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ORIGINAL ARTICLE

Radiographic analysis of type II odontoid fractures in a geriatric patient population: description and pathomechanism of the "Geier"-deformity

Maximilian Reinhold · C. Bellabarba · R. Bransford · J. Chapman · W. Krengel · M. Lee · T. Wagner

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Abstract
Introduction Type II odontoid fractures are one among the most common cervical spine fractures in the elders. We reviewed a consecutive series of patients, aged 65 years and older, presenting to our institution with type II odontoid fractures. Our analysis focused on the radiographic outcome, union rate and the development of cervical spine postural deformity.
Patients/methods Indications for surgical treatment (OP) included displaced or unstable injuries. Stable, non-displaced injuries or patients with significant co-morbidities were treated nonoperatively (non-op).
Results Ninety patients (50 f, 40 m) with an average age of 83 years (65–101) were identified. 31 (34.4%) patients were received OP and 57 (63.3%) were received non-op treatments. The hospital length of stay was significantly longer after OP (mean 10 days vs. 6 days non-op) treatment ($p = 0.007$). At follow-up, higher union rates were noted in the OP (76.2%) than in the non-op group (58.3%).
Conclusion We observed a characteristic cervical spine deformity in geriatric patients with type II odontoid fractures, and have termed this the "Geier-deformity". Clinical findings of the deformity include sagittal imbalance and kyphosis of the lower cervical spine.

Keywords Cervical spine · Odontoid fracture · Geriatric patients · Radiographic analysis · Operative non-operative treatment

M. Reinhold (✉) · C. Bellabarba · R. Bransford · J. Chapman · M. Lee · T. Wagner
Department of Orthopaedic Surgery/Spine Services, Harborview Medical Center, University of Washington School of Medicine, 325 9th Avenue, Seattle, WA 98104, USA
e-mail: maximilian.reinhold@i-med.ac.at
URL: http://uwmedicine.washington.edu/Facilities/Harborvi

M. Reinhold
Department of Orthopaedic Surgery, Medical University Innsbruck, Innsbruck, Austria

W. Krengel
Department of Orthopaedic Surgery, Seattle Children's, Seattle, WA, USA

Introduction

Type II odontoid fractures make up 40–82% of odontoid fractures [42]. They frequently occur in the elders as a result of ground level falls or other low-energy injury mechanisms. The injury is associated with an increased mortality as a result of complications related to fracture non-union and high co-morbidity rates in this particular patient population [30, 33]. The optimal method of treatment for odontoid fractures, especially in the elderly, remains controversial [27].

The aim of this study was (1) to analyze the radiographic outcome and union rates of Anderson and D'Alonzo [2] type II odontoid fractures in a geriatric patient population defined as 65 years and older with regard to operative and non-operative treatment, and (2) to define a fracture subclassification and use radiographic measures to assess the neural canal balance of the cervical spine, and (3) to describe clinical findings of a cervical spine deformity and proposed pathomechanism, observed in elderly patients, called the "Geier[1]-deformity".

[1] Geier (German): vulture/Am. A. buzzard.

Table 1 Detailed summary of radiographic measurements on AD, DC, and at FU

Radiographic parameter	Direction	Treatment	Admission (AD)						Discharge (DC)						Follow-up (FU)					
			n	Mean	Median	SD	Min	Max	*n*	Mean	Median	SD	Min	Max	*n*	Mean	Median	SD	Min	Max
Fracture displacement (mm)		**Non-op**	55	1.8	1.0	2.3	0.0	11.3	48	3.2	2.6	3.8	0.0	17.7	23	2.8	1.9	3.3	0.0	11.5
		OP	29	4.7	4.0	3.8	0.0	15.4	30	0.5	0.0	1.7	0.0	5.2	21	1.2	0.0	2.3	0.0	7.7
Angulation C1/2 (°)	**Lordotic**		89	32.8	32.9	9.1	9.3	59.6	83	34.4	34.3	11.0	10.2	73.7	46	31.8	29.8	10.0	8.2	61.9
Absolut angle C2–C7 (°)	**Kyphotic**		2	5.3	5.3	5.3	1.5	9.0	3	17.9	12.2	12.3	9.5	32.1	5	22.3	12.3	15.4	10.5	41.3
	Neutral		1	0.0	0.0	0.0	0.0	0.0	2	0.0	0.0	0.0	0.0	0.0	0					
	Lordotic		79	33.1	32.9	16.8	83.1	83.1	70	30.5	30.1	12.3	3.4	64.8	37	27.2	23.7	18.8	6.5	70.9
Neural canal angulation McCrae-C7 (°)	**Kyphotic**		0						0						0					
	Neutral		0						0						0					
	Lordotic		85	65.9	64.8	19.9	11.5	118.8	78	62.8	65.0	16.9	18.2	107.7	44	64.8	63.6	17.5	22.0	109.4
Neural canal displacement Occiput-C7 (mm)	**Anterior**		35	10.9	10.3	5.8	3.2	25.8	31	22.5	17.3	16.8	3.3	72.9	37	42.0	33.7	27.5	6.5	114.3
	Neutral		21	0.0	0.0	0.0	0.0	0.0	20	0.0	0.0	0.0	0.0	0.0	6	0.0	0.0	0.0	0.0	0.0
	Posterior		31	13.4	12.5	6.8	4.0	33.5	24	18.3	12.9	12.6	3.0	43.5	2	18.7	18.7	13.9	9.0	28.6
Range of motion (°)	**n/a**		0						2	11.4	11.4	2.7	9.5	13.3	33	16.2	16.2	12.0	0.0	40.0
Cervicothoracic junction C7–T4 (°)	**Kyphotic**		64	15.3	13.0	11.4	1.7	52.4	21	13.3	15.0	8.3	2.2	34.2	8	14.2	13.4	6.1	7.5	23.0
	Neutral		5	0.0	0.0	0.0	0.0	0.0	2	0.0	0.0	0.0	0.0	0.0	2	0.0	0.0	0.0	0.0	0.0
	Lordotic		1	10.4	10.4	0.0	10.4	10.4	1	19.8	19.8	0.0	19.8	19.8	1	2.7	2.7	0.0	2.7	2.7

