Treatment of Odontoid Fractures in the Aging Population

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KEY POINTS
- Odontoid fractures are the most common fracture type among the elderly population.
- Radiographic evaluation of odontoid fractures with plain films, computed tomographic imaging, and MRI plays a major role in treatment decisions.
- An array of conservative measures exists for the management of odontoid fractures ranging from semirigid orthoses to halo immobilization. Each type of brace has its own distinct risks and benefits.
- The 2 primary categories of surgical intervention for odontoid fractures are ventral odontoid screw fixation and posterior atlantoaxial arthrodesis. Fusion rates for both procedures are excellent in most patients, but pitfalls exist with both operative approaches that must be considered when selecting patients for these operations.
- There is a strong need for further high-quality research into optimal management of odontoid fractures in the elderly, a need that will only increase as the population ages worldwide.

INTRODUCTION

Nearly 20% of cervical fractures involve the odontoid process.1 This fracture pattern most often results from a forced hyperflexion or hyperextension mechanism.2 The elderly are especially vulnerable to this injury pattern and frequently present with odontoid injury after ground-level falls with associated hyperextension.3 The optimal management strategy for odontoid fractures remains controversial, particularly in the elderly,8 because of the high morbidity and mortality with both conservative and operative intervention.7 As the population ages, the landscape of spinal surgery is poised to shift dramatically,8,9 and the treatment of these patients becomes an increasingly common problem among practitioners treating spinal conditions. This review discusses the management of odontoid fractures among the elderly, with a focus on the various treatment options and their outcomes.

PATIENT EVALUATION

The definition of the elderly patient is not widely agreed on, and, as in other patient populations, there is significant heterogeneity among patients of this age group.10 Among patients who are older than 70 years, however, odontoid fractures comprise the most common cervical spine fracture and in those older than 80 years the most common overall spine fracture.11 Evaluation of patients in whom odontoid fracture is suspected consists of radiographic studies in addition to clinical evaluation. These studies can aid in definition of the fracture and in the decision on how to manage the injury.
Radiographic Evaluation

Anderson and D’Alonzo\textsuperscript{12} defined 3 types of dens fractures based on radiographic fracture pattern. Fractures involving only the tip of the odontoid are characterized as type I, those through the base as type II, and those that extend into the vertebral body as type III (Fig. 1). Although most type III and almost all type I fractures eventually fuse with conservative management in a cervical collar, nonunion rates for type II injuries are significantly higher.\textsuperscript{13}

The initial diagnostic evaluation of traumatic cervical spine injuries often includes plain radiographs, usually consisting of an anterior–posterior projection, a lateral projection, and an open-mouth view for visualization of the odontoid.\textsuperscript{14} In cases in which a fracture is identified on plain radiographs, and in those in which the index of suspicion is high, radiographs are generally followed by computerized tomography (CT).\textsuperscript{15} CT allows for both a confirmation of the presence of a fracture and improved definition of fracture morphology for use in subsequent management decisions.\textsuperscript{16} Indeed, the effectiveness of CT for cervical spine trauma, combined with its ubiquity in modern practice, led some to question the need for plain radiographs in this patient population.

The role of MRI in odontoid fractures remains an area of debate. Although ligamentous injury, specifically of the transverse atlantal ligament, may be missed on plain radiographs and CT, the incidence of this seems to be low—between 0% and 10%.\textsuperscript{17–19} Despite the rarity of this injury, the integrity of the transverse ligament is an important consideration in the treatment algorithm. Although well-aligned bony fractures may heal with orthosis, ligamentous injury in addition to the fracture has a significantly lower healing rate.\textsuperscript{20} Additionally, if the prospect of operative intervention is entertained, odontoid screw fixation would not be appropriate in the setting of ligamentous injury.\textsuperscript{21}

\begin{figure}
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\caption{The Anderson and D’Alonzo\textsuperscript{12} odontoid fracture classification. (A) Anterior/posterior views. (B) Lateral views.}
\end{figure}
Complicating decisions about the use of MRI in the elderly are that MRI findings may also be difficult to interpret in this population because of their bone composition and misinterpretation can lead to misdiagnosis.22

