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Type II odontoid fracture in elderly patients treated conservatively: is fracture healing the goal?

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Abstract:	Purpose: Analysis of functional outcome of elderly patients with type II odontoid fractures treated conservatively in relation to their radiological outcome. Methods: 50 geriatric patients with type II odontoid fractures were treated with Aspen/Vista collars. On admission, each patient was assessed assigning ASA score, modified Rankin scale (mRS-pre) and Charlson Comorbidity Index (CCI). 12-15 months after treatment, functional evaluations were performed employing a second modified Rankin scale (mRS-post) together with Neck Disability Index (NDI) and Smiley Webster Pain Scale (SWPS). Radiological outcome was evaluated through dynamic cervical spine x-rays at 3 months and cervical spine CT scans 6 months after treatment. Three different conditions were identified: stable union, stable nonunion, unstable nonunion. Results: Among the 50 patients, 24 reached a stable union while 26 a stable nonunion. Comparing the two groups, no differences of ASA (p=0.60), CCI (p=0.85) and mRS-pre (p=0.14) were noted. Similarly, no differences of mRS-post (p=0.96), SWPS (p=0.85)

	and NDI (p=0.51) were observed between patients who reached an osseous fusion and those with a stable fibrous non-union. No effects of age, sex, ASA, mRS-pre, fracture dislocation and radiological outcome were discovered on functional outcome. At logistic regression analysis, female sex and high values of CCI emerged associated with worse NDI. Conclusions: In geriatric type II odontoid fractures pre-injury clinical status and comorbidities overcome imaging in determining post-treatment level of function. Hard collar immobilization led to a favourable functional outcome with mRS-post, NDI and SWPS values diffusely encouraging whatever a bony union or a fibrous nonunion was obtained.
Response to Reviewers:	Reviewers' comments: Reviewer #1: This topic should deserve a much better approach. This purely retrospective analysis of the results of collar treatment in 50 geriatrics patients tells us only a partial truth and vision of this already largely analyzed topic. There is no description of sub-classification of type II fracture, or demonstrated baseline instability, the author assumed that there patient suffer from unstable fracture without clear demonstration, and included in fact patient already dismissed for surgery. Thank you for your comment. Since the vast majority of the patients (83%) revealed a horizontal fracture line, no significant differences emerged from a Roy-Camille sub-classification, therefore this data wouldn't have added important evidences, taking in account even the relatively small patient sample. According to the literature we considered unstable all the type II odontoid fractures (independently from the direction of the fracture line) and stable type I and type III ones (excluded from the study) (Koech F, Spine 2008) but, thanks to your comment, we modified the manuscript naming as "unstable" only those type II fractures with at least one of the following conditions which led to surgery, in order not to generate confusion: fracture gap of more than 2 mm, antero-posterior displacement of more than 5 mm and odontoid angulation of more than 11°. As specified in the Methods and according to literature {Konieczny MR (J Bone Joint Surg Am. 2012;94:e144(1-6)), Koivikko MP (J Bone Joint Surg Br, 2004, 86: 1146–115), Elgafy H (Am J Orthop (Belle Mead NJ). 2009, 38: 410–416), Joaquim AF (Neurosurg Focus 38 (4):E11, 2015)}, despite the absence of formally shared criteria, in all the patients these aforementioned conditions were considered signs of severe instability in which conservative treatments wouldn't have been sufficient and surgery has been believed mandatory. It is well known that collar achieve a high rate of non union, without necessary clinical consequences. The unsolved question is is really useful to submit those old patient to a prolonged collard if the clinical benefit is not so clear, could this be reduced to 6 weeks for exemple, or no collar at all? those question can not be answered through this study, so nothing really new in this field, and despite a well written paper I an not recommend publication. Thank you for your interesting questions. All the patients had the indication to wear collar even during their bed rest as well as in sitting or standing position. Since no collar-related complications were observed and nobody worsened their level of function, the prolonged immobilization with collar has not negatively compromised the advantages obtained adopting such conservative treatment, so 8-12 weeks of external immobilization appeared useful with a clinical benefit in terms of all the parameters of functional outcome analyzed. We do believe that this period could be shortened to 6 weeks or less, but it is difficult to establish in advance a time interval in which the partial mechanical silence provided by the collar is sufficient to determine that stiff fibrous union, which guarantees adequate stability to the fracture. It's our purpose to investigate such a time shortening of immobilization with other patients we're enrolling for the second step of this project, since we need a significantly larger number of patients to investigate this hypothesis and we have declared our relatively small patient sample as a limitation in this sense. Our study analyzes the relation between functional and radiological outcome in geriatric odontoid fractures treated conservatively adopting scores, indexes and parameters and it is the first in literature analyzing and comparing objective clinical and radiological data in this field and in aged-population. Reviewer #2: Dear authors, thank you for the opportunity to review your interesting paper. Mat. & Meth:

