

Anterior fixation of odontoid fractures in an elderly population

Clinical article

ANDREW T. DAILEY, M.D.,¹ DAVID HART, M.D.,² MICHAEL A. FINN, M.D.,¹
MEIC H. SCHMIDT, M.D.,¹ RONALD I. APFELBAUM, M.D.,¹

¹Department of Neurosurgery, University of Utah, Salt Lake City, Utah; ²Department of Neurological Surgery, Case Western Reserve University, Cleveland, Ohio

Object. Fractures of the odontoid process are the most common fractures of the cervical spine in patients over the age of 70 years. The incidence of fracture nonunion in this population has been estimated to be 20-fold greater than that in patients under the age of 50 years if surgical stabilization is not used. Anterior and posterior approaches have both been advocated, with excellent results reported, but surgeons should understand the drawbacks of the various techniques before employing them in clinical practice.

Methods. A retrospective review was undertaken to identify patients who had direct fixation of an odontoid fracture at a single institution from 1991 to 2006. Patients were followed up using flexion-extension radiographs, and stability was evaluated as bone union, fibrous union, or nonunion. Patients with bone or fibrous union were classified as stable. In addition, the incidence of procedure- and nonprocedure-related complications was extracted from the medical record.

Results. Of the 57 patients over age 70 who underwent placement of an odontoid screw, 42 underwent follow-up from 3 to 62 months (mean 15 months). Stability was confirmed in 81% of these patients. In patients with fixation using 2 screws, 96% demonstrated stability on radiographs at final follow-up. Only 56% of patients with fixation using a single screw demonstrated stability on radiographs. In the immediate postoperative period, 25% of patients required a feeding tube and 19% had aspiration pneumonia that required antibiotic treatment.

Conclusions. Direct fixation of Type II odontoid fractures showed stability rates > 80% in this challenging population. Significantly higher stabilization rates were achieved when 2 screws were placed. The anterior approach was associated with a relatively high dysphagia rate, and patients must be counseled about this risk before surgery. (DOI: 10.3171/2009.7.SPINE08589)

KEY WORDS • elderly • fracture • odontoid process • odontoid screw

ODONTOID fractures comprise up to 20% of all cervical spine fractures.^{14,21,28,65} In patients \geq 70 years old, Type II odontoid fractures are the most common type of cervical fracture.^{52,57} As the population ages, the incidence of Type II odontoid fractures is likely to continue to increase. Because cortical and cancellous portions of the dens become significantly less robust with age, these fractures may occur in the setting of low-impact mechanisms such as ground-level falls in elderly patients.² The instability of these fractures can lead to immediate or delayed spinal cord and respiratory injuries, potentially leading to devastating neurological compromise and death.³⁴

The optimal treatment for Type II odontoid fractures

in older patients remains controversial.^{9,11,15,35,65} Current stabilization modalities include external rigid immobilization or surgical fixation. Although rigid orthoses can lead to successful fusion at the fracture site, there is a higher rate of pseudarthrosis, with reported rates ranging from 15 to 85%.^{17,30,32,52,54} Factors that have been reported to contribute to nonunion include advanced age, delay in treatment, anterior displacement > 4 mm, and posteriorly displaced fractures.^{22,57} Lennarson et al.⁴³ reported a case control series of patients with Type II odontoid fractures treated using halo vest immobilization. The risk of failure was 21 times greater in patients over the age of 50 years in this study. Other authors have reported increased morbidity and death secondary to cardiopulmonary compro-

mise in elderly patients with odontoid fractures treated with halo vest immobilization.^{32,60,64}

The complications of external immobilization in patients ≥ 50 years old suggest that surgical fixation should be considered as a treatment option for functional members of this patient group. Posterior cervical fusion had historically been the primary alternative for patients with odontoid fractures when external immobilization either failed or was considered inappropriate. Although it results in higher fusion rates, posterior arthrodesis of the C1–2 vertebrae eliminates all of the normal C1–2 rotary motion, which accounts for 50% of the total cervical rotary motion, and 10% of cervical flexion and extension.^{8,15,66} Consequently, anterior odontoid screw fixation was developed as an alternative treatment option. This is an osteosynthetic technique and provides immediate stability, promotes healing, and may preserve the majority of the remaining C1–2 motion. Since its introduction in the early 1980s, this technique has gained wide acceptance through advances in instrumentation and fluoroscopic technique.¹³ This approach offers several advantages, including decreased surgical soft-tissue trauma, lack of requirement for bone grafting, decreased risk of injury to the vertebral arteries, and preservation of C1–2 rotational motion. It requires less operative time and often can shorten hospital stay and convalescence. The utility of this method of treatment can be limited by nonreducible fractures due to fragment geometry or by body habitus such as a barrel-shaped chest, short neck, and cervical or thoracic kyphosis, which may prevent proper trajectory of the screw placement. Although not all patients are candidates for direct fixation because of anatomical limitations, multiple studies have demonstrated fusion rates of 80–100% using this treatment modality when it can be used.^{8,12,19,25,42,51,63} We report our experience, including both medical and procedural complications, with direct anterior fixation of odontoid fractures in an exclusively elderly population.