**Risk Factors for Odontoid Fracture**

The predilection for odontoid fractures in the elderly is believed to be secondary to progressive degenerative changes in the cervical spine as individuals age.23 As these changes occur, motion in the subaxial cervical spine decreases, leaving the C1–2 segment as the most mobile portion of the neck. One recent study suggests that elderly individuals with severe osteoporosis and with significant degeneration of the atlanto-odontoid joint combined with a smoothened lateral atlantoaxial joint may be at higher risk for type II odontoid fractures after trauma.24 A vascular mechanism has been implicated as well, with a watershed area at the base of the dens that is more pronounced in the elderly, contributing to fracture risk.9

Premorbid clinical risk factors for odontoid fractures after trauma in the elderly population have not been well studied,7 although variables ranging from the location of the fall25 to racial/ethnic disparities26 have been investigated in the general trauma literature. As is the case with other traumatic injuries, worse premorbid health seems to be associated with increased morbidity and mortality in odontoid fractures regardless of management strategy,7 as is the presence of neurologic deficit.27

**CONSERVATIVE MANAGEMENT**

Conservative management for odontoid fractures most commonly consists of rigid external fixation—with either a hard cervical collar or halo immobilization. These options are sometimes chosen in the elderly because of concerns for operative morbidity in this fragile population.28 This risk must be counterbalanced with the higher rates of nonunion with external immobilization alone.29

**Orthotic Types**

A variety of braces are currently marketed for the management of cervical injury, falling into 4 broad categories as defined by Johnson and colleagues.30 The least restrictive cervical collar is the so-called soft collar. Although comfortable and economical, soft collars provide little in the way of motion limitation and, therefore, play little role in the management of odontoid fractures. The second category is the semirigid orthosis, generally comprising 2 interlocking polymer segments; this category includes the Aspen (Fig. 2) and Miami-J collars.31 These collars provide significantly more motion limitation—especially of rotational movement—compared with soft collars, at the cost of a lower degree of comfort.32 The Minerva brace includes a thoracic element to the construct and commonly incorporates a posterior occipital bolster with a mandibular brace, providing further limitation of flexion and extension. The most restrictive external orthotic solution is the halo vest. Although offering the maximal movement limitation in all planes—flexion/extension, rotation, and

Fig. 2. Artist’s representation of (A) hard cervical Aspen collar, (B) cervicothoracic brace, and (C) halo brace.
lateral bending—\textsuperscript{31,32} the halo requires physician expertise for application.\textsuperscript{33} The use of pins for halo vest fixation also necessitates the use of local anesthetic and can lead to various complications, including infection, nerve injury, and even fractures and durotomy.\textsuperscript{34}

\textbf{Outcomes and Complications}

There remains a significant lack of high-quality evidence in the literature with regard to outcomes after conservative management of odontoid fractures in the elderly,\textsuperscript{6} with most studies on the topic consisting of small case series. Interpretation of the results is hampered by the use of a variety of brace types between and even within individual studies.

Rates of bony fusion with external immobilization and type II fractures vary depending on the study from as low as 23\% to as high as 82\%,\textsuperscript{35–37} Although osseous fusion has classically been the standard of success in the healing of odontoid fractures, a body of literature exists suggesting that in asymptomatic patients who are stable on flexion/extension imaging, so-called fibrous union should also be considered an acceptable outcome.\textsuperscript{38,39}