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Is the follow-up period long enough for the validity and the reliability of the results?yes
Are the statistical data and analysis correctly presented?yes
Are the results reported with enough relevant data?yes
Does the discussion reflect the interpretation of the results with reference to pertinent work in the literature?partially
Are the conclusions relevant?no
Does the length of the article correspond to its level of interest?yes
Are the figures, tables and drawings suitable in number and quality (see instructions to authors)?yes
Are the legends appropriate?yes
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A part of this work has been accepted for an oral presentation at the next EUROSPINE 2018, Barcelona, Spain, 19-21 September 2018.

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Key points

[elderly, odontoid, fracture, collar, outcome, healing]

1. In geriatric type II odontoid fractures pre-injury clinical status and comorbidities overcome imaging in determining post-treatment level of function.

2. Independently from all the other factors, high values of Charlson Comorbidity Index (CCI) and female sex are associated with worse Neck Disability Index (NDI).

3. Hard collar immobilization lead to a favorable functional outcome whatever a bony union or a fibrous nonunion is obtained.

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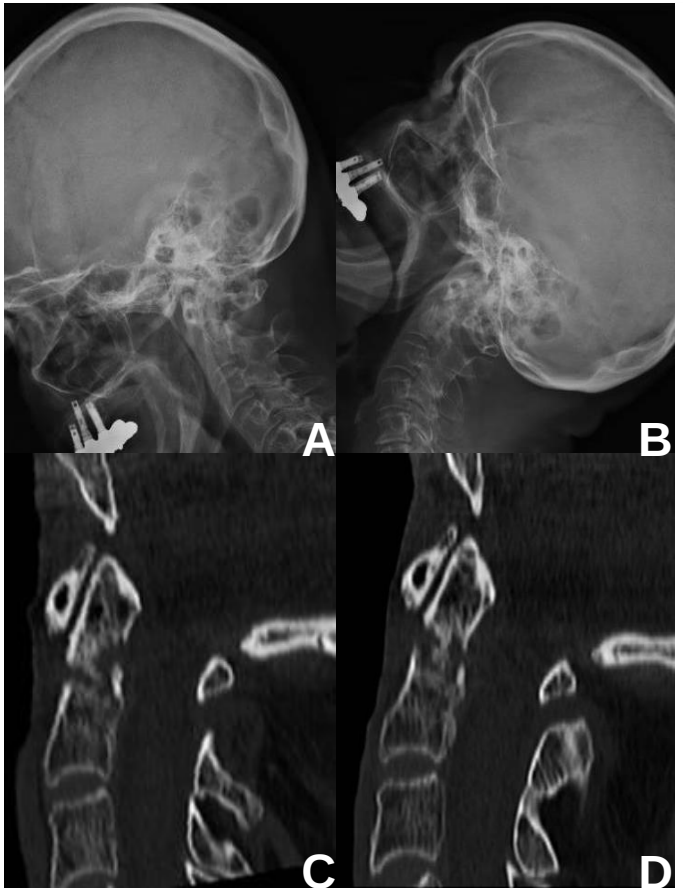
Table 4: Analysis of factors in relation to functional outcome (dichotomous mRS-post, NDI and SWPS)

	Dicot. mRS-post (p)	*Dicot. NDI (p)*	*Dicot. SWPS (p)*
Age (< 80 Vs ≥ 80 ys)	0.68	0.85	0.86
Sex (Male Vs Female)	0.37	0.16	0.42
ASA score (1-2 Vs 3-4)	0.68	0.85	0.25
Charlson Comorbidity Index (2-5 Vs 6-8)	0.56	0.02	0.67
Pre-treatment Modified Rankin Scale (0-3 Vs 4-5)	0.68	0.74	0.95
Fracture dislocation (< 3mm Vs > 3mm)	0.58	0.92	0.69
Radiological outcome (Union Vs Nonunion)	0.97	0.84	0.58

Figure 2: Dynamic cervical spine x-rays (flexion, A; extension, B) at 3 months and dynamic cervical spine CT-scan (flexion, C; extension, D) settling any doubts on evolutionary instability 6 months after injury.



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Take Home Messages

1. The adoption of stability as the most pertinent measure of radiological outcome may reduce the requirement for secondary operative stabilization and its associated risks in the elderly.

2. Pre-treatment disability, physical status and comorbidities are determinant of post-treatment level of function more than age, fracture characteristics and fracture healing attitude.

3. In elderly patients adequate stability can be achieved in the setting of fibrous union and hard collars provide enough immobilization to reach this goal.

