Type II odontoid fractures in the elderly: early failure of nonsurgical treatment

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The optimum treatment of Type II odontoid fractures in the geriatric population remains controversial. Coexisting medical conditions encountered in the elderly patient often increase operative risk and make cervical immobilization difficult to tolerate. Previous studies have shown increased morbidity and mortality and decreased fusion rates for Type II odontoid fractures treated with cervical orthoses in the geriatric population, whereas low morbidity and mortality rates with operative management have recently been documented. To investigate the role of surgical and nonsurgical treatment, a retrospective analysis was performed of patients with Type II odontoid fractures who were at least 65 years old and were consecutively admitted to a single medical center from 1994 to 1998. Twenty patients met inclusion criteria. In 12 patients nonsurgical management with a cervical orthosis was attempted. The nonsurgical management failed early in six patients, with one associated death. Eleven patients were treated surgically with either anterior odontoid screw fixation or posterior C1–2 transarticular screw fixation and modified Gallie fusion. Postoperatively one patient required revision of the C1–2 transarticular screws, and there was one death. In conclusion Type II odontoid fractures in this elderly population were associated with early 10% morbidity and 20% mortality rates. Nonsurgical management of Type II odontoid fractures failed early in six (50%) of 12 patients, whereas surgical treatment failed early in one of 11 (9%) patients. Both the nonsurgical and surgical treatments resulted in approximately 10% morbidity and 10% mortality rates.

KEY WORDS • odontoid • fracture • geriatric • surgical management • nonsurgical management

The optimum treatment of Type II odontoid fractures in the elderly remains controversial.[7,10–12] The medical frailty of the geriatric patient often compromises treatment, increasing the risks of both nonsurgical management with a cervical orthosis and surgical treatment with internal fixation and fusion. Surgical and nonsurgical treatment of odontoid fractures in the elderly is associated with higher morbidity and mortality rates when compared with younger patients with similar injuries.[7,10,11]

Authors of recent investigations have reported that prolonged cervical immobilization in a halo-thoracic vest is often not well tolerated by the geriatric patient, leading to increased morbidity and mortality rates and a high rate of nonunion, while authors of contemporary reports of surgically treated Type II odontoid fractures in the elderly have found acceptably low morbidity and mortality rates with a high rate of union.[4,–7,11] To further investigate the role of surgical and nonsurgical treatment of Type II odontoid fractures in the elderly, we retrospectively reviewed the records of all patients aged 65 years or older in whom a diagnosis of Type II odontoid fracture had been made and who were admitted to Harborview Medical Center between 1994 and 1998.

Abbreviation used in this manuscript: SCI = spinal cord injury.

CLINICAL MATERIAL AND METHODS

A retrospective review was performed of the records of patients aged 65 years or older who were consecutively admitted to a single medical center (regional level 1 trauma center) with a diagnosis of C-2 fracture between 1994 and 1998. Thirty-six patients aged 65 years or older were consecutively admitted with a diagnosis of C-2 fracture during the years of the study. Odontoid fractures were classified according to the method of Anderson and D'Alonzo.[1] Of the 36 patients, 20 had Type II odontoid fractures. There were 12 men and eight women, ranging in age from 66 to 92 years (mean 80 years). These 20 patients represent approximately 4% of all patients admitted to Harborview Medical Center for management of cervical spine fractures during the years of the study. After obtaining approval from the human subjects review committee, the radiological studies and medical records for each of the study patients were reviewed. Each case was categorized according to age, sex, mechanism of injury, type of spine fracture, odontoid displacement, neurological injury, associated nonspinal injuries, treatment given, complications, hospitalization days, follow-up period, and outcome. Follow-up assessment consisted of reviewing outpatient medical records and radiographic studies; when follow up was limited over time, the patient or patient's family was contacted regarding long-term outcome. Fusion was defined as evidence of bone healing at the odontoid fracture site or posterior C1–2 bone graft fusion site and, when available, absence of movement on flexion–extension radiographs. Early failure of treatment was defined as inadequate immobilization of the fracture within the first 30 days of treatment, inability of the patient to tolerate the treatment resulting in a change of the treatment plan, or death of the patient within 30 days of the treatment.