As described previously, the halo brace provides the most rigid external construct available, and historically many practitioners have advocated its use as the first-line treatment for elderly patients with odontoid fractures.\textsuperscript{37,39} Fusion rates with halo fixation can reach as high as 90\%, although significant variability exists because of the heterogeneity of the literature.\textsuperscript{8} Despite the rigidity offered by the halo, significant attention was paid in the last decade to the high rate of complications associated with their use in the elderly. Morbidity—primarily consisting of pneumonias—was reported in up to 52\% of this patient population with halo vest immobilization.\textsuperscript{40} Mortality rates are often similarly high, leading one author to deem the halo a “death sentence” for older patients with cervical fractures.\textsuperscript{41} Despite these concerns, in carefully chosen cases, many surgeons continue to have high rates of success with halo fixation.\textsuperscript{42}

Concerns over the use of halo fixation led some to use semirigid braces and cervicothoracic bracing systems such as the Minerva brace to treat patients with dens fractures. Sime and colleagues\textsuperscript{53} recently did a meta-analysis of 13 studies examining differences in outcomes and complication rates between these alternative systems and the halo. With regard to achieving stability—defined as osseous fusion or fibrous nonunion without motion on flexion/extension films—patients placed in halos had a success rate of 84\%, whereas those in semirigid orthoses had a success rate of 63\%, and those placed in Minerva braces had a success rate of 65\%. Halo patients had an overall mortality rate of 25\%, whereas those in semirigid orthoses had a mortality rate of 28\%, and those with Minerva braces had a mortality rate of 25\%. None of these differences, however, reached statistical significance. These findings were supported by a recent combined prospective/retrospective analysis of halo fixation versus semirigid orthoses by Patel and colleagues\textsuperscript{44} that also found no significant difference in outcomes, although the authors noted that bony union was more common with the halo.

Although conservative measures may sometimes be the treatment option of choice for patients and their families,\textsuperscript{45} care must be taken to avoid neurologic catastrophe. Close follow-up including surveillance radiography is necessary, as symptoms of progressive myelopathy were reported to develop years after the initial injury.\textsuperscript{46}

\textbf{SURGICAL INTERVENTION}

There are many indications for surgical intervention in odontoid fractures, including instability, symptomatology, and psychosocial variables, all of which must be carefully weighed with the risks of surgery itself and tailored to the individual patient.\textsuperscript{46} Symptoms in these patients can range from neck pain to radicular symptoms to myelopathy\textsuperscript{45} and may worsen with time or with subsequent trauma. There is evidence that surgical intervention may reduce mortality among elderly patients with odontoid fractures compared with conservative management\textsuperscript{17,48} and that the elderly may be at particular risk for failure of osseous healing with bracing alone.\textsuperscript{49,50} There is also evidence that quality-of-life outcomes for elderly patients with nonoperative treatment are worse than those of patients who receive surgery.\textsuperscript{51}

Surgical intervention for odontoid fractures can be broadly divided into 2 categories: dorsal fixation, consisting of a variety of atlantoaxial constructs, and ventral fixation, with the placement of a direct odontoid screw.

\textbf{Ventral Fixation}

Initially reported by Nakanishi in 1980,\textsuperscript{52} direct screw fixation of the odontoid process was first described in the English-language literature by Böhler.\textsuperscript{53} With proper technique, the procedure allows for stabilization of the fracture with minimal soft tissue disruption and maintenance of rotation at the atlantoaxial joint, all while avoiding the need for autograft or allograft (Fig. 3).\textsuperscript{52} Rates of fusion
in patients undergoing odontoid screw fixation are high, with a rate of 88% in the series of 147 cases by Apfelbaum and colleagues. Complications of odontoid screw fixation in elderly patients most commonly consist of pneumonia and dysphagia, although more serious complications such as intraoperative hardware failure and mortality have been reported.