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ABSTRACT

Purpose: Analysis of functional outcome of elderly patients with type II odontoid fractures treated conservatively in relation to their radiological outcome.
Methods: 50 geriatric patients with type II odontoid fractures were treated with Aspen/Vista collars. On admission, each patient was assessed assigning ASA score, modified Rankin scale (mRS-pre) and Charlson Comorbidity Index (CCI). 12-15 months after treatment, functional evaluations were performed employing a second modified Rankin scale (mRS-post) together with Neck Disability Index (NDI) and Smiley Webster Pain Scale (SWPS). Radiological outcome was evaluated through dynamic cervical spine x-rays at 3 months and cervical spine CT scans 6 months after treatment. Three different conditions were identified: stable union, stable nonunion, unstable nonunion. Surgery was preferred whenever a fracture gap >2 mm, an antero-posterior displacement >5 mm, an odontoid angulation >11° or neurological deficits occurred.
Results: Among the 50 patients, 24 reached a stable union while 26 a stable nonunion. Comparing the two groups, no differences of ASA (p=0.60), CCI (p=0.85) and mRS-pre (p=0.14) were noted. Similarly, no differences of mRS-post (p=0.96), SWPS (p=0.85) and NDI (p=0.51) were observed between patients who reached an osseous fusion and those with a stable fibrous non-union. No effects of age, sex, ASA, mRS-pre, fracture dislocation and radiological outcome were discovered on functional outcome. At logistic regression analysis, female sex and high values of CCI emerged associated with worse NDI.
Conclusions: In geriatric type II odontoid fractures pre-injury clinical status and comorbidities overcome imaging in determining post-treatment level of function. Hard collar immobilization led to a favourable functional outcome with mRS-post, NDI and SWPS values diffusely encouraging whatever a bony union or a fibrous nonunion was obtained.

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INTRODUCTION

Odontoid fracture represents the most common cervical spine fracture for patients aged 65 years or over and it is the most common spine fracture for patients older than 80 years of age[1]. Osteoporosis, scarce blood supply to the base of the odontoid and altered regional biomechanics predispose these patients to non-healing[2]. One of the main goals of treatment should be focused on rapid mobilization of the patients whatever the choice for odontoid stabilization. Much of the morbidity of type II geriatric odontoid fractures has traditionally been thought to be due to the risk of non-healing, thus radiological osseous union has been used to determine the optimal treatment outcome[2, 3]. Some authors instead consider a stable non-union an acceptable result in the elderly[3, 4]. Considered the high rates of morbidity and mortality of surgical fixations in this subset of patients, the significant complications and the increased morbidity associated with halo vest immobilizations[5, 6], we analyzed the functional outcome of patients aged 65 or over with type II odontoid fractures, reaching bony union or nonunion after treatment with hard cervical collar.

MATERIALS AND METHODS

Study population

From January 2012 through December 2016, 204 consecutive patients were treated for type II odontoid fractures in four different trauma centers of Emilia Romagna, Italy (Bologna-Maggiore Pizzardi Hospital, Ferrara University Hospital, Parma University Hospital, Cesena-Bufalini Hospital). Patients under 65 years or with missing/incomplete data were excluded from the study together with those ones treated surgically or with halo vest. Type III odontoid fractures, previous surgery involving the subaxial cervical spine, penetrating mechanism of injury and cognitive impairment were other exclusion criteria. Among the remaining 60 patients, 7 died before 6-month follow-up and 3 were lost at follow-up. At the hospital admission all the 50 patients eligible for the study underwent a baseline cervical spine CT evaluation performed using a multidetector scanner. Images always contained multiplanar reconstructions (MPR), which were systematically reviewed to classify each fracture according to the Anderson and D'Alonzo and the Roy-Camille classifications. Dislocation of the odontoid process was measured whether necessary. The mechanism of injury was distinguished in low-energy trauma, motor vehicle collision and high-energy trauma. Aspen®/Vista® collars (Aspen Medical Products, Irvine, CA, USA), worn for 8-12 weeks, were preferred to optimize external immobilization while reducing the risk of decubitus. Because of the retrospective character of this study, with several surgeons being involved over the long observation period in different centers, there was no standardized protocol to direct the choice of nonsurgical or surgical treatment. Nevertheless, all the treating physicians preferred surgery in the presence of neurological deficits and whenever a fracture gap of more than 2 mm, an antero-posterior displacement of more than 5 mm or an odontoid angulation of more than 11° occurred[7-10]. Although the absence of formally shared criteria, these aforementioned conditions were considered signs of severe instability in which conservative treatments wouldn't have been sufficient and surgery has been believed mandatory.