RESULTS

Patient Population

The mechanism of injury was a fall in 15 patients, a motor vehicle accident in three patients, bicycle accident in one patient, and one patient was struck by an automobile. Four patients had associated spine fractures at other segmental levels, and nine patients had associated nonspinal injuries. The number of days in the hospital ranged from 1 to 24 days, with a mean of 12.5 days. The surgical and nonsurgical groups were similar with respect to age, sex, mechanism of injury, type of spine fracture, SCI, associated nonspinal injuries, and follow-up period (Tables 1 and 2).

Evaluation of initial radiological studies revealed that at the time of diagnosis the odontoid displacement ranged from 0 to 11 mm, with a mean displacement of 5.4 mm. In the nonsurgical group the mean odontoid displacement was 4.5 mm, whereas in the surgical group the mean odontoid displacement was 6.6 mm. The odontoid fragment was anteriorly displaced in three patients and posteriorly displaced in 16 patients. Spinal cord injury was present in three patients and was always associated with posterior displacement of the odontoid.

Management Protocol

All patients were evaluated at Harborview Medical Center. When an odontoid fracture was suspected or diagnosed, the neurological and orthopedic surgical teams were consulted. Patients with suspected or diagnosed odontoid fractures underwent high-resolution computerized tomography scanning from the occiput to C-3. Magnetic resonance imaging was performed in all patients with suspected or diagnosed SCIs. After the diagnosis of odontoid fracture was made, the patient either underwent cervical traction for realignment of the odontoid or a cervical orthosis was directly applied. The treatment options were discussed with the patient and family, including a review of the advantages and risks of nonsurgical and surgical treatments. Treatment selection was based on the surgeon's recommendation and patient–family preferences. The primary treatment was nonsurgical in 14 patients and surgical in six patients. The goal of nonsurgical and surgical treatment was to stabilize the Type II odontoid fracture and mobilize the patient early during the hospitalization. After treatment with either a cervical orthosis or surgical fixation/fusion, serial cervical radiographs were performed with the patient in the supine and upright positions to evaluate for evidence of instability. If the patient was unable to tolerate the cervical orthosis or if fracture alignment could not be maintained in the cervical orthosis, the patient underwent surgical fixation/fusion. Inadequate stabilization of the odontoid fracture in the cervical orthosis was determined on serial cervical radiographs by the senior treating surgeon over a period of time ranging from 6 to 28 days after the injury.

RESULTS OF PATIENT FOLLOW-UP REVIEW

Outcome analysis revealed that four patients died during the initial hospitalization. Two patients died after admission to the hospital, secondary to injuries unrelated to the odontoid fracture: a 91-year-old woman with severe dementia and a closed head injury died soon after admission when support was withdrawn and an 81-year-old man treated in a Minerva brace died of a significant closed head injury 6 days after the injury. The two remaining deaths occurred during treatment of the Type II odontoid fracture (one in the nonsurgical group and one in the surgical group): an 86-year-old man treated in a Minerva brace developed pneumonia and died after a respiratory arrest and an 84-year-old man died of cardiopulmonary failure postoperatively. Of the 16 patients discharged from the hospital, follow-up data were available for 15 patients with a mean follow-up time of 14 months. For one patient discharged from the hospital who was doing well, there was no information after the initial hospitalization.

Nonsurgical Treatment

Nonsurgical management was used in 14 of the 20 patients (Table 1). The mean age in the nonsurgical group was 81 years, of whom 57% were men. The mechanism of injury was a fall in nine patients and associated spinal fractures were present at other segmental levels in three patients. One patient had an SCI, and seven patients had associated nonspinal injuries. The mean hospitalization time was 13 days for patients who were initially managed nonsurgically. The average follow-up time in the nonsurgical group was 13 months.