This study is not a comparison of anterior versus posterior surgical approaches, as we offered odontoid screw fixation as the preferred surgical approach in most patients. Only in patients whose neck geometry precluded the low trajectory approach needed to place an odontoid screw, or in whom the bone quality was believed to be too poor for screw fixation, was C1–2 posterior instrumented fusion offered as the surgical option (see *Discussion*).

Methods

After approval from the University of Utah Institutional Review Board, the senior author's database of all cervical surgeries performed over a 15-year period (1991–2005) was queried to identify all patients who had an odontoid fracture treated using direct anterior fixation. These patients were treated by 1 of 7 surgeons. Patients with suitable anatomy (see *Discussion*) were offered odontoid screw fixation or immobilization in a rigid cervical orthosis. If the patient was deemed an acceptable risk for surgery and the patient or family wished to proceed, fixation with either 1 or 2 screws was attempted. The operating surgeon determined how many screws to use. Some

surgeons had a preference for the placement of 2 screws in all patients with suitable anatomy, while others used 1 screw if they believed it had sufficient purchase. Patients were monitored until stability was confirmed with either bridging of trabeculated bone across the fracture (bone fusion) or by lack of motion on flexion-extension radiographs despite the presence of a residual fracture line (stable fibrous union).

We reviewed all hospital and outpatient records to identify major and minor complications associated with anterior odontoid screw fixation. Procedure-related complications included nonunion, oropharyngeal difficulties such as dysphagia requiring feeding tube placements, and aspiration pneumonia. Nonprocedural complications included myocardial infarction, sepsis, deep vein thrombosis, and other morbidities that are frequently associated with surgery in the elderly population.

Statistical Analysis

A chi-square analysis was performed to evaluate whether there was a benefit to placement of 2 screws rather than a single screw. A probability value ≤ 0.05 was considered statistically significant.

Results

Over a 15-year period (1991–2005), 57 patients over the age of 70 with Anderson and D'Alonzo³ Type II and shallow Type III odontoid fractures were treated by direct anterior screw fixation using the technique described by Apfelbaum.⁶ Of these 57 patients, 42 underwent follow-up from 3 to 62 months (mean 15 months). The 30 women (53%) and 27 men (47%) ranged in age from 70 to 96 years, with a mean age of 81.2 years. There were 54 Type II (95%) and 3 shallow Type III (5%) odontoid fractures. Ground-level falls and vehicle-related accidents accounted for 36 (63%) of 57 and 11 (19%) of 57 fractures, respectively. The remaining fractures resulted from a fall from a height in 8 (14%) of 57 patients and unknown mechanisms in 2 (4%) of 57 patients. Associated cervical fractures included 11 C-1 fractures (19%), 1 additional C-2 fracture (2%), and 4 subaxial cervical spine fractures (7%). All patients were neurologically intact in regard to their odontoid fracture and its effect on upper cervical cord function.

One screw was used in 21 patients (37%), and the remaining 36 patients (63%) underwent placement of 2 screws. Clinical notes after surgery were available in 52 of 57 patients. Of these 52 patients, 3 were treated with halo vest immobilization and 33 were immobilized for at least 4 weeks in a collar. No cervical orthosis was used in the remaining patients.

Patient follow-up ranged from 0 to 62 months, with a mean duration of 14 months. A total of 7 (12%) of 57 patients were lost to follow-up after hospital discharge. Additionally, 5 (9%) of 57 patients died during the perioperative period (within 3 months) because of cardiopulmonary complications (4 of 5) or suspected gastrointestinal hemorrhage (1 of 5). Three patients (5%) had no follow-up after the initial postoperative visit at 1 month, and 1 of these patients later died of pulmonary complications.

Anterior fixation of odontoid fractures in the elderly

A total of 42 patients had flexion-extension radiographs available at 3 months from which fusion status could be assessed. Radiographs revealed a stable bone union in 24 (57%) of 42 patients, a stable fibrous union in 10 (24%), and a nonunion in 8 (19%). Overall, 81% of these patients were stable radiographically at their last follow-up visit. One patient with a nonunion required a longer screw after the original screw displaced inferiorly. Three (7%) of the 42 patients experienced early hardware failure with toggling of the screw through the anterior cortex of the C-2 vertebral body. Two of these 3 patients underwent successful reduction and posterior C1–2 fusion; the other patient needed an extensive posterior cervical fusion with instrumentation from the occiput to C-4 after failure of 2 anterior screws and difficulty gaining fixation into C-1 or C-2 at the revision posterior procedure.