Functional and radiological assessment

On admission, each patient was clinically assessed adopting ASA score, modified Rankinscale (mRS-pre) and Charlson Comorbidity Index (CCI) respectively for estimating general physical status, degree of disability and mortality risk according to comorbidities. All patients were followed-up as outpatients at 1-3-6-12 month. From 12 to 15 months after treatment, functional evaluations were performed employing a second modified Rankin scale (mRS-post) together with the Neck Disability Index (NDI) and the Smiley Webster Pain Scale (SWPS), investigating general disability, neck-related disability and ability to return to work/former activity, respectively. Both NDI and SWPS were delivered as phone interview questionnaires by two different operators. In some cases, these questionnaires were administered as outpatients. The radiological outcome was evaluated through dynamic cervical spine x-rays at 3 months and CT scans of the cervical spine with MPR 6 months after treatment (*Figure 1*). In cases with doubtful fracture healing attitude, dynamic cervical spine CT scans were obtained to rule out instability (*Figure 2*). According to the evidences of both CT scan and dynamic x-rays, three different conditions were identified: stable union, stable nonunion, unstable nonunion. Union was defined by the evidence of bone trabeculae crossing the fracture line in absence of loss of cortical continuity and sclerotic borders/bone resorption of fracture's fragments. Fracture stability was determined by the absence of secondary

displacement of the odontoid process, proven through dynamic cervical spine imaging. In debatable cases, in which a dynamic cervical spine CT-scan was performed, those fractures revealing an increase of displacement over 2 mm were considered unstable. Every fracture showing a radiological outcome characterized by the absence of osseous union and a secondary odontoid process displacement was classified as "unstable nonunion".

Statistical analysis

The statistical analyses were performed with MedCalc, version 15.4 (1993-2015 MedCalc Software bvba). The main analyses of differences in terms of demographic data, preinjury level of function, comorbidity and radiological outcome were performed using a Student t-test for continuous variables and a Chi-square test for categorical variables. The Mann-Whitney test was adopted to compare functional outcome between the group of patients with stable union and that one with stable nonunion of odontoid fracture. Testing of the significance of changes of pre-injury level of function between patients with stable union and those ones with stable nonunion was performed through repeated measures of analysis of variance (ANOVA). The same analysis was adopted to verify the impact of age on outcome both in stable union and in stable nonunion. Analysis of contingency tables was performed to investigate the relation of patients' demographic, comorbidities, fracture's characteristic and radiological outcome with favourable/unfavourable functional outcome. Logistic regression analysis examined the impact of gender and CCI on dichotomous NDI (1-48% Vs 50-100%) outcome. Results presenting $p \leq 0.05$ were considered statistically significant.

RESULTS

Study population

Of the total 60 patients eligible for the study 7 died (12%). In all these cases no treatment-related complications were noted as co-determinants of death, while all of them reported significant comorbidities at the admission which resulted to be the cause of exitus in all the death certificates. Excluding the 3 patients lost at follow-up, the remaining 50 treated with hard collar immobilization were divided as follows: 24 who reached a stable bony union and 26 who obtained a stable fibrous non-union. All the fractures were classified as type II and in 7 cases an associated fracture of the posterior arch of the atlas were recorded. Nor spinal cord injuries nor neurologic impairments were evident at the admission. The vast majority of patients (n=41/50) sustained their odontoid fracture from a low-energy impact such as a minor fall, while motor vehicle collision was significantly more common in the stable-nonunion than in stable-union group (n=6/26 Vs n=1/24). Minor head traumas without sequelae were recorded in 5 cases, fracture of C1 ring in 3 cases, while cranio-facial fractures, ribs fractures and fractures of extremities respectively in 3,2 and 1 case. All the 3 patients with concomitant fractures of the atlas reached a bony fracture union. The median fracture fragment dislocation resulted 3 mm in the stable-non-union group and 1.9 mm in the stable-union group (t-test, p=0.05) (*Table 1*) with 2mm of maximum increase of displacement at the follow-up with dynamic cervical spine imaging. Comparing the two groups (stable union Vs stable non-union), no differences in terms of ASA (t-test, p=0.60), CCI (t-test, p=0.85) and mRS-pre (t-test, p=0.14) were noted in terms of pre-treatment level of function (*Table 2*). None of the rates of the specific comorbidity assessed differed significantly between the stable-union and the stable-nonunion group. None of the patients had non-union with instability. The age was not correlated with the cause of injury (F [2,47] = 1.726, p=0.189) and, assumed the same type of immobilization

for all the patients enrolled, both age (t-test, p=0.39) and sex (Chi-squared test, p=0.22) revealed no correlations with the radiological outcome.