Table 2 Patient numbers and treatment types at FU ($n_{total} = 45$)

Non-operative ($n = 24$, 42.1%)	Operative ($n = 21$, 67.7%)
Hard collar ($n = 20$)	C1/2 post segmental fusion ($n = 9$)
Soft collar ($n = 1$)	C1/2 transarticular screw ($n = 7$)
Halo vest ($n = 3$)	Odontoid screw ($n = 3$)
	Occipito-cervical fusion ($n = 2$)

Patients and methods

This is a retrospective cohort study of patients with Anderson and D'Alonzo type II [2] odontoid fractures from a single level I trauma center, Harborview Medical Center (HMC), in Seattle, WA, USA. After obtaining approval from the human subjects review committee, medical records of each patient were reviewed. Radiological imaging studies available in the hospital's picture archiving and communication system (PACS) were analysed. All consecutive patients admitted during the 48 months study period from 1st January 2004 until 31st December 2007 were included.

Inclusion criteria

All patients age 65 years or older at the time on admission, treated for type II odontoid fractures were included.

Exclusion criteria

Patients less than 65 years of age or patients 65 years of age or older with fractures other than type II odontoid fractures were excluded.

Follow-up criteria

The follow-up (FU) assessment included a medical chart and imaging study review. The primary endpoint for FU data was 31st December 2009. In patients with repeated FU visits, results from the endmost radiological studies were used for analysis.

Data collection

After admission to the hospital and during the course of treatment the following parameters were documented:

- Admission (AD) data
  - Gender
  - Date of birth
  - Date of injury
  - Type of injury (Ground level fall, bicycle injury, motor vehicle injury, others/unknown)
  - Date of admission
  - Image modality (Computed Tomography (CT), x-rays of cervical spine including anterior-posterior (AP), Lateral (lat), Open Mouth odontoid views (OM) and flexion/extension films, Magnetic Resonance Imaging (MRI), primary imaging not available (n/a))
  - Patient position of imaging (supine position, upright position)
  - Imaging study modifier (with external support, without external support).
- Severety of osteoporosis

  Grading of the severity of osteoporosis of the body of axis [28]:

  1. *None*: normal trabecular pattern with normal cortical thickness;
  2. *Mild*: decrease in the amount of trabeculae with no areas of absent trabeculae (holes) and normal cortical thickness;
  3. *Moderate*: absent trabeculae (holes) involving less than 50% of the transverse diameter of the bone with cortical thinning;
  4. *Severe*: absent trabeculae (holes) involving more than 50% of the transverse diameter of the bone with cortical thinning.
- Fracture subclassification

  The following subclassification of Anderson and D'Alonzo type II fractures was used according to the fracture morphology:

  1. Transverse (fracture line ± 10° perpendicular to posterior wall of axis)
  2. Oblique anterior (fracture line from anterior caudal to posterior cranial)
  3. Oblique posterior (fracture line from anterior-cranial to posterior-caudal)
  4. Comminuted (multiple fracture lines and bony fragments)
  5. Miscellaneous/other.

  Documentation of C1/C2 combination injuries/fractures (yes/no)
- Analysis of radiographic and CT images on admission (AD), discharge (DC) from hospital and follow-up (FU):

  The image modality (CT, conventional radiographs), type (multiplanar reconstruction, a.p./lat./transoral view, flexion/extension films), patient position (supine/upright), modifier (with or without external support of cervical spine), and date of imaging study were recorded. Kyphotic deformity was labeled with

