union of the odontoid), or other accompanying injuries, or the nature of the injury (high-energy *vs* simple fall), did not correlate with the outcome of treatment. There was no statistically significant association between gender and outcome. Nonunion occurred significantly more often in patients over 65 years of age. However, patients older than 65 years more often had fractures which displaced posteriorly (Table III). Of the 25 patients

Table III. Failures of conservative treatment stratified by age and posterior displacement on admission and discharge, by number and *percentage*

	Number of conservative treatment failures/total (% failures within category)			
	Displacement on admission		Displacement on discharge	
Age (yrs)	More than 5 mm posteriorly	Anteriorly, non-displaced or up to 5 mm posteriorly	More than 2 mm posteriorly	Anteriorly, non-displaced or up to 2 mm posteriorly
< 65	4/6 *(67)*	14/38 *(37)*	9/10 *(90)*	9/34 *(26)*
> 65	11/13 *(85)*	8/12 *(67)*	10/11 *(91)*	9/14 *(64)*

Table IV. Results of binary logistic regression analysis. Binary-dependent variable failure of conservative treatment

Covariate	B	Wald	p value	Odds ratio (95% CI)
Posterior displacement > 5 mm on admission or > 2 mm on discharge	2.5	12.4	0.0004	12.4 (3.1 to 50.3)
Fracture gap on admission or discharge	2.9	6.2	0.013	17.7 (1.8 to 171.3)
Delay > 4 days before treatment	2.3	5.8	0.016	9.7 (1.5 to 61.6)
Constant	-6.2	-	-	- -

Model chi-squared 35.2; three degrees of freedom; p < 0.0001

who were older than 65 years, ten had a fracture gap, compared with five of the 44 patients who were under 65 years old.

To control simultaneously for multiple confounding factors in a binary logistic regression analysis the binary-dependent variable was failure of conservative treatment. Age served as a continuous covariate. Of the six binary covariates used in the model, one indicated whether the age was over 65 years, a second indicated gender, a third any delay before treatment (> 4 days), a fourth whether there was a fracture gap, and a fifth whether any posterior angulation had exceeded 20°. Because of multicollinearity, variables indicating posterior displacement on admission and on discharge were combined into one binary variable indicating any posterior displacement of more than 5 mm on admission or more than 2 mm on discharge. This variable served as a sixth covariate. The results of logistic regression and estimated odds ratios are summarised in Table IV. With three of the covariates (posterior displacement, fracture gap, and delay), the model was significant at the <0.0001 level (model chi-squared statistic), predicting 84.1% of the outcomes correctly (Table V). Controlling at the same time for posterior displacement, fracture gap, and delay, the remaining covariates (age, p = 0.32; age over 65 years, p = 0.55; gender, p = 0.23; and posterior angulation, p = 0.88) each failed to improve the model's accuracy (likelihood ratio test statistic) and were rejected.

Union occurred in 26 of the 31 patients who had none of the four risk factors (> 5 mm posterior displacement, >2 mm posterior redisplacement, fracture gap or delay of more than four days), and conversely, in only six of 38 patients who had any of the risk factors (p = 0.00000001). Exclusion of redisplacement from the list of risk factors, a risk factor which is unknown at the time of the primary clinical decision as to whether or not a halo vest should be applied, still yields a good prediction; 26 of 36 patients with none of the risk factors on admission had united fractures, compared with only six of 33 patients with any risk factor (p = 0.000009).

Table V. Classification table for regression model

	Predicted failure		
Observed failure	No	Yes	Percentage correct
No	32	5	*86.5*
Yes	6	26	*81.2*
Overall			*84.1*

Discussion

In the patients with type-II fractures treated in a halo vest, fracture gap and posterior displacement of the odontoid fragment were associated with nonunion. More specifically, we found nonunion to be associated with more than 1 mm of fracture gap, more than 5 mm of posterior displacement on admission, more than 2 mm of posterior displacement after application of a halo vest, and delayed start of treatment.

There is controversy as to the best treatment protocol for type-II fractures. Some authors recommend external stabilisation, using a halo vest for all type-II fractures.[3] Others recommend this only for undisplaced fractures.[6,11,19] A third group advocates primary surgical treatment.[15,20,21] Use of a cervical brace only in elderly patients has also been suggested,[10,12] but evidence is increasing that this is insufficient to allow healing of the fracture.[5,8,11] Although treatment in a halo vest may be associated with a relatively high incidence of complications and reduced ranges of movement of the cervical spine in elderly patients,[22] the long-term functional outcome is not significantly worse than that after surgery.[22] Surgical treatment by either a posterior or an anterior approach has been effective but is technically demanding and associated with complications.[5,20,23] Posterior fusion adversely affects the rotational range of movement.[22] Most authors agree that surgical treatment should be used in patients for whom conservative treatment cannot be undertaken or conservative treatment has failed.

Considerable variation occurs in the incidence of union.[3-13,21,24] In many studies, inclusion criteria and categories of patients have varied. Differences relate particularly to the inclusion of patients after failed conservative treatment has been followed by surgical stabilisation. Sometimes, fractures have been classified as ununited after unsuccessful conservative treatment and sometimes separately into a group of surgically-treated cases, thus biasing the results towards a high rate of success for conservative treatment. The inclusion of type-III fractures, which generally heal well, in a study of odontoid fractures would be likely to raise the rate of success.