Functional outcome

According to the NDI, no significant differences were observed between patients with fracture union and nonunion with a median value of 16 and 17, respectively. Independently from the radiological outcome, a non-significant trend towards worse NDI values was observed in younger (65-79 years) patients (t-test, p=0.18). Adopting the same age distinction, no substantial variations were documented among patients younger and older than 80 years in terms of mRS-post (*U*=118.5, p=0.29) and SWPS (*U*=212, p=0.35). No significant differences were observed between patients who reached an osseous fracture fusion and those with a stable fibrous non-union in terms of mRS-post (*U*=309.5, p=0.96), SWPS (*U*=303, p=0.85) and NDI (t-test, p=0.51). No collar-related complications such as decubitus ulceration were documented. None of the patients' change in functional level was owing to neurologic deterioration and, although with the limitation of a median follow-up of 16 months (range 12 – 27 months) for all patients, none developed clinical myelopathy or spinal cord injury during that period (*Table 3*). From the analysis of contingency tables for mRS-post, NDI and SWPS, no effects of age, sex, ASA, mRS-pre, fracture dislocation and radiological outcome were discovered on functional outcome. A significant result was noted, instead, for the CCI, which revealed a role in contributing to the final level of function esclusively in terms of NDI (Chi-squared test, p=0.02) (*Table 4*). When correcting for confounding variables at logistic regression analysis, both female sex and high values of CCI emerged associated with worse NDI (*Table 5*).

DISCUSSION

For type II odontoid fractures there are no standard treatment guidelines and their management and aims are even more controversial in aged population. Functional outcome after collar management in this subset of patients have not been well defined and it remains unclear for those patients who do not achieve fracture bony union after treatment[6]. This study provides a multiparametric assessment of functional outcome for a cohort of 50 elderly patients with type II odontoid fracture treated with hard cervical collar and stratified on the basis of radiological outcome (stable bony union Vs stable fibrous nonunion). Follow-up mortality rate was 12%, which is in line with the range from 4% to 42% reported in literature[6, 11, 12]for nonoperatively-treated type II odontoid fractures in elderly. The low mortality rate in our study may possibly be attributed to the emphasis on earlier mobilization of these patients soon after collar fitting[6].

Sex, age, mechanism of injury together with comorbidity and pre-treatment level of function didn't affect fracture consolidation attitude, while, similarly to other authors[13], we found that favourable functional outcome was positively correlated with advancing age, although this was outside statistical significance. All the fractures showed a displacement <5mm and no differences were noted in terms of secondary neurological impairment and functional outcome between odontoid dislocation <3mm or >3mm. The 52% of stable fibrous union in our series is in the range reported in literature for type II geriatric odontoid fracture[6].

Albeit many authors emphasize fracture's stability as the main goal to pursue with or without a proper osseous union[3, 14-16] some others still address their treatment strategy considering nonunion of odontoid process as a life-threatening condition[17-22]. In our patient cohort a similar distribution of stable-nonunion was noted between elderly and ultra-elderly and no significant differences of

functional outcome were recorded between patients with stable-union and those with stable-nonunion[6, 23]. Although with the limitation of a median follow-up of 16 months, nor complications nor crossovers to surgery occurred in both groups, thus odontoid fracture stable-nonunion didn't negatively influence the clinical course.

Consistent with the findings of other studies[14-16, 24], no patient developed delayed neurological sequelae, as consequence of nonunion, or showed worsening of their clinical conditions during the follow-up[12].

While Vaccaro et al. and Schroeder et al. reported significantly improved NDI, short-form-36 and mortality in patients treated operatively, we registered good and excellent functional outcome even with hard collar in asymptomatic patients with fracture gap, dislocation and odontoid angulation respectively <2mm, <5mm and <11°[2, 25, 26].

High values of CCI appeared associated with worse NDI, thus emphasizing how age-related comorbidities play a crucial role, and how in the elderly, assumed a fibrous or osseous fracture stability, pre-injury clinical status overcomes imaging in determining post-treatment level of function[27].

Similarly, worse neck disabilities concerned female sex. This evidence should be further investigated, in order to define if neuropsychological aspects, gender-related characteristics of the cervical tension band or specific daily activities can contribute to this association.

The 86% of the patients reported a good or excellent SWPS and with a median NDI of 16% and 17% respectively in stable-union and stable-nonunion group, differently from other authors[20], we didn't notice disabling levels of residuals neck pain due to the mobilization with hard collar.

Overall immobilization with this cervical orthosis led to a favourable functional outcome with mRS-post, NDI and SWPS values diffusely encouraging whatever a bony union or a fibrous nonunion was obtained[6, 23]. Aspen/Vista collars granted an adequate compromise between the need for providing a satisfactory cranio-cervical immobilization and the purposes to minimize orthosis-related complications, to allow early mobilization promoting maximum respiratory function and preservation of mental health[28].