After admission to the hospital two patients died of injuries unrelated to the odontoid fracture or treatment of the odontoid fracture; these two patients have been excluded from the further analysis of nonsurgical management. Of the remaining 12 patients, eight were treated with a halo-thoracic vest, two were treated with a Minerva brace, and two were treated with a Miami J collar. The type of cervical orthosis was chosen based on the anatomy of the fracture combined with the medical frailty of the patient. Nondisplaced nondistracted Type II fractures in medically frail patients were more likely to be treated with a Miami J collar, whereas displaced distracted Type II fractures in medically healthy patients were more likely to be treated with a Minerva brace or halo-thoracic vest.

The nonsurgical treatment failed early in six patients and was associated with a complication in one patient. The nonsurgical early failures included: an 86-year-old man treated with a Minerva brace who developed pneumonia and died after a respiratory arrest; a 92-year-old woman treated with a halo-thoracic vest who developed failure to thrive (unable to ambulate in the halo-thoracic vest, she became depressed and refused to eat) and subsequently underwent a posterior fixation and fusion with

TABLE 1
*Characteristics of patients who were managed nonsurgically**

Case No.	Age (yrs), Sex	Mechanism of Injury	Type of Fx	Odontoid Displacement (mm)	SCI	Associated Injuries	Treatment	Hospitalization (days)	Follow Up (mos)	Outcome: Radiological	Outcome: Clinical
1	83, F	fall	II	0	no	minor CHI	Miami J	3	5	stable fusion	routine activity
2	89, F	fall	II	2 ant	no	CVA	halo	12	4	stable fusion	routine activity
3	81, M	fall	II	3 post	no	major CHI	Minerva	7	NA	NA	death 7 days after CHI
4	87, F	fall	II	8 post	no	none	Miami J	12	2	stable	routine activity
5	81, M	fall	II	1 post	no	minor CHI, radius & metacarpal fx	Minerva	12	12	inadequate stabilization, failed Minerva	NA
6	92, F	fall	II	5 post	no	none	halo	24	6	adequate stabilization	failure to thrive, failed halo
10	66, M	fall	II	2 post	no	scalp laceration	halo	13	22	inadequate stabilization, failed halo	NA
12	79, M	bicycle accident	II & C-1	5 post	no	none	halo	9	5	stable fusion	routine activity
13	71, M	MVA	II	10 post	cent cord synd	none	halo	16	32	inadequate stabilization, failed halo	NA
14	76, F	pedestrian struck by car	II	3 post	no	minor CHI, pelvic, tibia, fibula & ankle fx	halo	13	24	NA	routine activity (death from GI bleed 24 mos after injury)
15	86, M	MVA	II & C-1	2 ant	no	none	Minerva	10	NA	NA	death from pneumonia/respiratory arrest 10 days after injury
16	80, M	fall	II	2 post	no	none	halo & Miami J	8	3	nonunion, stable	routine activity
18	91, F	fall	II	10 post	no	major CHI	Miami J support withdrawn	1	NA	NA	death 1 day after injury
20	70, M	MVA	II, C-1, C6–7 laminae, T-5 comp	10 post	no	none	halo	24	30	inadequate stabilization, failed halo	NA

* Ant = anterior; cent cord synd = central cord syndrome; CHI = closed head injury; comp = compound; CVA = cerebrovascular accident; fx = fracture; GI = gastrointestinal; MVA = motor vehicle accident; NA = not available; post = posterior.

removal of the halo-thoracic vest postoperatively; and four patients (three treated with a halo-thoracic vest and one treated with a Minerva brace) who had inadequate stabilization of the fracture in the cervical orthosis and required surgical intervention (Fig. 1). The average odontoid movement/dynamic displacement in the halo-thoracic vest or Minerva brace for the four patients with inadequate stabilization of the fracture was 6.3 mm. The nonsurgical complication was a pin site infection with loosening of the halo ring requiring antibiotics and adjustment of the pins.