Of the 26 patients treated with 2 screws, 19 attained solid bone union (Fig. 1), 6 attained a stable fibrous union, and 1 had nonunion. Of the 16 patients treated with 1 screw, 5 attained solid bone union, 4 attained stable fibrous union (Fig. 2), and 7 had nonunion (Fig. 3). Chi-square analysis revealed that there was a significant benefit to the placement of 2 screws ($p \leq 0.05$). When patients with fusion and fibrous union were classified together as stable patients, 25 (96%) of 26 patients with 2 screws were stable, whereas 9 (56%) of 16 of those with 1 screw were stable (Table 1).

In the early postoperative period, 20 (35%) of 57 patients experienced dysphagia. Of these 20 patients, 6 had mild dysphagia that did not require treatment beyond dietary modification and 14 patients (25%) needed placement of a temporary feeding tube for a period ranging from 2 days to 4 months. There were also 11 (19%) of 57 patients with perioperative pneumonia. One patient had laryngeal spasm postoperatively that led to reintubation. Three patients (5%) suffered from perioperative myocardial infarctions.

Discussion

We routinely attempt to monitor patients who undergo odontoid screw fixation for 2 years or until solid bone fusion is observed. The elderly group included in this study presents a challenge in this regard because they may die or become disabled because of other causes and fail to be able to return for follow-up. Excluding the 12 patients who died or were lost to follow-up early, we were able to follow-up 100% of the remaining patients for 3 months, 88% for 6 months, 55% for 12 months, and 29% for 24 months. Fusion percentages increased progressively with the duration of follow-up. Seventy-six percent of patients with follow-up > 6 months demonstrated bone fusion and 16% had a fibrous union.

The long-term goal of this surgery is to stabilize the C1–2 region and prevent neurological injury. Fibrous union occurs initially and then progresses to bone fusion, often over a significant period of time. If adequate fibrous union does not occur, there will be increasing absorption of bone around the screws, resulting in failure of fixation and increased motion. In the absence of such changes involving the screws, if the patient's neck remains stable on flexion-extension radiographs, we believe we have achieved the goals of surgery, and therefore, we consider this a good result. In our experience if we have a long enough follow-up period, fibrous union remains stable and gradually progresses in most patients to bone union, but this may take an extended period of time. If we consider only the patients in our series in whom we have follow-up data for a minimum of 6 months, the percentage of bone fusion was 76%, with an additional 16% showing fibrous union. This rate is higher than the overall figure stated for the entire series and reflects this progressive increase in bone fusion over time. In contradistinction, failure to achieve adequate stability is usually quickly manifested by increased motion and fixation failure within a few weeks to months.



Fig. 1. Lateral flexion (left) and extension (right) radiographs obtained at 3-month follow-up in an 80-year-old woman who suffered a Type II fracture after a ground-level fall and was treated with insertion of 2 screws. These images demonstrate lack of motion across the fracture site and trabecular bridging bone.



Fig. 2. Lateral flexion (*left*) and extension (*right*) radiographs obtained at 3-month follow-up in a 73-year-old woman who suffered a Type II fracture after a ground-level fall and was treated with insertion of 1 screw. These images demonstrate lack of trabecular bridging at the fracture site, but lack of motion indicating stable fibrous union.

Optimal treatment for Type II odontoid fractures in elderly patients remains controversial because of the prevalence of increased comorbidities and decreased bone density associated with the elderly population. Although these patients were all neurologically intact, fractures of the odontoid always result in instability unless C-1 is fused to C-2 or odontoid integrity is restored. Therefore, the potential exists for catastrophic neurological compromise with any additional trauma, even minor trauma. Treatment to immobilize and ultimately stabilize the neck is indicated in most patients. The published “Guidelines for the Management of Acute Cervical Spine and Spinal Cord Injuries,” an evidence-based review, proposed as a guideline that “Type II odontoid fractures in patients 50 years or older should be considered for surgical stabilization and fusion.”⁷⁵ Even in the absence of potentially catastrophic results from additional trauma, patients may also complain of neck pain, which can become chronic if neck stability is not achieved.