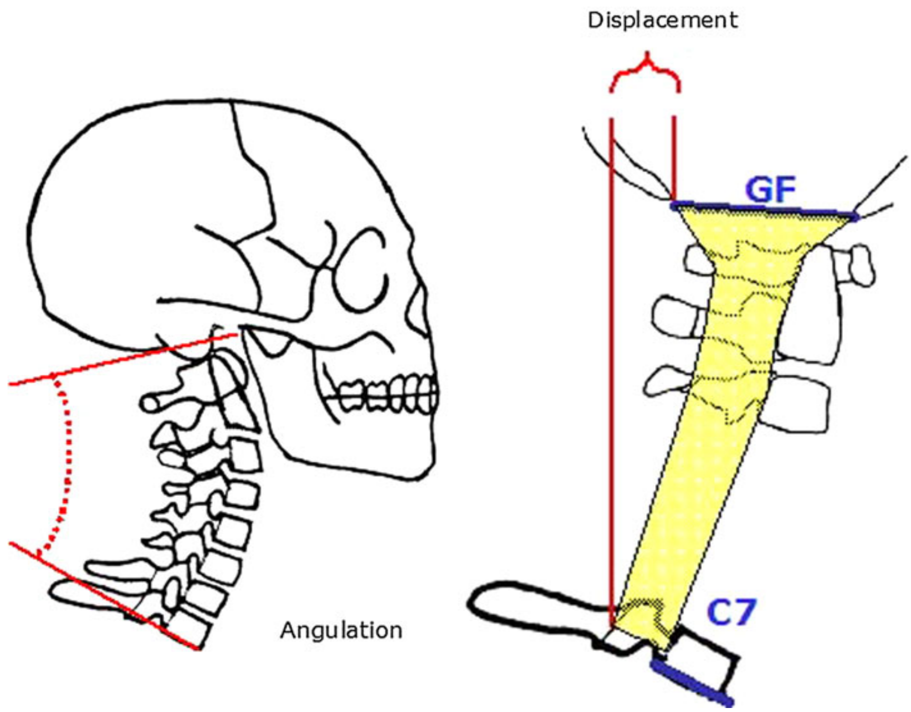

Fig. 1 Measurement of the neural canal balance defined by **a** the displacement/distance between opisthion and spinolaminar line at midvertebral height of C7 (mm) [anterior, posterior], **b** angulation (°) between McCrae's line (*connecting line* between basion and opisthion) and tangent to the lower endplate of C7

a negative (−) prefix lordotic deformity with a positive (+) prefix. The following linear and angular parameters were repeatedly measured.

1. Odontoid fracture displacement (mm) and direction (anterior, posterior, and lateral) by drawing lines along the posterior aspect of the dens fragment and the intact caudal body of C2.
2. Neural canal balance of the cervical spine defined by (a) the displacement/distance between opisthion and spinolaminar line at midvertebral height of C7 (mm) (anterior, posterior), (b) angulation [°] between McCrae's line (connecting line between basion and opisthion) and tangent to the lower endplate of C7 (Fig. 1).
3. Sagittal alignment of the cervicothoracic junction [Cobb angle between VB endplates (C7-T4) [°].
4 C1/C2 angulation between the connecting line of the centres of the marrow cavities of the anterior and posterior arch of C1 and the endplate of C2.
5. Absolute angle (AA)° of the cervical spine measured by the C2–C7 posterior tangent method described by Harrison et al. [23].

- Range of motion
  - Range of motion (ROM) of the cervical spine by flexion/extension films in the lateral projection calculated by the summation of the cervical angle in flexion and in extension [19].

- Union/Non-union

  Bridwell's criteria [10] were used and adapted to assess for bony union/non-union and evidence of bone healing at the odontoid fracture site or posterior C1/2 bone graf fusion site:

  1. Grade I (fused and incorporated),
  2. Grade II (partially incorporated),
  3. Grade III (lucent line present),
  4. Grade IV (pseudoarthrosis).

  Union was defined as Bridwell Grade I-II without movement on flexion–extension radiographs, when available.

- Treatment indications

  Indications for surgical treatment included displaced or unstable injuries. Indications for non-operative treatment were stable, non-displaced injuries, significant co-morbidities, or patient's preference.

- Treatment failure

  Treatment failure was defined as the necessity to change the initial intention to treat, e.g. aborted surgery or patients who failed non-operative treatment and subsequently underwent operative treatement secondary to inadequate immobilization, inability to tolerate external fixation, or persistent neck pain.

Fig. 2 Type II odontoid fracture subgroup frequencies clockwise from left upper corner: (1) transverse fracture ($n = 33$, 36.3%), (2) oblique anterior ($n = 1.1\%$), (3) oblique posterior ($n = 48$, 52.7%), and (4) comminuted ($n = 1$, 1.1%) fracture pattern (other $n = 7$, 7.7%, missing $n = 1$, 1.1%)

Data management and statistical analysis

The data managment and analysis was carried out with Excel (Microsoft Inc.) and SPSS (Version 17, SPSS Inc.) for Windows. Standardized statistical test [*t* test, Wilcoxon-, Mann–Whitney-test, $\chi 2$ test, multivariance data and regression analysis (ANOVA)] were used for comparison.

Results

Patient population

50 (56%) female and 40 (44%) male patients were included. The average age at the time of injury was 83 years (65–101 years). Non-OP patients (mean 84 years) were older than OP patients (mean 81 years) ($p = 0.43$).

Cause of injury

The most common mechanisms of injury were "ground level falls" ($n = 69$). Patients sustaining high-energy trauma ($n = 8$) [e.g. motor vehicle accidents (MVA)] showed an average age of 78 years and were significantly younger than patients the remaining 70 patients involved in low-engery trauma ($n = 70$) and average age of 84 years ($p < 0.05$).

Hospital course

Seventy-two (80%) of the patients were admitted during the first 24 h after the injury, 8 (9%) within the first week after the injury, and 10 (11%) were admitted more than 8 days after the injury. The hospital length of stay ranged from 0 to 42 days with a mean of 7 days and was significantly longer for patients with OP treatment (mean 10 days, median 8 days) compared to non-op treatment (mean 6 days) ($p = 0.007$).

Radiological findings

Fracture morphology

A fracture subclassification for Anderson and D'Alonzo type II dens fractures was used: we found 47 (52%) oblique posterior, 33 (37%) transverse, 1 (1%) oblique anterior, 1 (1%) comminuted, and 7 other fractures that did not fit into the subclassification (8%) ($n = 1$ missing) (Fig. 2).