Of the 12 patients in whom nonsurgical treatment with a cervical orthosis was attempted, six patients were discharged from the hospital in the cervical orthosis and completed the course of treatment in the cervical orthosis. Of those six patients, all returned to routine activity with no late neurological deterioration. Radiological evaluation revealed that three of the six patients developed a stable bone fusion, one patient developed a stable nonunion, and one patient with dementia treated with a Miami J collar was stable at 2-month follow up (in one patient there was insufficient follow-up radiographic data). The mean initial odontoid displacement in patients who completed a course of treatment in a cervical orthosis was 3.3 mm, whereas the mean initial odontoid displacement in patients in whom the cervical orthosis failed early was 5 mm. Age, mechanism of injury, type of spine fracture, and associated nonspinal injuries were similar among those patients in whom nonsurgical treatment failed and those patients who completed a course of nonsurgical treatment in a cervical orthosis.

Operative Treatment

Operative stabilization was performed in 11 of the 20 patients (Table 2). The mean age in the surgical group was 76 years, with 73% being men. The mechanism of injury was a fall in nine patients, and associated spinal fractures were present at other segmental levels in two patients. Three patients had SCIs, and four patients had associated nonspinal injuries. The mean hospitalization time was 14

TABLE 2

*Characteristics of patients who underwent surgery as a primary or secondary treatment**

Case No.	Age (yrs), Sex	Mechanism of Injury	Type of Fx	Odontoid Displacement (mm)	SCI	Associated Injuries	Treatment	Hospitalization (days)	Follow Up (mos)	Outcome: Radiological	Outcome: Clinical
Primary operative management											
7	84, M	fall	II	5 post	no	none	trans screws w/ modified Gallie/Philadelphia	5	NA	NA	died 3 days after surgery/cardiopulmonary failure
8	74, M	fall	II	9 post	no	scalp laceration	trans screws w/ modified Gallie/ Miami J	13	36	stable fusion	routine activity (died of prostate cancer 3 yrs postinjury)
9	66, M	fall	II, C-1	7 post	Frankel D	none	trans screws w/ modified Gallie/ halo	19	0	NA	NA
11	71, M	fall	II	2 post	Frankel A	none	trans screws w/ modified Gallie/ Philadelphia	18	3	stable fusion	Frankel A, ventilator-dependent quadriplegic
17	86, F	fall	II	11 post	no	none	trans screws w/ modified Gallie/ Miami J	18	6	stable fusion	routine activity
19	79, F	fall	II	11 post	no	ankle fx	trans screws w/ modified Gallie/ Miami J	12	20	stable fusion	routine activity
Secondary operative management											
5	81, M	fall	II	1 post	no	minor CHI, radius and metacarpal fx	odontoid screw/ halo	13	12	stable fusion	routine activity
6	92, F	fall	II	5 ant	no	none	trans screws w/ modified Gallie/ Miami J	24	6	stable fusion	routine activity
10	66, M	fall	II	2 post	no	scalp laceration	odontoid screw/ halo	13	22	stable fusion	routine activity
13	71, M	MVA	II	10 post	cent cord synd	no	trans screws w/ modified Gallie/ Miami J	16	32	NA	routine activity
20	70, M	MVA	II, C-1, C6–7 laminae, T-5 comp	10 post	no	none	trans screws w/ Gallie BG (no wiring)/ Minerva	24	30	stable fusion	routine activity

* trans = transarticular.

days for patients who were initially treated surgically. The average follow-up period in the surgical group was 17 months.

Surgical treatment consisted of posterior C1–2 transarticular screw fixation with a modified Gallie fusion in nine patients and anterior odontoid screw fixation in two patients. The patients treated primarily with surgery and those treated surgically after failure of nonsurgical treatment were similar with respect to age, sex, mechanism of injury, type of spine fracture, SCI, associated nonspinal injuries, and follow-up period. The mean initial odontoid displacement in patients primarily treated with surgery was 7.5 mm, whereas the mean initial odontoid displacement in patients in whom nonsurgical treatment failed and who required surgical intervention was 5.6 mm.

Surgical treatment failed early in one patient and was associated with a complication in one patient. The surgical early failure occurred in an 84-year-old man who died of cardiopulmonary failure in the early postoperative period. The complication occurred in a 66-year-old man with an associated C-1 fracture and SCI who required revision of the posterior C1–2 transarticular screw fixation and placement in a halo-thoracic brace postoperatively.