Although external fixation remains an option in the elderly population, the fusion rate between 7 and 75% is much lower than that in younger patients.^{9,17,32,43,44,47} In addition, immobilization with a halo vest in patients older than 65 years old has been associated with a mortality rate that is 4 times greater than that of patients younger than 65 years old,^{48,64} with a high incidence of aspiration pneumonia and respiratory arrest. In reviewing a series of 78 patients with odontoid fractures over the age of 65, Tashjian et al.⁶⁴ found an in-hospital mortality rate > 30% in patients immobilized in a halo vest and a 2-fold increase in pulmonary and cardiac complications. The high incidence of mortality using halo vest immobilization in elderly patients suggests that surgical stabilization is a reasonable treatment option in these patients.

Posterior C1–2 arthrodesis had been used when external immobilization failed or was an inappropriate treatment modality, and the addition of rigid fixation with transarticular screws has provided fusion rates >

95%, although with a substantial reduction in axial rotation.^{11,15,18,20,27,37,61} The procedure is more extensive than odontoid screw fixation, carries increased risk, and requires the patients to remain hospitalized longer. As a result of these considerations, anterior fixation of the odontoid as described by Bohler¹³ and Nakanishi et al.⁵³ has become a popular choice for treatment of fractures that are noncomminuted and are readily realigned. The surgery is less traumatic, allowing patients to be mobilized rapidly postoperatively, and reduces morbidity and death associated with external immobilization alone.^{11,12,33,64} In a large meta-analysis of the literature, Julien et al.³⁹ reported an overall stability rate of 87% for odontoid screw fixation. Subach et al.⁶³ reported a series of younger patients (mean age 35 years) and found a fusion rate of 95% for single screw fixation. In the largest series published in the literature, Apfelbaum et al.⁸ reported on 129 patients with recent odontoid fractures, in whom they achieved a bone union rate of 88%.

Our clinical practice is to evaluate patients with odontoid fractures using thin-sectioned CT scans and reconstructed images in the coronal and sagittal planes. The cancellous bone within the odontoid process is usually very weak, with the real strength of the odontoid achieved by the cortical shell. The apical cortex is the most dense area. For this reason, it is essential that odontoid fixation screws engage the cortex fully; to do so, a shallow trajectory from the low cervical area is necessary. The guide tube instrumentation we have developed^{7,8} facilitates performing this accurately, but the patient’s anatomy must allow this trajectory. Subaxial cervical spondylosis may result in a rigid neck in a straight or even kyphotic angulation that are contraindicated for this trajectory, and a large chest and short neck, alone or in combination with the above, may also limit access. Unless the patient can be positioned so that a straight tool alongside the neck achieves the desired pathway through C-2 and clears the chest, this procedure is not offered. This means at times



Fig. 3. Sagittal CT scan reconstruction confirming obvious nonunion with bone resorption, lack of bone healing, and pull-out of a single odontoid screw in an 83-year-old woman treated for a Type II odontoid fracture. This patient was successfully treated using a posterior C1–2 fusion.

that the patient is prepared for both approaches, and a decision is made in the operating room when positioning the patient.

Bone density for screw fixation is harder to evaluate. Because the lag screw compresses between the inferior cortex of C-2 and the apical odontoid cortex, the 2 strongest areas of C-2, these areas are examined critically on the CT scans to make decisions. Lack of good bone density elsewhere in C-2 is not usually a contraindication. However, additional fractures within the body of C-2 are usually a contraindication to anterior odontoid screw fixation.

Using these criteria, we have been able to use odontoid screw fixation in most of our elderly patients with an acute fracture. During the same time period as the odontoid screw cases we are reporting, we performed 219 C1–2 posterior fusions, of which 52 were in patients older than 70 years of age but only 6 of these were for acute odontoid fractures. We, therefore, could successfully place odontoid screws in 90% of the elderly patients we treated for acute odontoid fractures over this 15-year interval.

Other major selection factors are the patient’s functional status and the wishes of the patient and patient’s family. We do not recommend surgical treatment for elderly patients who have an extremely poor quality of life, such as an elderly patient with dementia living in a nursing home, unless the family insists. On the other hand, age alone is not the issue because many elderly patients have a good quality of life, perhaps living unassisted and at times even working. The severity of underlying medical conditions is evaluated as for similar surgery at any age.

The success of direct fixation in older patients has varied widely throughout the literature. Berlemann and

TABLE 1: Summary of fusion data in elderly patients who underwent anterior fixation of odontoid fractures

No. of Screws	Stable		Unstable
	No. of Patients w/ Fusion (%)	No. of Patients w/ Fibrous Union (%)	No. of Patients w/ Nonunion (%)
1	5 (31)	4 (25)	7 (44)
2	19 (73)	6 (23)	1 (4)

Schwarzenbach¹² reported on 19 patients who had direct odontoid fixation and found that 84% attained solid fusion, with all patients attaining stability by either fibrous or bone union. Recently, Platzer et al.⁵⁵ showed a union rate of 88% in patients older than 65 years and documented normal range of motion in > 90% of the patients. We have shown an 81% overall union rate using an anterior approach in elderly patients, which is comparable to results reported in other series.^{1,26,36,55} However, not all series have confirmed high success rates; Anderson et al.⁴ report a success rate of < 30% in their series. As a result, many surgeons advocate a C1–2 posterior fixation for elderly patients with odontoid fractures,^{11,27,47} and fusion rates > 95% using this approach in older patients have been reported. As in the overall patient population, posterior approaches carry additional risks, including risks of injury to the vertebral artery, and the cardiac and pulmonary complications of prone positioning in the elderly patient must be considered if posterior fixation is attempted.