In the debated topic of odontoid fractures in the elderly, our study emphasizes once again the lack of correlation between clinical and radiological healing processes[3, 6, 20]. According to other authors[13] we consider an aggressive radiological follow-up as a key point to switch timely to the surgical strategy whether necessary[14]. At the 6 months assessment with dynamic cervical spine imaging (x-rays or CT scan), fracture fragment stability, defined as the absence of secondary odontoid process dislocation, appeared in our patients as the necessary and sufficient condition to start a gradual weaning from the cervical orthosis. In this sense the use of dynamic cervical spine CT scan to avoid underestimation of nonunion rate and to settle any doubts on evolutionary instability, after inconclusive functional x-rays, gives strength to the study[23].

We didn't note an association of radiographic union with optimal functional outcome and, according to other studies[3, 22], we demonstrated that adequate stability can be achieved in the setting of fibrous union, rather than bony union[15, 16] and that hard collars provide enough immobilization to reach this goal[29]. Since a stable nonunion may represent a satisfactory target for elderly patients and fracture's characteristics and comorbidity have to be considered in decision making, conservative strategy in type II geriatric odontoid fractures appears as the result of a sort of specific treatment algorithm, which future multicentric studies could help to conceive providing a larger sample of this patient subgroup.

Limitations of this study lie in its retrospective design, in the relatively low patient sample size and in its mean age of 82.7 years with high rate of octogenarians, who often fell in the (anesthesiologist-driven) tendency to prefer nonsurgical minimally invasive treatment and whose deaths appeared always related to complications from underlying medical conditions. Further limitations are the absence of a standardized protocol of treatment and the median follow-up of 16 months, which could have led to underestimate the risk of late onset myelopathy whose progression, in patients with established nonunion, may take several years[22, 29].

CONCLUSION

The adoption of stability as the most pertinent measure of radiological outcome may reduce the requirement for secondary operative stabilization and its associated risks in the elderly patients[20]. Therefore, in aged population nonoperative treatment of ununited odontoid fractures may be a reasonable management strategy, provided that a fibrous union imparts some measure of stability, there are few symptoms, and there is low risk of neurological impairment[14, 15, 29]. Nevertheless, a close follow-up treatment protocol should be considered for patients who are poor candidates for surgical fusion[6]. All the patients had the indication to wear collar even during their bed rest as well as in sitting or standing position. Since no collar-related complications were observed and nobody worsened their level of function, the prolonged immobilization with collar has not negatively compromised the advantages obtained adopting such conservative treatment, so 8-12 weeks of external immobilization appeared useful with a clinical benefit in terms of all the parameters of functional outcome analyzed. Probably this period could be shortened, but it is difficult to establish in advance a time interval in which the partial mechanical silence provided by the collar results sufficient to generate that stiff fibrous union, which guarantees adequate stability to the fracture. Our study is the first evaluating post-treatment mRS, NDI and SWPS in geriatric type II odontoid fractures treated with cervical collar related to pre-treatment clinical conditions, comorbidity and level of function. Through the analysis of these multiple parameters, although in the setting of a retrospective cohort study, we add quality to the evidences on lack of correlation between radiological and functional outcome, supporting stronger the recommendation for hard collars when treating nonoperatively geriatric odontoid fractures.

FIGURE LEGENDS

Figure 1: Evolution of non-union of a geriatric type II odontoid fracture: post-traumatic (A), 3 months (B) and 6 months (C) CT-scan

Figure 2: Dynamic cervical spine x-rays (flexion, A; extension,B) at 3 months and dynamic cervical spine CT-scan (flexion, C; extension, D) settling any doubts on evolutionary instability 6 months after injury

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Figure 1

Figure 1. Evolution of non-union of a geriatric type II odontoid fracture: post-traumatic (A), 3 months (B) and 6 months (C) CT-scan.