Of the nine patients treated with posterior C1–2 transarticular screw fixation with a modified Gallie fusion, eight were managed postoperatively with either a Philadelphia collar or a Miami J collar for an average of 4 to 6 weeks. Halo-thoracic vest immobilization had failed in both patients treated with anterior odontoid screw fixation because of excessive movement at the fracture site; postoperatively both patients were maintained in the halo-thoracic vest because of poor odontoid screw fixation in osteoporotic bone. The anterior odontoid screw succeeded in providing internal fixation and prevented further odon-

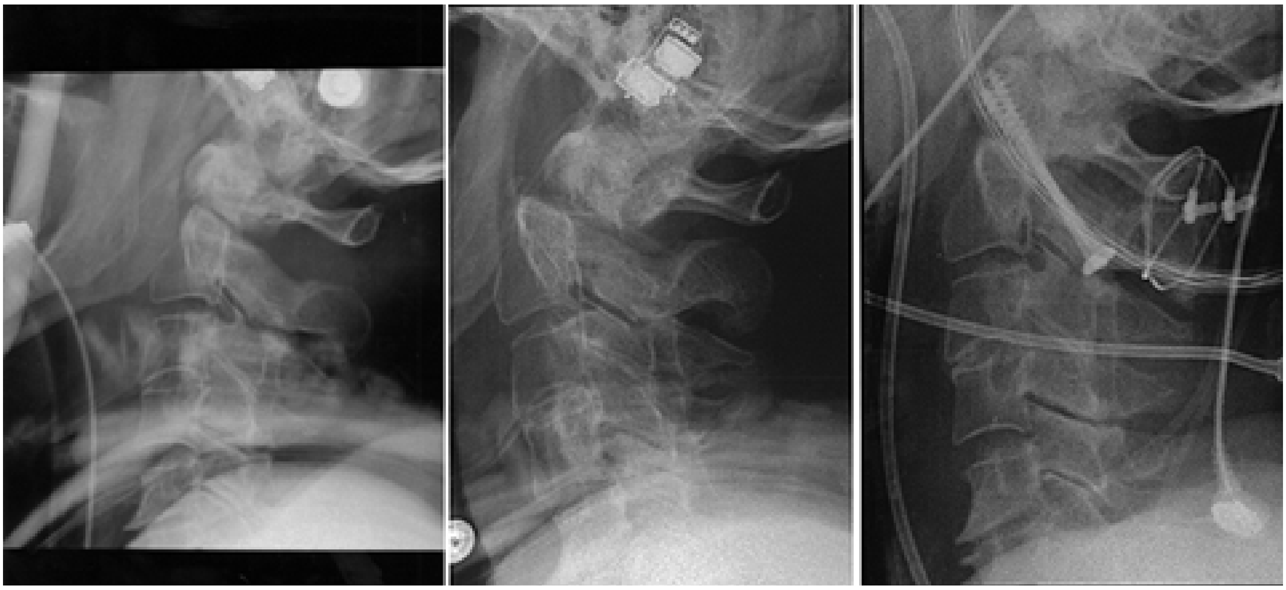

Fig. 1. Radiographs of the cervical spine obtained in a 71-year-old man involved in a motor vehicle accident who sustained a Type II odontoid fracture and an incomplete SCI. A: A supine lateral radiograph revealing near anatomical alignment of the odontoid fracture in a halo-thoracic vest. B: An upright lateral radiograph revealing posterior displacement of the odontoid in the halo-thoracic vest. C: Despite attempted nonsurgical management, the odontoid fracture was not adequately immobilized in the halo-thoracic vest, and the patient required posterior C1–2 transarticular screw fixation with modified Gallie fusion.

toid movement at the fracture site but did not obviate the need for postoperative halo-thoracic vest immobilization.

Of the 10 patients discharged from the hospital after surgical treatment, eight returned to routine activity with no late neurological deterioration; one patient was doing well at the time of discharge but there was no long-term follow-up data available; and one patient remained a Frankel Grade A ventilator-dependent quadriplegic at 3-month follow-up examination. A stable bone fusion was achieved in all eight patients with available radiological follow-up data.