One reason for the disparity in fusion rates reported in the literature may be the use of a 1-screw or 2-screw technique in the elderly population. Many authors have advocated multiple-screw fixation, which would prevent an axis of rotation around a single screw and theoretically would also increase construct strength.^{1,13,24,29} No significant improvement in load-bearing capacity or flexion-extension and rotational stiffness has been demonstrated with the addition of a second screw in a cadaveric model;⁵⁸ however, these biomechanical studies have not addressed the density of the specimen, and thus, relevance to the elderly population with osteopenic bone remains questionable. Also, loss of construct strength with repetitive motion was not evaluated. In addition, CT evaluation of the upper cervical spine in patients with odontoid fractures has revealed a higher incidence of atlantodontoid arthritis and ankylosis than in an age-matched cohort, suggesting that these patients are prone to higher stresses across the base of the dens.⁴¹ Clinically, similar fusion rates have been described when a single screw has been used for Type II odontoid fractures.^{16,24,31,38,42,61,63} However, Platzer et al.⁵⁵ achieved high success rates using 2 screws, and we noted a significantly higher success rate ($p \leq 0.05$) in our patients undergoing instrumentation with 2 screws (96 vs 56%). The validity of this conclusion can be questioned, because the patients were not randomized, and those receiving 2 screws may have had a broader dens over which to fuse. Nevertheless, it is logical that the addition of another screw adds rotational stability in the osteopenic bone of the elderly, which should increase the chance of fusion. These patients whose weakened bone

fractured in a low impact injury are different than younger patients whose bone is stronger, requiring much greater force to fracture. In younger patients, the interlocking of the more dense bone edges at the fracture site may result in more stabilization, so that 1 screw is adequate. This may explain why studies with a larger number of younger patients may not show a benefit in placing 2 screws.

We encountered a relatively high incidence of postoperative dysphagia in our patient group, with 35% of the patients needing diet modification or a nasogastric tube after surgery. Given the mean age in our patient group (81.2 years), it suggests the vulnerability of the elderly population to anterior cervical surgery. The authors of multiple studies evaluating dysphagia in the elderly after anterior cervical spine surgery have suggested that the elderly patient's esophagus becomes fibrotic and thus, less tolerant to retraction, compared with the normal histology observed in younger patients. In fact, progressive dysphagia is a natural sequelae of senescence.⁵⁹ Rates of dysphagia after anterior cervical surgery may be as high as 60% immediately after surgery and persist in up to 21% of patients at 6 months.^{10,56,62,67,68} In addition, rates of dysphagia may be underreported in up to 80% of patients.²³

The consequences of dysphagia are greater than a need for a nasogastric or gastrostomy tube because aspiration pneumonia may develop in patients with an aberrant swallowing mechanism.⁴⁹ The incidence of pneumonia increases with aging, with an almost 6-fold higher incidence in those 75 years old or older compared with those younger than 60 years old.^{40,45} In our series, 11% of patients had postoperative aspiration pneumonia that required either antibiotic treatment, readmission to the intensive care unit, or, in 2 cases, prolonged intubation. The natural tendency toward swallowing disorders that occurs with senescence may be further compounded by the potential for injury of the superior laryngeal nerve, the internal branch of which provides sensory innervation to the mucosa of the larynx. The nerve leaves the vagus in the carotid sheath and courses medially in close proximity to the superior laryngeal artery to pierce the thyrohyoid membrane at approximately the C3–4 level.⁵⁰ Damage can result from excessive traction, accidental ligation, or postoperative swelling,⁴⁶ and further increase the risk of aspiration pneumonia through impairment of laryngeal sensation and the cough reflex. Avoidance of dysphagia may be minimized by familiarity with the anatomy and avoidance of aggressive retraction, but elderly patients, especially those who have undergone previous cervical surgery, need to be counseled regarding the risks of dysphagia when treating odontoid fractures.