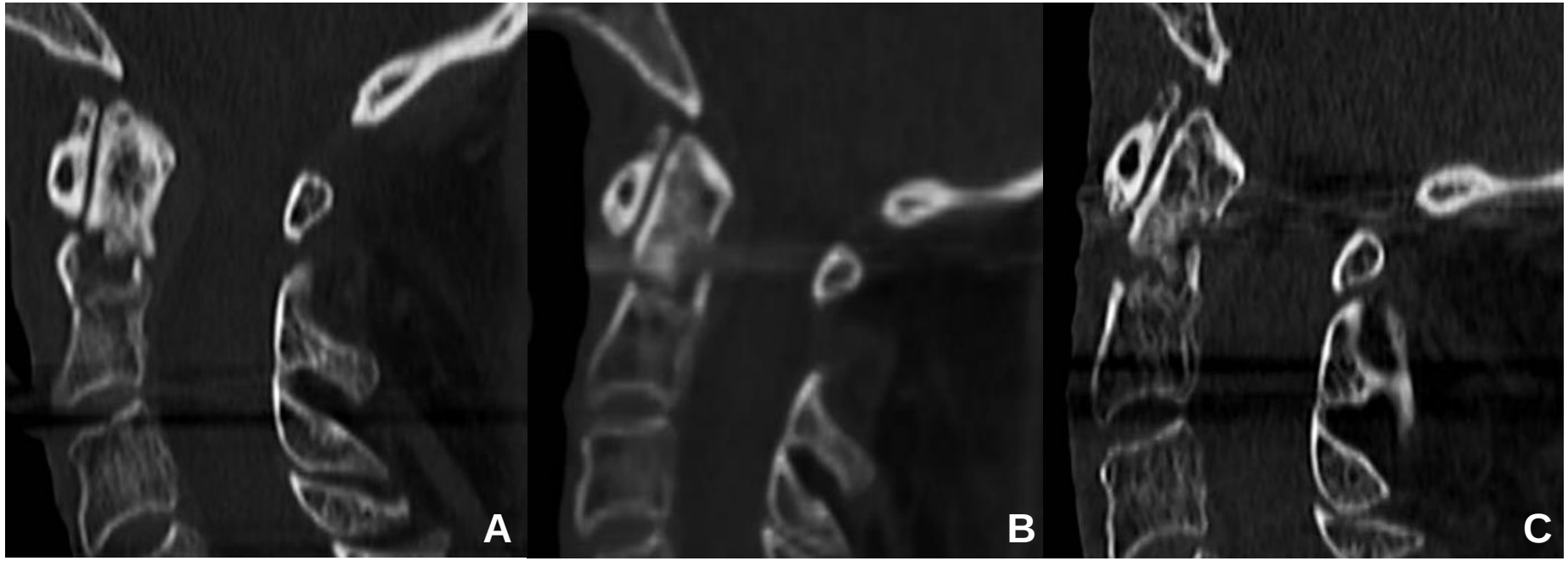
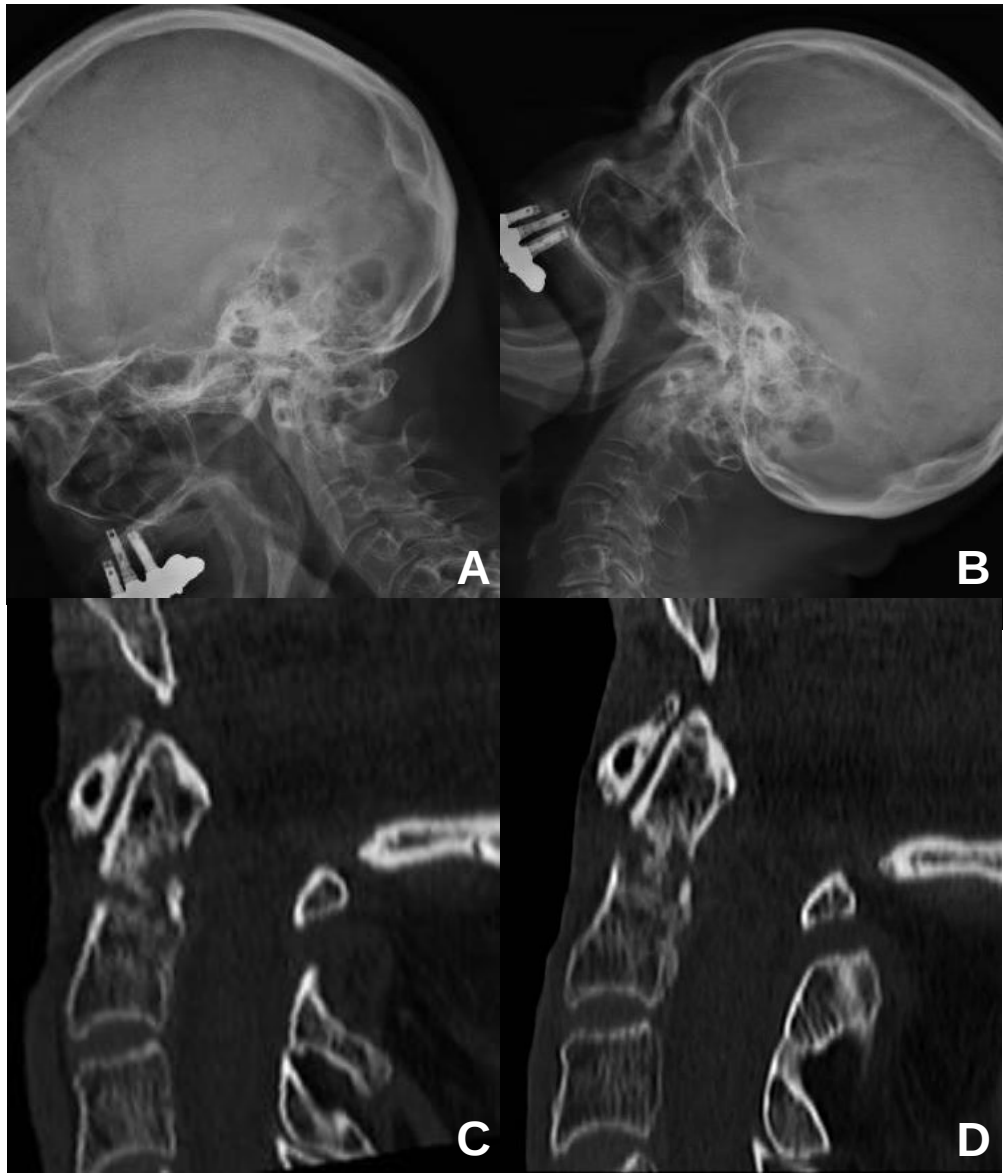