DISCUSSION

Treatment of odontoid fractures in the elderly can be difficult and is often associated with significant morbidity and mortality rates.[1,3,4,7, 9–12] Pepin, et al.,[11] reported on 41 patients with odontoid fractures, 19 of whom were aged 60 years or older. Halo-thoracic vest immobilization was attempted in four patients older than 60 years; in three the halo-thoracic vest failed, leading to death in one patient and requiring removal of the orthosis in the other two. The authors concluded that a more conservative approach would be beneficial in the elderly. Hanigan, et al.,[7] reported on 19 patients aged 80 years or older with odontoid fractures. Five (26%) of the 19 patients died during hospitalization. All five deaths were associated with bed rest and nonsurgical management in a cervical collar. Of two patients treated in a halo-thoracic vest one required removal of the halo secondary to respiratory compromise. None of the five patients surgically treated died, and there was no evidence of late neurological deterioration in patients who developed a stable nonunion. The authors concluded that prolonged bed rest and rigid immobilization were associated with significant morbidity and mortality rates, whereas treatment in a Philadelphia collar with formation of a stable fibrous union may be sufficient in the elderly.

Ryan, et al.,[12] reported on 30 patients aged 60 years or older with Type II odontoid fractures. Only one patient underwent primary spinal fusion with the remaining treatments ranging from nothing to a halocast. In this geriatric population there was a 77% nonunion rate but no evidence of late neurological deterioration on follow-up evaluation. Bednar, et al.,[4] reported a 46% in-hospital mortality rate in 33 consecutive elderly patients with Type II odontoid fractures who were managed nonsurgically and no in-hospital deaths in 11 consecutive patients who were treated surgically. The authors concluded that an aggressive primary surgical management protocol can significantly decrease in-hospital mortality. The authors of three recent series on surgically treated elderly patients with odontoid fractures have reported surgical mortality rates from 0 to 57%.[5,6,10]

The current study represents a retrospective review of patients aged 65 years or older with Type II odontoid fractures who were consecutively admitted to a single medical center over a 5-year period. Consistent with previous investigations, low-energy falls accounted for the majority of the fractures, posterior displacement of the odontoid predominated, SCI was associated with posterior displacement of the odontoid, and associated in-hospital deaths were high at 20%.[4,7,9,11,12] Initial treatment was chosen based on the anatomy of the fracture and the medical frailty of the patient, combined with the wishes of the patient and family. The mean initial odontoid displacement was greatest (7.5 mm) in those patients treated primarily with surgery and least in those patients who completed a course of treatment in a cervical orthosis (3.3 mm).

In 14 (70%) of 20 patients the primary treatment was nonsurgical. The nonsurgical treatment consisted of an external cervical orthosis, which was a halo-thoracic vest, Minerva brace, or Miami J collar. The goal of treatment with the cervical orthosis was stabilization of the odontoid fracture and early mobilization of the patient. Of the 12 patients treated in a cervical orthosis six were treatment failures. All of the treatment failures and complications were in patients treated in either a halo-thoracic vest or Minerva brace. Treatment failed in six of 10 patients treated with either a halo-thoracic vest or Minerva brace. The failure of these cervical orthoses in which a a thoracic vest was used was secondary to either restricted mobility producing respiratory compromise and failure to thrive or inadequate stabilization of the fracture. Lind, et al.,[8] published data suggesting that there might be decreased ventilatory capacity in patients wearing halo-thoracic orthoses, and Anderson, et al.,[2] documented movement of the cervical spine in the halo-thoracic vest after cervical spine injury. A possible explanation for the high failure rate of cervical orthoses in which a thoracic vest is used in the elderly is that the decreased respiratory reserve in the geriatric population is significantly further compromised by the thoracic vest, leading to morbidity and death. The decreased respiratory reserve in the elderly may also limit a tight fit between the vest and the thorax, resulting in inadequate external immobilization. A true evaluation of the less restrictive Miami J collar is not possible in this study because of the small number of patients treated with this cervical orthosis.