Conclusions

Type II odontoid fractures represent a significant percentage of cervical injuries in the elderly population. Optimal treatment in this group of patients remains controversial. We report an overall 81% rate of stable union using anterior odontoid screw fixation for these types of fractures. The use of 2 screws when possible increased the success rate from 56 to 96%. The high incidence of

clinically significant dysphagia and, to a lesser extent, aspiration pneumonia postoperatively serves as a cautionary note and highlights the susceptibility of the elderly population to dysphagia-related complications of anterior cervical surgery. Knowledge of this concern can be factored into surgical decision-making, and proper patient counseling can help prepare the elderly patient for possible risks. These issues must be weighed against the loss of function and morbidity associated with posterior arthrodesis, which can be avoided with direct anterior screw fixation. We believe that anterior odontoid screw fixation is an effective alternative to posterior arthrodesis for Type II and shallow Type III odontoid fractures in selected elderly patients. As with any surgical procedure in the elderly, the risks of complications and death are increased and need to be evaluated on a case-by-case basis.

Disclosure

Dr. Apfelbaum reports that he helped develop instrumentation for placing odontoid screws (Aesculap AG), but has no ongoing financial interest in the system. Dr. Hart has served as a consultant to Aesculap and DePuy Spine.

Acknowledgment

The authors thank Kristin Kraus, M.Sc., for her editorial assistance in preparing this paper.

References

1. Aebi M, Etter C, Coscia M: Fractures of the odontoid process. Treatment with anterior screw fixation. **Spine** **14**:1065–1070, 1989
2. Amling M, Posl M, Wening VJ, Ritzel H, Hahn M, Delling G: Structural heterogeneity within the axis: the main cause in the etiology of dens fractures. A histomorphometric analysis of 37 normal and osteoporotic autopsy cases. **J Neurosurg** **83**: 330–335, 1995
3. Anderson LD, D'Alonzo RT: Fractures of the odontoid process of the axis. **J Bone Joint Surg Am** **56**:1663–1674, 1974
4. Andersson S, Rodriguez M, Olerud C: Odontoid fractures: high complication rate associated with anterior screw fixation in the elderly. **Eur Spine J** **9**:56–60, 2000
5. Anonymous: Isolated fractures of the axis in adults. **Neurosurgery** **50** (3 Suppl):S125–S139, 2002
6. Apfelbaum RI: Anterior screw fixation for odontoid fractures, in Rengachary SS, Wilkins RH (eds): **Neurosurgical Operative Atlas, Vol 2**. Park Ridge, IL: American Association of Neurological Surgeons, 1992, pp 189–199
7. Apfelbaum RI, Kriskovich MD, Haller JR: On the incidence, cause, and prevention of recurrent laryngeal nerve palsies during anterior cervical spine surgery. **Spine** **25**:2906–2912, 2000
8. Apfelbaum RI, Lonser RR, Veres R, Casey A: Direct anterior screw fixation for recent and remote odontoid fractures. **J Neurosurg** **93**:227–236, 2000
9. Apuzzo ML, Heiden JS, Weiss MH, Ackerson TT, Harvey JP, Kurze T: Acute fractures of the odontoid process. An analysis of 45 cases. **J Neurosurg** **48**:85–91, 1978
10. Bazaz R, Lee MJ, Yoo JU: Incidence of dysphagia after anterior cervical spine surgery: a prospective study. **Spine** **27**: 2453–2458, 2002
11. 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