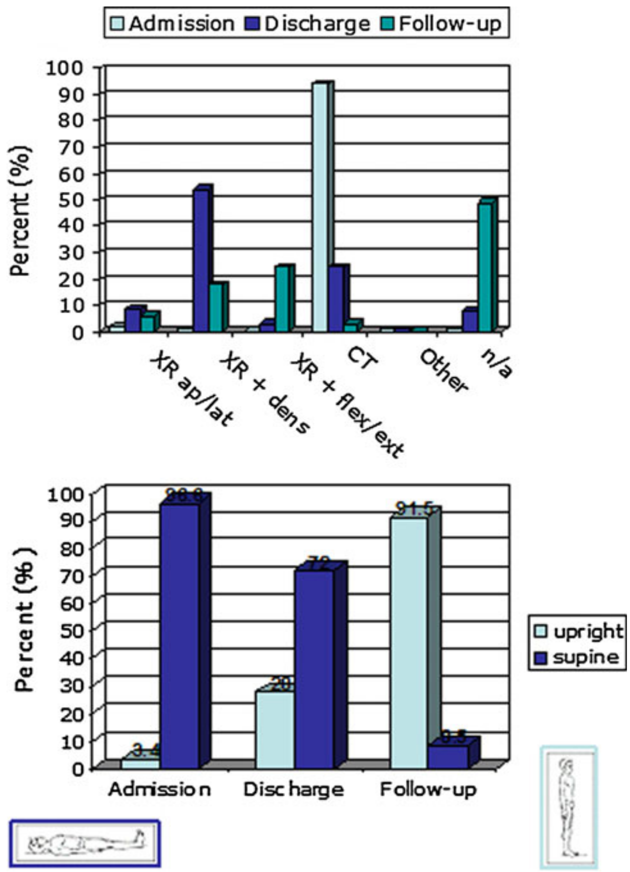

Fig. 3 **a** Frequency of image modalities available for assessment on admission, discharge, and FU in percent ($n_{total} = 90$). **b** Patient position during image acquisition on admission, discharge and FU

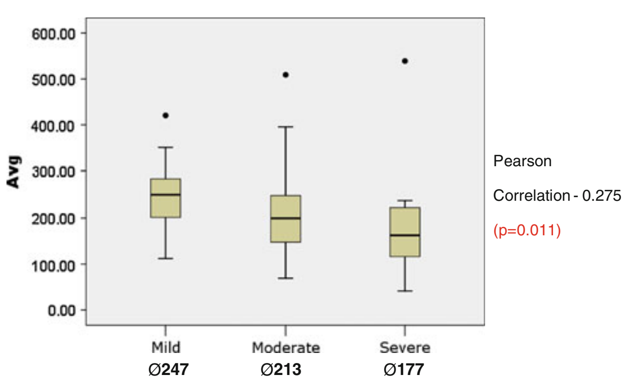

Fig. 4 Statistically significant correlation (−0.275, $p = 0.011$) between osteoporosis classification and average pixel statistics as seen in a *boxed region of interest* (ROI) at the body of the axis with a decreasing pixel average from categories mild (mean 247), moderate (mean 213) to severe (mean 177)

Fourty-three (48%) of type II odontoid fractures occured as a C1/C2 combination injury with additional fractures of the atlas (C1), e.g. anterior and/or posterior ring fractures. The relative frequency of atlas in combination a type II axis fractures was 60% ($n = 28$) in oblique posterior and 40% ($n = 13$) in the transverse subtype.

CT scans with multiplanar reconstructions were available for 85 (94%) of the patients on the initial assessment, conventional X-rays of the cervical spine in two planes (a.p. and lateral) in 2 (2%) patients, and 1 (1%) patient had conventional X-rays of the cervical spine in two planes with an additional transoral view of the dens (Fig. 3).

Osteoporosis

The severity of osteoporosis [28] was assessed at the body of the axis. None of the patients showed a normal trabecular pattern with normal cortical thickness. Instead 72% ($n = 65$) of the patients had moderate or severe osteoporosis with absent trabeculae (holes) and cortical thinning. The correlation coefficient for the osteoporosis classification by Lakshmanan and "average" pixel statistics calculated from Centricity® Enterprise Web boxed ROI (region of interest) measurements was −0.0275 and significant ($p = 0.011$) (Fig. 4).

Patient age and average pixels (e.g. BMD) showed a statistically significant correlation ($r = 0.219$, $p = 0.045$). The average pixel number in patient with fracture union (202.23) and non-union at FU (229.98) did not differ significantly ($p = 0.302$).

Measurements

Fracture displacement

On initial assessment 53 (60%) patients had either posterior ($n = 50$) or anterior ($n = 3$) displaced fracture. The mean fracture displacement (mm) on AD was 2.8 mm compared to 2.1 mm on DC and 1.9 mm on FU. OP patients presented with significantly more displacement than non-op patients on admission (non-op 1.8 vs. OP 4.7 mm, $p < 0.001$) and DC (non-op 3.2 vs. OP 0.5 mm, $p < 0.001$). The opposite was found at FU with less displacement in the OP group [1.2 vs. 2.8 mm (non-op), $p = 0.07$].

Patients with a healed fracture at FU had significantly less ($n = 30$, mean 1.3 mm) fracture displacement than those with a non-union fracture ($n = 15$, mean 3.3 mm) ($p = 0.027$).

A detailed summary of the fracture displacement (mm) along with other relevant linear and angular measurements of the cervical spine are listed in Table 1.