The goal of surgical treatment of Type II odontoid fractures is internal fixation and ultimately fusion of the fracture or bone graft. Although both anterior odontoid screw fixation and posterior C1–2 transarticular screw fixation with modified Gallie fusion achieved these goals in this population, the two patients treated with anterior odontoid screws were maintained in a halo-thoracic vest postoperatively because of poor odontoid screw fixation in osteoporotic bone. Because halo-thoracic vest immobilization has been associated with increased morbidity and death in the geriatric population in multiple studies (including this study), the posterior C1–2 transarticular screw fixation with modified Gallie fusion was a superior procedure, providing better internal fixation and allowing for earlier mobilization in a less restrictive brace.

The morbidity and mortality rates for the nonsurgical and surgical groups were similar; however, there was a higher rate of failure in the nonsurgical group. For those patients completing nonsurgical and surgical management, the clinical outcomes were similar, but the surgical group had a higher rate of stable fusion based on follow-up radiographic evaluation. The long-term outcome of a stable nonunion in the geriatric population may be adequate and needs to be further studied.

CONCLUSIONS

Type II odontoid fractures in this elderly population were associated with an in-hospital rates of 10% morbidity and 20% mortality. Nonsurgical treatment with a halo-thoracic vest or Minerva brace resulted in a 60% early failure rate (six of 10 patients) with 10% morbidity and 10% mortality rates, whereas surgical treatment was well tolerated, resulting in a 9% early failure rate (one of 11 patients) with 9% morbidity and 9% mortality rates. Posterior C1–2 transarticular screw fixation with modified Gallie fusion provided superior internal fixation and avoided the need for postoperative halo-thoracic vest or Minerva brace immobilization when the Type II odontoid fracture was not associated with other spinal fractures. Further study needs to be undertaken to investigate the role of less restrictive cervical orthoses and surgical intervention in the long-term outcome of Type II odontoid fractures in the geriatric population.

References

1. Anderson LD, D'Alonzo RT: Fractures of the odontoid process of the axis. **J Bone Joint Surg (Am) 56:**1663–1674, 1974
2. Anderson PA, Budorick TE, Easton KB, et al: Failure of halo vest to prevent in vivo motion in patients with injured cervical spines. **Spine 16 (Suppl 10):**S501–S505, 1991
3. Apuzzo MLJ, Heiden JS, Weiss MH, et al: Acute fractures of the odontoid process. An analysis of 45 cases. **J Neurosurg 48:** 85–91, 1978
4. Bednar DA, Parikh J, Hummel J: Management of type II odontoid process fractures in geriatric patients; a prospective study of sequential cohorts with attention to survivorship. **J Spinal Disord 8:**166–169, 1995
5. Berlemann U, Schwarzenbach O: Dens fractures in the elderly. Results of anterior screw fixation in 19 elderly patients. **Acta Orthop Scand 68:**319–324, 1997
6. Campanelli M, Kattner KA, Stroink A, et al: Posterior C1-C2 transarticular screw fixation in the treatment of displaced type II odontoid fractures in the geriatric population—review of seven cases. **Surg Neurol 51:**596–601, 1999
7. Hanigan WC, Powell FC, Elwood PW, et al: Odontoid fractures in elderly patients. **J Neurosurg 78:**32–35, 1993
8. Lind B, Bake B, Lundqvist C, et al: Influence of halo vest treatment on vital capacity. **Spine 12:**449–452, 1987
9. Marchesi DG: Management of odontoid fractures. **Orthopedics 20:**911–916, 1997
10. Muller EJ, Wick M, Russe O, et al: Management of odontoid fractures in the elderly. **Eur Spine J 8:**360–365, 1999
11. Pepin JW, Bourne RB, Hawkins RJ: Odontoid fractures, with special reference to the elderly patient. **Clin Orthop (193):** 178–183, 1985
12. Ryan MD, Taylor TKF: Odontoid fractures in the elderly. **J Spinal Disord 6:**397–401, 1993

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