Anterior fixation of odontoid fractures in the elderly

- 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
- Bohler J: Anterior stabilization for acute fractures and non-unions of the dens. **J Bone Joint Surg Am** **64**:18–27, 1982
- Borne GM, Bedou GL, Pinaudeau M, Cristino G, Hussein A: Odontoid process fracture osteosynthesis with a direct screw fixation technique in nine consecutive cases. **J Neurosurg** **68**:223–226, 1988
- Campanelli M, Kattner KA, Stroink A, Gupta K, West S: Posterior C1-C2 transarticular screw fixation in the treatment of displaced type II odontoid fractures in the geriatric population—a review of seven cases. **Surg Neurol** **51**:596–601, 1999
- Chang KW, Liu YW, Cheng PG, Chang L, Suen KL, Chung WL, et al: One Herbert double-threaded compression screw fixation of displaced type II odontoid fractures. **J Spinal Disord** **7**:62–69, 1994
- Clark CR, White AA 3rd: Fractures of the dens. A multicenter study. **J Bone Joint Surg Am** **67**:1340–1348, 1985
- Coyne TJ, Fehlings MG, Wallace MC, Bernstein M, Tator CH: C1-C2 posterior cervical fusion: long-term evaluation of results and efficacy. **Neurosurgery** **37**:688–693, 1995
- Dickman CA, Foley KT, Sonntag VK, Smith MM: Cannulated screws for odontoid screw fixation and atlantoaxial transarticular screw fixation. Technical note. **J Neurosurg** **83**:1095–1100, 1995
- Dickman CA, Sonntag VK: Posterior C1-C2 transarticular screw fixation for atlantoaxial arthrodesis. **Neurosurgery** **43**:275–281, 1998
- Dickson H, Engel S, Blum P, Jones RF: Odontoid fractures, systemic disease and conservative care. **Aust N Z J Surg** **54**:243–247, 1984
- Dunn ME, Seljeskog EL: Experience in the management of odontoid process injuries: an analysis of 128 cases. **Neurosurgery** **18**:306–310, 1986
- Edwards CC 2nd, Karpitskaya Y, Cha C, Heller JG, Laurysen C, Yoon ST, et al: Accurate identification of adverse outcomes after cervical spine surgery. **J Bone Joint Surg Am** **86**:251–256, 2004
- ElSaghir H, Bohm H: Anderson type II fracture of the odontoid process: results of anterior screw fixation. **J Spinal Disord** **13**:527–531, 2000
- Esses SI, Bednar DA: Screw fixation of odontoid fractures and nonunions. **Spine** **16**:S483–S485, 1991
- Fountas KN, Kapsalaki EZ, Karampelas I, Feltes CH, Dimopoulos VG, Machinis TG, et al: Results of long-term follow-up in patients undergoing anterior screw fixation for type II and rostral type III odontoid fractures. **Spine** **30**:661–669, 2005
- Frangen TM, Zilkens C, Muhr G, Schinkel C: Odontoid fractures in the elderly: Dorsal C1/C2 fusion is superior to halo-vest immobilization. **J Trauma** **63**:83–89, 2007
- Fujii E, Kobayashi K, Hirabayashi K: Treatment in fractures of the odontoid process. **Spine** **13**:604–609, 1988
- Geisler FH, Cheng C, Poka A, Brumback RJ: Anterior screw fixation of posteriorly displaced type II odontoid fractures. **Neurosurgery** **25**:30–38, 1989
- Govender S, Grootboom M: Fractures of the dens—the results of non-rigid immobilization. **Injury** **19**:165–167, 1988
- Graziano G, Jaggars C, Lee M, Lynch W: A comparative study of fixation techniques for type II fractures of the odontoid process. **Spine** **18**:2383–2387, 1993
- Hadley MN, Dickman CA, Browner CM, Sonntag VK: Acute axis fractures: a review of 229 cases. **J Neurosurg** **71**:642–647, 1989
- Hanigan WC, Powell FC, Elwood PW, Henderson JP: Odontoid fractures in elderly patients. **J Neurosurg** **78**:32–35, 1993
- Harrop JS, Sharan AD, Przybylski GJ: Epidemiology of spinal cord injury after acute odontoid fractures. **Neurosurg Focus** **8**:e4, 2000
- Hart R, Saterbak A, Rapp T, Clark CR: Nonoperative management of dens fracture nonunion in elderly patients without myelopathy. **Spine** **25**:1339–1343, 2000
- Henry AD, Bohly J, Grosse A: Fixation of odontoid fractures by an anterior screw. **J Bone Joint Surg Br** **81**:472–477, 1999
- Jeanneret B, Magerl F: Primary posterior fusion C1/2 in odontoid fractures: indications, technique, and results of transarticular screw fixation. **J Spinal Disord** **5**:464–475, 1992
- Jenkins JD, Coric D, Branch CL Jr: A clinical comparison of one- and two-screw odontoid fixation. **J Neurosurg** **89**:366–370, 1998
- Julien TD, Frankel B, Traynelis VC, Ryken TC: Evidence-based analysis of odontoid fracture management. **Neurosurg Focus** **8**:e1, 2000
- Koivula I, Sten M, Makela PH: Risk factors for pneumonia in the elderly. **Am J Med** **96**:313–320, 1994
- Lakshmanan P, Jones A, Howes J, Lyons K: CT evaluation of the pattern of odontoid fractures in the elderly - relationship to upper cervical spine osteoarthritis. **Eur Spine J** **14**:78–83, 2005
- Lee SH, Sung JK: Anterior odontoid fixation using a 4.5-mm Herbert screw: The first report of 20 consecutive cases with odontoid fracture. **Surg Neurol** **66**:361–366, 2006
- Lennarson PJ, Mostafavi H, Traynelis VC, Walters BC: Management of type II dens fractures: a case-control study. **Spine** **25**:1234–1237, 2000
- Lind B, Nordwall A, Sihlbom H: Odontoid fractures treated with halo-vest. **Spine** **12**:173–177, 1987
- Loeb M, McGeer A, McArthur M, Walter S, Simor AE: Risk factors for pneumonia and other lower respiratory tract infections in elderly residents of long-term care facilities. **Arch Intern Med** **159**:2058–2064, 1999
- Lu J, Ebraheim NA, Nadim Y, Huntoon M: Anterior approach to the cervical spine: surgical anatomy. **Orthopedics** **23**:841–845, 2000
- Maak TG, Grauer JN: The contemporary treatment of odontoid injuries. **Spine** **31**:S53–S60, 2006
- Majerik S, Tashjian RZ, Biffi WL, Harrington DT, Cioffi WG: Halo vest immobilization in the elderly: a death sentence? **J Trauma** **59**:350–358, 2005
- Marik PE, Kaplan D: Aspiration pneumonia and dysphagia in the elderly. **Chest** **124**:328–336, 2003
- Melamed H, Harris MB, Awasthi D: Anatomic considerations of superior laryngeal nerve during anterior cervical spine procedures. **Spine** **27**:E83–E86, 2002
- Moon MS, Moon JL, Sun DH: Treatment of dens fracture in adults: A report of thirty-two cases. **Bull Hosp Jt Dis** **63**:108–112, 2006
- Muller EJ, Wick M, Russe O, Muhr G: Management of odontoid fractures in the elderly. **Eur Spine J** **8**:360–365, 1999
- Nakanishi T, Sasaki T, Tokita N, Hirabayashi K: Internal fixation for the odontoid fracture. **Orthop Trans** **6**:176–183, 1982
- Pepin JW, Bourne RB, Hawkins RJ: Odontoid fractures, with special reference to the elderly patient. **Clin Orthop Relat Res** **(193)**:178–183, 1985
- Platzer P, Thalhammer G, Ostermann R, Wieland T, Vecsel V, Gaebler C: Anterior screw fixation of odontoid fractures comparing younger and elderly patients. **Spine** **32**:1714–1720, 2007
- Riley LH III, Skolasky RL, Albert TJ, Vaccaro AR, Heller JG: Dysphagia after anterior cervical decompression and fusion: prevalence and risk factors from a longitudinal cohort study. **Spine** **30**:2564–2569, 2005
- Ryan MD, Henderson JJ: The epidemiology of fractures and