Neural canal balance

Figure 1 Outlines two measures applied to describe the change of the sagital alignment of the neural canal during treatment: (1) neural canal angluation (°) between

McCrae's line [8], drawn from the basion to the opisthion representing the level of the foramen magnum and the tangent to the lower endplate of C7. (2) Displacement (mm) determined by the distance between the opisthion and mid vertebral level of the C7 spinolaminar line.

The mean lordotic neural canal angulation of the patient population was 65.9° (OP 64° vs non-op 68°) on AD ($n = 85$), 63° (OP 64° vs non-op 66°) at DC ($n = 78$), and 64.8° (OP 62° vs non-op 68°) at FU ($n = 44$). Neural canal angluation at FU varied according to fracture pattern [transverse (64°) vs. oblique posterior (67°)] and differed fracture union 62° [non-union (71°)].

The average anterior displacement increased over time from 10.9 mm on AD, 22.5 mm at DC, to 42 mm at FU. No significant differences of anterior neural canal displacement comparing upright images only for OP (mean 36.9 mm, range 6–107 mm) versus non-op patients (mean 51.2 mm, range 20–114 mm).

At the same time an increase of the average kyphosis represented by the mean absolute angle C2–C7 of 5.2° on AD, 17.9° at DC, and 22.3° at FU with corresponding loss of lordosis measuring 33.1° on AD, 30.5° at DC, and 27.2° at FU was noted. This tendency of patients can commonly be described as "stooping" forward resulting in a loss of their upright posture.

A summary of all angular measurements are listed in Table 3.

Treatment

A total of 90 patients were included. Of those 57 (63%) patients were treated with a non-operative (non-op), or operative (OP $n = 31$, 34%) procedure. One patient (1%) was found not to require a specific therapy for a non-displaced, non-acute odontoid fracture. One (1%) patient expired from an asystolic arrest, before an intended odontoid screw fixation.

The median time between AD to the hospital and definitive treatment was 0 days [mean 3.57 days, range 2–149 days)]. Non-op treatment methods included soft cervical collar ($n = 6$, 11%), hard cervical collar ($n = 45$, 79%), halo vest ($n = 5$, 9%), and cervical traction ($n = 1$, 2%). OP treatment included C1/2 posterior segmental fusion ($n = 14$, 45%), C1/2 transarticular screws ($n = 8$, 26%), odontoid screws ($n = 6$, 19%), and occipito-cervical fusions ($n = 3$, 10%). The overall average length of the hospital stay was 7 days [median 5 days (range 0–42 days)] with a significantly longer hospital stays between patients receiving operative (mean 9.94 days, median 8 days) compared to non-op treatment (mean 5.72 days, median 4 days) ($p = 0.007$).

Eleven patients initially treated with cervical collars had failed initial non-op treatment and were converted to an OP procedure. Of that one death related to a flaccid paralysis in all 4 extremities after obtaining upright X-rays of the cervical spine films in a collar secondary to a posterior C2-fracture dislocation. An attempted surgical stabilization was aborted because the patient developed severe hypotension on induction of anesthesia. Instead the patient had to be placed in cervical traction. Later a decision to initiate comfort care was made after a family conference and decision. Four patients initially treated in a halo-vest had to be converted to a C1/C2 segmental fixation ($n = 3$), and occipito-cervical fusion ($n = 1$).

One C1/C2 transarticular screw fixation was unsuccessful and had to be revised surgically to a C1/2 posterior segmental fixation 2 weeks later.

Follow-up (FU)

Follow-up data were available on 45 (51%) patients. The average time from the date of discharge from the hospital until FU was 6 months. Four (4%) patients have had a FU within 4 weeks after discharge, 19 (21%) within 1–3 months, 8 (9%) 3–6 months, and 15 (17%) patients were followed more than 6 months after DC from hospital (Table 2).

Thirty (65%) of 46 patients with Bridwell Grade I or II at FU were considered as bony union. Sixteen (35%) patients had documented non-unions (Bridwell Grade III or IV). Surgical treatment [OP ($n_{total} = 16$, 76%)] resulted in higher union rates during the first 3 months ($n = 6$) and later ($n = 10$), when compared with non-op treatment [non-op ($n_{total} = 14$, 58%)] during the same time period ($n = 7 < 3$ months; $n = 7 > 3$ months) ($p > 0.05$) (Fig. 5). The highest union rate was observed following C1/C2 transarticular screw fixation and occipito-cervical fusion (each 100%), followed by C1/2 posterior segmental fusion (67%), and anterior odontoid screw fixation odontoid (33%).

Within the OP group significantly more [$n = 12$ (86%) of 14 patients] patients had a bony union sustaining obique posterior fractures when compared to transverse fractures [$n = 2$ (40%)] five patients with ($p = 0.046$).

The union rate in the age group 65–80 years was higher (72%) than the union rate in patient 81 years and older (61%).

