Management of Odontoid Fractures in the Elderly: A Review of the Literature and an Evidence-Based Treatment Algorithm

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Odontoid fractures are the most common fracture of the axis and the most common cervical spine fracture in patients over 65. Despite their frequency, there is considerable ambiguity regarding optimal management strategies for these fractures in the elderly. Poor bone health and medical comorbidities contribute to increased surgical risk in this population; however, nonoperative management is associated with a risk of nonunion or fibrous union. We provide a review of the existing literature and discuss the classification and evaluation of odontoid fractures. The merits of operative vs nonoperative management, fibrous union, and the choice of operative approach in elderly patients are discussed. A treatment algorithm is presented based on the available literature. We believe that type I and type III odontoid fractures can be managed in a collar in most cases. Type II fractures with any additonal risk factors for nonunion (displacement, comminution, etc) should be considered for surgical management. However, the risks of surgery in an elderly population must be carefully considered on a case-by-case basis. In a frail elderly patient, a fibrous nonunion with close follow-up is an acceptable outcome. If operative management is chosen, a posterior approach is should be chosen when fracture- or patient-related factors make an anterior approach challenging. The high levels of morbidity and mortality associated with odontoid fractures should encourage all providers to pursue medical co-management and optimization of bone health following diagnosis.

KEY WORDS: Odontoid, Geriatric, Dens, Type II odontoid fracture, C1-C2 fusion, Operative management, Nonunion

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Odontoid fractures are the most common fracture of the axis and are the most common type of cervical spine fracture in patients over 65.[1,2] The growing elderly population in the United States has seen the incidence of odontoid fractures more than double over the past decade.[2] The incidence of odontoid fractures is approximately 21.4 per 100 000 inpatient Medicare admissions, and it is estimated that the cost of treating these fractures exceeds $1.5 billion.[3]

Despite rising incidence and costs, there is considerable ambiguity regarding optimal management strategies for these fractures in the elderly. In a geriatric population, poor bone health and medical comorbidities contribute to increased surgical risk; however, nonoperative management is associated with a risk of nonunion and resulting complications. Striking the right balance between these options is a difficult challenge. This manuscript seeks to provide a balanced review towards the etiology, evaluation, and management of odontoid fractures in the elderly.

ABBREVIATIONS: CT, computed tomography; **CVA,** cerebrovascular accident; **HV,** halo vest; **MRI,** magnetic resonance imaging; **NDI,** neck disability index; **NSQIP,** National Surgical Quality Improvement Program; **TAL,** transverse atlantal ligament

OVERVIEW OF ODONTOID FRACTURES

Patho-Anatomy of Odontoid Fractures

Several anatomic and morphological studies have described the trabecular anatomy of the odontoid process.[4-10] Most of these

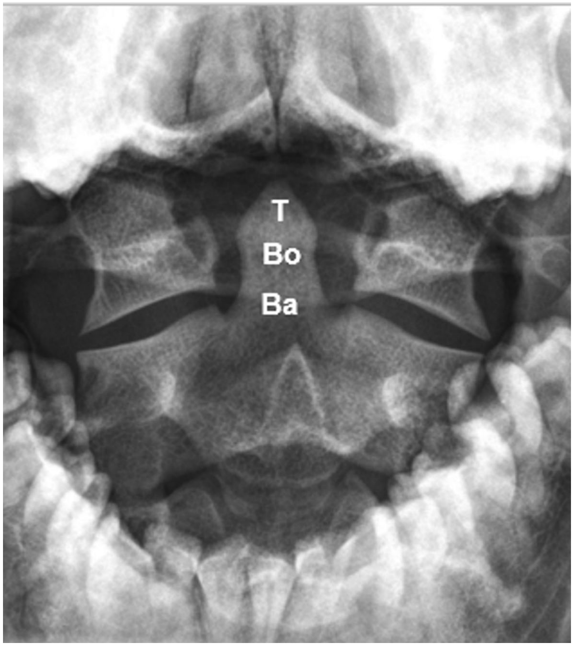

FIGURE 1. *An open-mouth anteroposterior X-ray of C2 showing the odontoid process and its regions: the tip (T), the body (Bo), and the base (Ba).*