- fracture-dislocations of the cervical spine. **Injury** **23**:38–40, 1992
58. Sasso R, Doherty BJ, Crawford MJ, Heggeness MH: Biomechanics of odontoid fracture fixation. Comparison of the one- and two-screw technique. **Spine** **18**:1950–1953, 1993
 59. Schindler JS, Kelly JH: Swallowing disorders in the elderly. **Laryngoscope** **112**:589–602, 2002
 60. Seybold EA, Bayley JC: Functional outcome of surgically and conservatively managed dens fractures. **Spine** **23**:1837–1846, 1998
 61. Shilpakar S, McLaughlin MR, Haid RW Jr, Rodts GE Jr, Subach BR: Management of acute odontoid fractures: operative techniques and complication avoidance. **Neurosurg Focus** **8**:e3, 2000
 62. Smith-Hammond CA, New KC, Pietrobon R, Curtis DJ, Scharver CH, Turner DA: Prospective analysis of incidence and risk factors of dysphagia in spine surgery patients: comparison of anterior cervical, posterior cervical, and lumbar procedures. **Spine** **29**:1441–1446, 2004
 63. Subach BR, Morone MA, Haid RW Jr, McLaughlin MR, Rodts GR, Comey CH: Management of acute odontoid fractures with single-screw anterior fixation. **Neurosurgery** **45**:812–820, 1999
 64. Tashjian RZ, Majercik S, Biffi WL, Palumbo MA, Cioffi WG: Halo-vest immobilization increases early morbidity and mortality in elderly odontoid fractures. **J Trauma** **60**:199–203, 2006
 65. Vaccaro AR, Madigan L, Ehrler DM: Contemporary management of adult cervical odontoid fractures. **Orthopedics** **23**:1109–1105, 2000
 66. White AA III, Panjabi MM: **Clinical biomechanics of the spine, ed 2**. Philadelphia: Lippincott, 1990
 67. Winslow CP, Winslow TJ, Wax MK: Dysphonia and dysphagia following the anterior approach to the cervical spine. **Arch Otolaryngol Head Neck Surg** **127**:51–55, 2001
 68. Yue WM, Brodner W, Highland TR: Persistent swallowing and voice problems after anterior cervical discectomy and fusion with allograft and plating: a 5- to 11-year follow-up study. **Eur Spine J** **14**:677–682, 2005

Manuscript submitted September 8, 2008.

Accepted July 29, 2009.

Address correspondence to: Andrew Dailey, M.D., Department of Neurosurgery, University of Utah, Salt Lake City, Utah 84132. email: andrew.dailey@hsc.utah.edu.