Discussion

Type II odontoid fractures are the most common fractures of the cervical spine in the elderly [11, 29, 32, 44]. Published literature on the radiological outcome in geriatric patients with type II odontoid fractures is scarce. To the knowledge of authors, this is the largest published consecutive case series following surgical and non-surgical

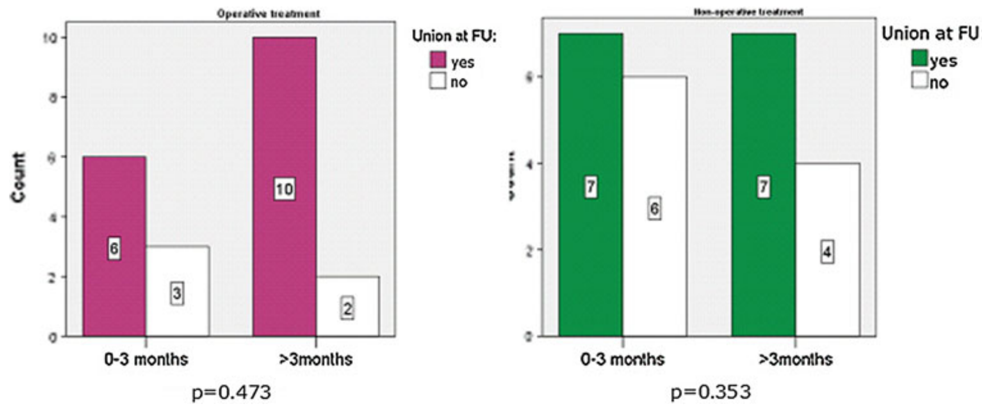

Fig. 5 Comparison of patient numbers and union rates following OP (n_{total} = 16, 76.2%) and non-op (n_{total} = 14, 58.3%) treatment

treatment of geriatric patients with type II odontoid fractures.

Initial radiographic assessment of the upper cervical spine in symptomatic patients has evolved from a historical three view cervical spine series (AP, lateral, and odontoid views) to a helical CT scan with sagittal and coronal reformats [21]. In our series 94% of the patients were initially assessed with a CT scan. We detected a high incidence of C1/C2 combination injuries in 48%. For this reason we do not consider concomitant C1 fractures a "complication" [5, 6] of the odontoid fracture, since this is rather commonplace in nearly 50% of this patient population.

The mean length of hospital stay was 7 days in our study population and significantly shorter when compared to 1994–1998 data from the same institution with a mean of 12.5 hospital days [27]. Our study showed that surgical treatment required a significantly longer hospital length of stay for 8 versus 4 days following non-op treatment. Dunn and Seljeskog [15] reported an average hospital length of stay of 7 days for halo fixation, 13 days for treatment by posterior cervical fusion, and 29 days by rotatory bed traction.

It has been recognized that there is a broader spectrum with subtypes of the Anderson and D'Alonzo type II odontoid fracture [4, 18]. None of the previously published classification systems specifically addressed varying type II fracture patterns in a geriatric patient population >65years of age. Based on our clinical experience and observation, we have introduced and applied a new classification system with four sub-categories including transverse, posterior oblique, anterior oblique and comminuted fractures. Classifying fractures were facilitated by multiplanar CT images available in 94% of our patients. Most commonly seen fracture types were transverse (53%) and posterior oblique (36%). Fracture morphology was found to have a significant impact on the radiological outcome. The union rate for surgical cases with posterior oblique was 86% and significantly higher than that of surgical cases with a transverse fracture pattern (40%).

For this study we chose a combination of several simple, reliable measures to allow for the assessment of the fracture, C1/C2 complex, and the remaining lower cervical spine in the lateral projection [8]. Imaging modality and patient position during image acquisition are relevant factors, especially in unstable type II odontoid fractures.

Initially non-displaced fractures frequently become displaced [2]. Posterior displacement is more commonly seen than the anterior displacement [36, 42]. In concordance with the literature [27] the initial mean odontoid fracture displacement was highest in the surgical group (4.7 mm vs. 1.8 mm non-surgical). The amount of fracture displacement (mm) on admission was not confirmed as a statistically significant factor for fracture union at FU in our series. Roberts et al. [41] found that the non-union rate for displaced fractures (30%) was higher than in non-displaced fractures (17%). Nourbakhsh et al. [35] pointed out that fracture displacement had a significant impact on radiological outcome only if non-operative treatment was persued, because OP treatment was found to provide significantly better results than non-op management. Platzer et al. [38] identified advanced age and fracture displacement as possible risk factors for the failure of halo fixation. Hadley et al. [20] reported an increase in non-union rates in type II odontoid fractures with dens displacement <6 mm from 26 to 67% with displacement >6 mm following halo-device immobilization.

In concordance with the pertinent literature [31] we found a significant correlation between a decreased bone-mineral density and advanced patient age. Ryan and Taylor [42] concluded that osteopenia is a contributory factor in the occurrence of odontoid fractures. Despite the fact that patients with fracture non-union at FU had a lower pixel average than those with healed fractures, the difference in bone density between both the age groups (65–80 years vs. >81 years) did not reach statistical significance in our study, thus a statistically significant correlation between the patient age and fracture union could not be confirmed likely because of the limited patient number available for FU.