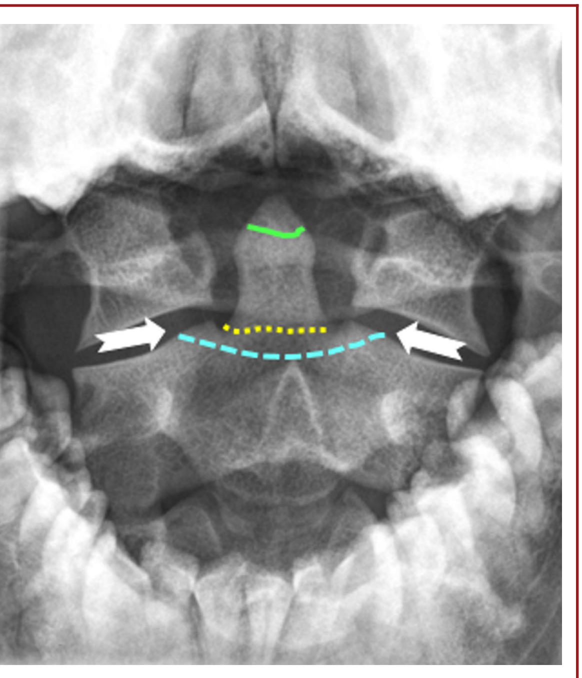

FIGURE 2. *The classification of odontoid fractures. Type I fractures involve avulsion off the tip of the odontoid (solid green line). Type II fractures occur at the odontoid base (dotted yellow line), while type III fractures extend into the C2 body (dashed blue line) and typically involve the superior C2 facet joint (arrows).*

papers divide the odontoid into 3 structurally distinct regions: the tip, the body, and the base (Figure 1).[5,7] As patients age, there are relatively larger reductions in bone density at the odontoid base relative the remainder of C2.[7] The structural weakness of the odontoid base coupled with increased bone loss due to age may underlie the high rate of odontoid fractures in the geriatric population.[7–9]

Classification of Odontoid Fractures

The most commonly used classification system for odontoid fractures is that of Anderson and D'Alonzo (Figure 2).[11] This classification divides odontoid fractures into 3 types: type I through the tip of the odontoid (due to avulsion of the alar and apical ligaments), type II at the base of the odontoid, and type III extending from the base of the odontoid into the vertebral body. In this landmark paper, fracture classification had a significant impact on prognosis: type II fractures had a 36.3% nonunion rate—a sharp contrast to type III fractures (7.6% nonunion rate) and type I fractures (0% nonunion rate).[11] Type II fractures are the most common type of odontoid fractures in the geriatric population.[1,2,12]

Some modifications to the original classification scheme have been suggested over the years. Hadley et al[13] introduced the concept of a type IIA fracture of the dens defined as a type II odontoid fracture with comminution. While these injuries are uncommon (5% of all odontoid fractures), Hadley considered them extremely unstable and incompatible with nonoperative management.[13]

Grauer et al[14] more recently proposed a treatment-based classification system for odontoid fractures seeking to clarify the distinction between type II and type III fractures. They used the superior C2 facet as the demarcation between type II and type III fractures; any fracture through the odontoid base not involving the superior C2 facet was defined as a type II fracture, while a fracture extending into the facet was defined as type III (Figure 2). Type II fractures are further subdivided to guide treatment: Type IIA fractures are nondisplaced; Type IIB fractures are displaced with a fracture line from anterior superior to posterior inferior; and type IIC fractures are anterior inferior to posterior superior with comminution present.[14] These authors recommend nonoperative treatment for type IIA fractures, anterior screw fixation for type IIB, and posterior atlantoaxial fusion for type IIC. Validation of the suggested treatment algorithm, however, has not been performed.

Nonunion in Type II Fractures

Since the original report by Anderson and D'Alonzo,[11] several authors have reported a high rate of nonunion in type II fractures.[15–25] While there is no consensus on why these fractures are difficult to heal, hypotheses include vascular insult, odontoid morphology, and ligamentous forces.[7,20,26-28]

The base of the dens represents a water-shed region between 2 arcades—1 supplying the body of C2 and another supplying the tip of the dens.[26] In addition to vascular insult, some authors have speculated that the cause of nonunion in type II fractures is the lack of cancellous bone at the odontoid base and the relatively low surface area available for healing.[7,8,20] Govender et al[20] observed that a principal difference between type II and type III fractures is the surface area of bone available for healing.[20] Finally, the ligaments attaching to the odontoid tip create a distracting force across the fracture site and may prevent healing.[28] We believe that the evidence best favors a combination of local distraction and vascular fragility to explain the relatively high nonunion rate seen in type II fractures.

Many additional risk factors have been associated with higher rates of nonunion including increased patient age,[20,29-31] fracture displacement (>50% displacement or >4-6 mm),[15,20,32-34] angulation,[35] posterior displacement,[20,31,32,36] and delay in the initiation of treatment (>3-7 d).[20,31,35]

Clinical and Radiographic Evaluation

Odontoid fractures are commonly missed injuries and up to 40% of geriatric patients with odontoid fractures may have a delay in diagnosis.[37] For this reason, practitioners must evaluate at-risk patients with vigilance and a high index of suspicion. The elderly patient with an odontoid fracture typically presents with neck pain after a ground level fall. Dysphagia may also sometimes be present if there is a large retropharyngeal hematoma. The reported rate of neurological injury in this population varies from 7.5% to 33%[37-40] with most studies reporting a rate between 7.5% and 13%.[38-40] In all patients with a suspected odontoid fracture, a thorough neurological examination should be performed. Because geriatric patients have a high prevalence of osteoporosis, other musculoskeletal injuries (such as other spine fractures, hip fractures, long bone fractures, etc) must also be ruled out.