The cohort which we studied is most likely to be unrepresentative of a general type-II fracture of the odontoid process seen in a trauma clinic. We focused on attempted conservative treatment. Several patients treated primarily by means of surgical fusion therefore had to be excluded, and many of these may have had relatively more unstable fractures. Their clinician's decision to undertake primary fusion and not to attempt conservative treatment, had presumably been made on the basis of the earlier literature. If these patients had been included in our study as cases for which conservative treatment had been insufficient, our results would have been biased towards detection of risk factors for nonunion similar to those previously reported (Table I).

Definitions of conservative treatment and nonunion of the odontoid raise several questions. Should the objective of conservative treatment be solid bony union of a fracture? Should only definite signs of nonunion be considered as failure? Is fibrotic union acceptable or even desirable? In such cases, how much remaining instability can be tolerated? In our opinion, to avoid late instability manifesting as chronic pain[4] or the rare but much-feared progressive myelopathy,[25] the primary goal should be bony union of every fracture. This is not always feasible. Although in many cases fibrous union is clinically acceptable, bony union seems nevertheless to be desirable. Accordingly, we classified cases of fibrous nonunion, many of which may have been clinically stable, as nonunion. This is of particular note in relation to our rates of union with a halo vest. Only 46% of the patients thus treated showed solid bony healing of the fracture. In the remainder, treatment in a halo vest often resulted in some degree of fibrous union. Surgical stabilisation was, however, needed in only nine (13%) of 69 patients.

Some authors[6,11,16,26] have reported that posteriorly-displaced fractures are especially prone to nonunion. In two relatively large studies,[7,9] nonunion was associated with more than 5 to 6 mm of displacement regardless of the direction of displacement. Hadley et al[9] reported an incidence of nonunion of 91% (10 of 11 patients) in fractures displaced > 5 mm posteriorly, of 57% (4 of 7 patients) in those displaced > 5 mm anteriorly, and of 10% (5 of 50 patients) in those displaced < 5 mm. Unfortunately, Greene et al[7] did not report whether the direction of the displacement was specifically tested. Govender et al[16] found in a prospective series of 109 patients treated in a Minerva cast or by a sterno-occipitomandibular immobiliser (SOMI) an increased incidence of nonunion in posteriorly displaced fractures and in fractures with anterior displacement exceeding 4 mm. Our data partially conflict with the results of these three studies. More than 5 mm of displacement was associated with nonunion in posteriorly-displaced fractures but not in those which were displaced anteriorly.

Posterior displacement of more than 2 mm on discharge from hospital correlated strongly with nonunion. Whether union fails to occur in such cases because bony contact is insufficient or impaired due to excessive skull traction, because blood supply is compromised, because the position of the head in the halo vest is awkward, or because posterior displacement reflects more extensive ligamentous injury is beyond the scope of our study. The practical implication of our findings is clear. If a type-II fracture immobilised by a halo vest is redisplacing posteriorly, the chances of achieving bony union by conservative means are poor. Our findings indicate that this would also be the case in patients diagnosed on admission with anteriorly displaced or undisplaced fractures. Since the position of a type-II fracture can vary considerably from one radiograph to another, a single measurement from a radiograph does not exclude instability due to posterior displacement.

Fractures of the odontoid process heal by the formation of endosteal bone, which requires close contact between the surfaces of the fracture and adequate immobilisation.[14] Our results are in accordance with this. A fracture gap beneath the odontoid fragment, pulled upwards by alar and apical ligaments strongly correlated with nonunion. This feature which is easily recognised in appropriately positioned radiographs is reasonably specific and could therefore be of value in predicting outcome.

Because angular tilting of an odontoid fragment is unlikely to give much indication of instability of a fracture, it is unsuitable for predicting the outcome of conservative treatment. Although significant associations between nonunion and angulation have been demonstrated, we found a considerable overlap of angulation between patients in whom union occurred and those in whom it did not. When our data were controlled for displacement, fracture gap, and delay of treatment, angulation had very little, if any predictive potential. In addition, angulation of the odontoid process is normally highly variable.[27]

Despite a high incidence of nonunion in our more elderly patients, we doubt whether conclusions can be drawn from such an association, because of the likelihood of confounding in a retrospective study. There may have been absolute contraindications to surgery in some elderly patients, or the clinicians may have been reluctant to operate on elderly patients, with the result that more of the unstable fractures will have been treated conservatively in elderly than in young patients. The inability of an elderly patient to tolerate treatment in a halo vest may result in a shorter period of immobilisation, which is inadequate for a type-II fracture. Age has been reported[12,16,17,26,28] to be associated with nonunion, but the studies concerned had no control for possible confounding effects. In a retrospective case-control study on 11 cases of nonunion and 22 of union, Lennarson et al[18] found that age (> 50 years) correlated with nonunion. The effects of gender and displacement of the fracture were overlooked; they were not statistically significant, and no further precautions for controlling their confounding effects were undertaken. We found no association between age and nonunion when the data were controlled for these confounding effects. Conversely, a delay of more than four days to treatment was significantly associated with poor outcome, after multivariate controlling for confounding. Since the number of observations was quite small, the validity of the observed threshold of four days is questionable. Dunn and Seljeskog[6] reported that the incidence of union fell from 75% to 25% when the diagnosis was delayed for more than a week, while Ryan and Taylor[17] found union in only 20% of patients presenting after two weeks. Govender et al[16] reported a rate of union of 76% using the Minerva cast or SOMI in patients presenting within 48 hours, 44% in those presenting within four to seven days and 0% in those presenting after one week.

Since nonunion in type-II fractures of the odontoid process can result in prolonged treatment in a halo vest or even in late surgical stabilisation, our results may help to identify those patients who require particular attention during follow-up in order to obtain the best possible results.

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