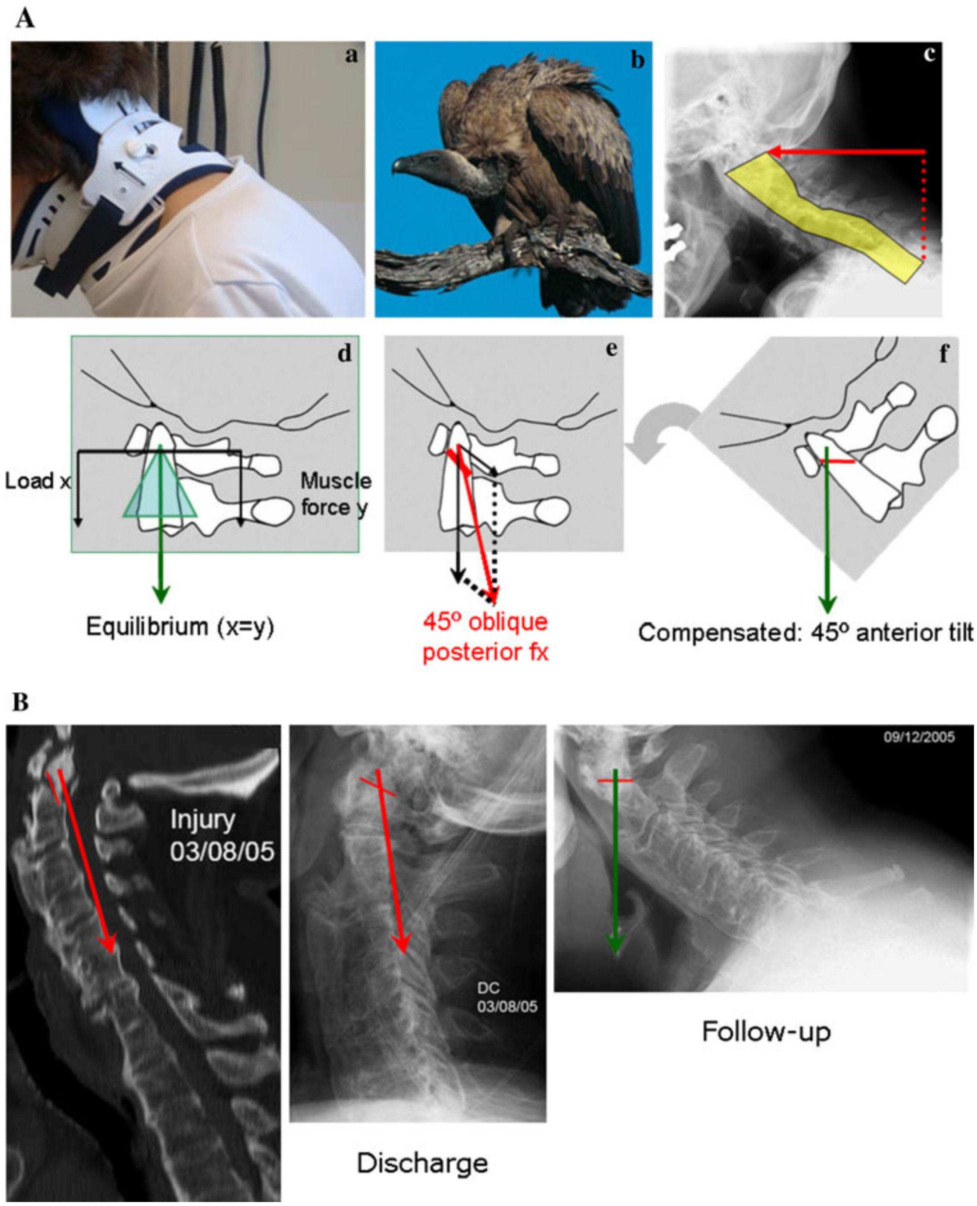

Fig. 6 **A** Clinical picture, naming, and lateral cervical spine X-ray, *a* clinical picture with patient wearing a Miami-J collar presenting at FU with a "stooped" forward position, *b* naming of the pathology according to the distinct features of a vulture's neck called "Geier-deformity", *c* corresponding lateral radiograph of the cervical spine showing the loss of the physiologic profile with loss of lordosis at in the subaxial cervical spine and increased kyphosis of the cervico-thoracic junction to compensate for the posterior oblique odontoid fracture. Hypothesis and possible explanation for the Geier-deformity, *d* equilibrium of load and muscle forces in the intact situation, *e* oblique posterior fracture line with corresponding force vectors in an upright position causing posterior displacement, *f* compensatory mechanism to counteract the posterior displacement by stooping/bending forward. **B** Case sample No 2 *left* sagittal reconstruction of CT scan obtained at the time of injury of a 73yrs old male patient presenting with posterior oblique diffuse idiopathic skeletal hyperostosis of the subaxial cervical spine, *middle* lateral xray of patient in upright position at discharge wearing a Miami-J-collar, *right* lateral X-ray obtained during FU in an stooped forward position and findings of the Geier-deformity as outlined in the text following non-operative treatment

There are no evidence-based treatment standards or guidelines for odontoid fracture management [22, 25]. Different treatment options remain subject to controversy, especially in the geriatric patient population [16, 37]. Recommendations for type II odontoid fractures treatment are not as straight forward as in type I and III fractures [40]. Regardless, the main objective should be to guarantee sufficient fracture stability, to allow for early patient mobilization in a comfortable, painless manner. In concordance with the literature, union rate in non-op patients was 58% [36, 42]. Non-operative management has been the treatment of choice for many years [41] and often results in