Despite favorable outcomes in many patients, there are contraindications to odontoid screw fixation that must be carefully assessed before surgery. Patients with comminuted fractures of the axis, fractures with transverse ligament disruption, and pathologic fractures are poor candidates for odontoid screw placement. Fractures greater than 6 months of age are also a contraindication, with data showing that chronic fractures have dramatically lower rates of fusion compared with more acute injuries. Historically, anteriorly oriented oblique fractures were thought to be a contraindication for odontoid screw placement, as the direction of the fracture parallels the screw trajectory and may lead to displacement during tightening of the screw, although there is some literature that suggests this may be overcome. Patient body habitus, specifically a broad barrel chest or a short neck, can lead to difficulty with achieving an optimal trajectory for odontoid screw placement, although this obstacle can be overcome with experience and variations in technique.

Osteoporosis can lead to significantly decreased rates of fusion in patients who undergo ventral odontoid screw fixation. This finding led to interest in the augmentation of the construct with polymethylmethacrylate-based cements. Early studies found that such augmentation significantly improves the strength of the construct, and early case reports showed feasibility in patients. Some have advocated the placement of 2 screws in the construct to improve biomechanical stability in patients. Although some biomechanical studies showed no difference in failure strength between 1 screw and 2 screws, a study by Dailey and colleagues found significant improvements in fusion rate with the 2-screw construct in the elderly population.

Dorsal Fixation

Dorsal approaches to fusion of the upper cervical spine have expanded considerably over the last several decades. Gallie described one of the earliest fusion techniques in the late 1930s, using sublaminar wiring combined with iliac crest graft. In the 1970s, Tucker reported the use of clamps to stabilize the C1-2 joint, attaching them to the laminae and interposing iliac crest graft between the spinous processes. Modern methods of screw fixation were developed by several practitioners, from the transarticular technique of Jeanneret and Magerl to the lateral mass/pars constructs of Goel and colleagues (Fig. 4).

Fusion rates for modern techniques of dorsal atlantoaxial fusion are excellent and in some studies approach 100%. A recent meta-analysis found significantly better fusion rates for posterior fusion compared with odontoid screw fixation. Morbidity associated with posterior fusion of the atlantoaxial joint includes the

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Fig. 3. (A) Lateral radiograph and (B) artist’s representation of odontoid screw fixation of type II odontoid fracture.
elimination of all rotation at the atlantoaxial junction, thus, decreasing overall cervical rotation by as much as 50%. Posterior spinal fusion also involves significantly more soft tissue dissection, thus, increasing both operating times and blood loss. Posterior approaches also place the vertebral arteries at risk, possibly leading to stroke or even death. As a result of these risks, careful evaluation of preoperative imaging—especially for possible aberrancies in the path of the vertebral artery or variations in the bony anatomy of the foramina—is crucial. Any brisk bleeding encountered during the procedure should be concerning for possible vertebral injury, and instrumentation of the contralateral side should be avoided until angiographic imaging can be obtained.

Other complications of posterior cervical fusion for odontoid fractures are similar to those of anterior fixation. The most common complications are pneumonia and dysphagia, which may occur in a significant percentage of patients and may necessitate intensive care level treatment and prolonged hospitalization. A less frequently described complication is a persistent occipital neuralgia secondary to transection of the C2 nerve during surgery. This neuralgia can lead to significant patient discomfort and anxiety that may be refractory to management. Despite these complications, posterior spinal fusion for odontoid fractures in the elderly remains an important tool in the armamentarium for treating these patients, especially in those with contraindications for placement of an odontoid screw such as chronic fractures and transverse ligament injury.

SUMMARY

With the aging of the world’s population, the frequency of type II odontoid fractures will inevitably increase. Although multiple treatment options exist for these patients, morbidity and mortality from odontoid fractures remain high among the elderly. There continues to be a significant lack of high-quality evidence to guide treatment of odontoid fractures in the aged, with most of the literature consisting of small case series. Further research is needed to identify which patients benefit most from the available treatment modalities, and further refinement of operative and postoperative techniques are needed to reduce complications associated with surgical intervention.

REFERENCES

7. Woods BI, Hohl JB, Braly B, et al. Mortality in elderly patients following operative and nonoperative...