Figure 2. Dynamic cervical spine x-rays (flexion, A; extension,B) at 3 months and dynamic cervical spine CT-scan (flexion, C; extension, D) settling any doubts on evolutionary instability 6 months after injury.



Tables

Table 1. Patient demographics and characteristic of trauma (expressed in mean and standard deviation and percentages)

	All (n=50)	**Stable-union (n=24)**	**Stable-nonunion (n=26)**	***p***
Age (mean yr ± SD)	82.7 ± 6.9	83.6 ± 6.4	81.9 ± 7.4	0.39
Sex				0.22
Male	20 (40%)	7	13	
Female	30 (60%)	17	13	
Cause of injury				0.15
Low-energy trauma	41 (82%)	22	19	
Motor vehicle collision	7 (14%)	1	6	
High-energy trauma	2 (4%)	1	1	
Fracture dislocation (median mm and range)	2 (0-5)	1.9 (0-5)	3 (0-5)	0.05
Spinal cord injury	-	-	-	

Table 2. Pre-treatment comorbidity and level of function

	All (n=50)	**Stable-union (n=24)**	**Stable-nonunion (n=26)**	***p***
ASA score	3 (1-4)	3 (1-3)	3 (1-4)	0.60
Charlson Comorbidity Index	5 (2-8)	5 (3-8)	5 (2-8)	0.85
Pre-treatment Modified Rankin Scale	2 (0-4)	2 (0-4)	3 (0-4)	0.14

Table 3. Functional outcome

	All (n=50)	**Stable-union (n=24)**	**Stable-nonunion (n=26)**	***p***
Complications (treatment-related)	-	-	-	
Neck Disability Index	16 (0-58)	16 (0-48)	17 (0-58)	0.51
Post-treatment Modified Rankin Scale	2 (0-4)	2 (0-4)	2 (0-4)	0.96
Smiley-Webster pain scale				0.85
Excellent	21 (42%)	11	10	
Good	22 (44%)	9	13	
Fair	6 (12%)	3	3	
Poor	1 (2%)	1	0	
Delayed myelopathy	-	-	-	

Table 4. Analysis of factors in relation to functional outcome (dichotomous mRS-post, NDI and SWPS)

	Dicot. mRS-post (p)	***Dicot. NDI (p)***	***Dicot. SWPS (p)***
Age (< 80 Vs ≥ 80 ys)	0.68	0.85	0.86
Sex (Male Vs Female)	0.37	0.16	0.42
ASA score (1-2 Vs 3-4)	0.68	0.85	0.25
Charlson Comorbidity Index (2-5 Vs 6-8)	0.56	0.02	0.67
Pre-treatment Modified Rankin Scale (0-3 Vs 4-5)	0.68	0.74	0.95
Fracture dislocation (< 3mm Vs > 3mm)	0.58	0.92	0.69
Radiological outcome (Union Vs Nonunion)	0.97	0.84	0.58

Table 5. Logistic regression analysis of factors affecting NDI outcome

Logistic regression analysis: dicothomous NDI	***p***	***OR***	***95% C.I. for OR Lower***	***95% C.I. for OR Upper***
Female sex	0,05	10,611	0,998	112,789
CCI: 6 or 7 or 8	0,008	12,671	1,893	84,810

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Disclosure of potential conflicts of interest

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☑ We have no potential conflict of interest.

Category of disclosure	Description of Interest/Arrangement

Article title "Type II odontoid fracture in elderly patients treated conservatively: is fracture healing the goal?"

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Herewith I confirm, on behalf of all authors, that the information provided is accurate.

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