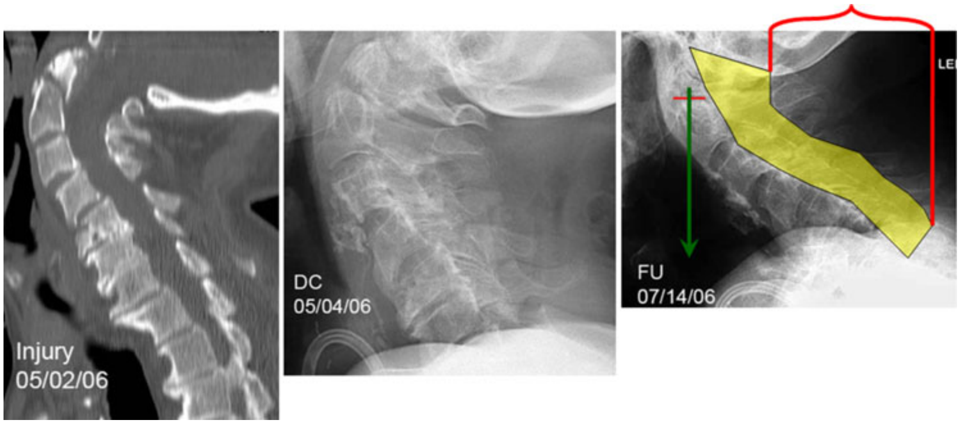

Fig. 7 Case sample of an 81-year-old male patient who sustained a fall in his bedroom and had posterior oblique odontoid fracture and severe degenerative changes of the subaxial cervical spine. *Left* CT scan at the time of injury; *middle* upright lateral X-ray at discharge with some posterior displacement; *right* "Geier-deformity" with lateral cervical spine radiograph obtained at follow-up with stooped forward position (neural canal outlined in yellow, red line to highlight fracture line, and green arrow indicating force vector in the stooped forward position; see also Fig. 6)

fracture stability, by either osseous union or fibrous union in almost all patients [26]. Thus stable fibrous union may be an acceptable aim in the elderly patient [16, 26]. The long-term outcome of stable non-unions remains unknown or might not even matter at all in these patients. Regardless of an increasing tendency toward the surgical treatment in the literature [9, 12], non-operative treatment remains a viable choice, and in many incidences is the only feasible alternative, particularly in geriatric patients with significant comorbidities [24]. Minerva plaster cast treatment [7] for unstable odontoid fractures was not considered a treatment option anymore in contrast to the treatment portfolio at the same institution in the mid-1990s [27]. Some authors consider halo thoracic bracing is preferable to cervical collars [26] while others have abandoned this Halo vest treatment [43], or found them poorly tolerated by the patients older than 75 years of age [36] with a questionable efficacy to prevent in vivo motion [3]. Similar to Polin and coworkers we favored the use of the rigid cervical orthosis in the majority of cases [39], given the lack of significant difference in the need for late surgical procedures and improved patient comfort with cervical orthosis and elimination of the risk of halo-related complications.

The union rate after OP treatment in our series of 76.2% was higher than non-op treatment (58.3%). In a review article Pryputniewicz and Hadley [40] identified several parameters in favor for OP treatment: (1) patient age >50 years, (2) comminuted fractures, and (3) posterior or significant dens displacement >5 mm.

Despite a high [22% ($n = 6$)] mortality rate in 27 elderly patients with type II odontoid fractures Frangen et al. [17] found the results of dorsal C1/C2 fusion superior to halo-vest immobilization.

Collins and Min [13] recommended anterior screw fixation with union rates of 77% and based on the low morbidity associated with this procedure, while Aebi et al. [1] found anterior screw fixation to be inappropriate for patients marked with osteoporsis. Dailey et al. [14] looked at type II odontoid fractures in a +70 years population and found stability rates >80% but cautioned about a relatively high dysphagia rate associated with the anterior approach, 25% of patients required a feeding tube and 19% had aspiration pneumonia that required antibiotic treatment [14]. We did not observe the complications but do agree that anterior screw fixation a less favorable option in elderly patients with poor bone stock. Based on our results we recommend segmental posterior screw fixation as the most reliable fixation technique for these patients.

Except anecdotal case reports [34], previous literature has paid no attention to the effects of odontoid fractures on the cervical spinal alignment below the level of injury. The authors observed a recurrent phenomenon consisting of deteriorating cervical sagittal spinal balance and postural changes in the elders following type II odontoid fractures. In particular these changes seem to occur after specific fracture patterns and fracture non-union. Given the distinct similarities to the deformity's appearance and patient stature with a vulture's neck, we have named this phenomenon "Geier[2]-deformity" (Fig. 6). Clinical findings of the Geier-deformity include an anterior displacement of the upper cervical spine, e.g. the occiput with reference to C7, a decreased lordorsis/increased kyphosis of C2–C7, resulting in a loss of the physiological alignment and stooped forward posture. This deformity is associated with

[2] Geier (German): vulture/Am. A. buzzard.

an oblique posterior fracture pattern and fracture non-union. The underlying pathomechanism may be disequilibrium of the anterior load and posterior muscle forces in the upper cervical spine (Figs. 6, 7).

The limitations of our study are based upon its FU rate (50%) and period (mean 6 months). In conclusion the authors believe that the goal of treatment should be to provide adequate stability for fracture healing, prevention of neurologic deterioration, and restoration or preservation of the physiological alignment of the cervical spine. In the absence of contraindications for general anesthesia surgical stabilization seems the favorable treatment of choice for unstable or displaced type II odontoid fractures. Operative treatment has a more reliable fracture union rate with superior radiological outcomes when compared to non-operative treatment at our institution. We therefore favor C1/C2 posterior segmental stabilization given the osteopenia and often poor stability of the bone-implant interface of anterior screws in the vertebral body of axis and odontoid process. In elders, fracture non-union in conjunction with a posterior oblique fracture pattern renders a high likelihood and may contribute to the loss of physiological cervical spinal alignment with distinct postural changes, called "Geier-defomity". Based on the results of the radiographic study we recommend taking odontoid fracture subtypes (e.g. transverse, oblique anterior, oblique posterior and comminuted) into consideration given the fact of their varying clinical behaviour and radiological outcome.

Conflict of interest None

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