Radiographic imaging has traditionally included anteroposterior, lateral, and open-mouth plain radiograph views of the odontoid. However, in the osteopenic elderly, these studies are of notoriously poor sensitivity. Hence where clinically indicated (acute posterior midline neck pain after a ground level fall) we recommend thin slice or spiral computed tomography (CT). Plain radiographs in flexion and extension still have usefulness in providing an extra degree of vigilance if CT images are normal. If an odontoid fracture is identified, attention should be given to the presence of comminution, angulation, and displacement as these can all increase the risk of nonunion.[11,15,20,26,30,32,33,35,41,42]

Greene et al[33,43] reported a 10% rate of transverse atlantal ligament (TAL) injury in type II odontoid fractures and recommended that all odontoid fractures receive a magnetic resonance imaging (MRI) to rule out this injury. Injury to the TAL can lead to instability at C1-C2 and requires stabilization via a C1-C2 fusion. However, this incidence of TAL injury has been called into doubt by more recent reports.[44,45] In a geriatric population, interobserver reliability of MRI scans to detect TAL injury decreases with patient age.[46] It does not make biomechanical sense that both the TAL and the odontoid base can fail from exactly the same force at exactly the same moment. In the setting of a known odontoid fracture the experience of the current authors is to treat the fracture assuming TAL integrity, confirming it with flexion and extension radiographs throughout the follow-up period.

CONSIDERATIONS FOR THE GERIATRIC POPULATION

Bone Health

In patients with osteoporosis, the base of the odontoid process has a 64% reduction in bone mass compared to the body of the C2 and the body of the odontoid process.[7] As such, geriatric patients presenting with odontoid fractures are highly likely to have osteoporosis. Like all fragility fractures, successfully treating geriatric patients with odontoid fractures (both operatively and nonoperatively) require providers to ensure that all necessary steps to optimize bone health have been pursued. These include: nutritional counseling (calcium and vitamin D supplementation), physical activity (exercise and fall prevention), lifestyle modifications (smoking cessation), diagnostic testing (dual-energy X-ray absorptiometry screening for bone mineral density), pharmacologic treatment for osteoporosis, and patient education.[47] We respectfully submit that this is the most important message of this chapter; treatment of geriatric odontoid fractures is about much more than the odontoid process.

Medical Comorbidities and Mortality

Mortality rates following odontoid fractures are similar to mortality rates following hip fractures.[48] Elderly patients with this injury have a 30-d mortality rate of approximately 10% to 25%[12,49] and a 1-yr mortality rate of 20% to 50%.[12,48-50] A low hemoglobin level, admission from a nursing home, neurological deficits, and type III fractures have been shown to be independent predictors of mortality following these injuries.[49]

In a majority of cases, the principal causes of death after odontoid fractures are related to the patients' medical comorbidities and not the injury itself.[48,49] Elderly patients with odontoid fractures frequently have cardiac, pulmonary, renal, or endocrine comorbidities.[51] Similar to hip fractures, a multidisciplinary care team may help reduce mortality following odontoid fractures. Patients presenting with this diagnosis may benefit from a referral to a geriatrics team to assist with management of their medical comorbidities.

MANAGEMENT OF ODONTOID FRACTURES

The treatment of odontoid fractures in the elderly requires surgeons to balance patients' medical comorbidities and surgical morbidity and mortality against the high rate of nonunion occurring with conservative management. Any surgeon with experience in this arena knows that surgical outcome can just as easily be adverse as it can beneficial.

Nonoperative Treatment Options

Historical Note: Skeletal Traction

In the earliest series of conservative fractures, conservative management typically entailed skeletal traction for 4 to 6 wk followed by cervical collar immobilization for a total treatment period lasting 3 to 4 mo. Success rates with this technique varied widely, averaging approximately 60% (Table 1). While skeletal traction formed the historical mainstay of treatment, the development of halo orthoses and other methods of immobilization have made this technique one of chiefly historical interest. This form of treatment was classically reserved for extremely unstable, critical care patients who are unable to undergo any other type of treatment.[28] We would not recommend the use of skeletal traction for the treatment of odontoid fractures except as a means to provide realignment prior to external or internal fixation.

Halo Vest Orthosis

The halo vest orthoses (HV) consists of a vest-type brace connected to a ring positioned circumferentially around the skull (halo ring). This device requires the application of a halo fixator and halo pins. While complications following halo pin placement are rare, infection, nerve, and even brain injury can occur. The HV, however, represents the most stable orthotic option available, providing the greatest control in flexion/extension, lateral bending, and rotation. Johnson et al[52] showed that the HV allowed approximately 5° less flexion-extension at C1-2 compared to a Philadelphia collar (3.4° vs 8.5°).

Data on patients with type II odontoid fractures treated with HV generally show approximately 75% treatment success (Table 1). Unfortunately, in the geriatric population, the rigidity provided by the HV may cause significant morbidity. Tahshijan et al[53] provided level III data in a series of 78 patients (mean age 80) treated for odontoid fractures with surgery, HV, or a cervical collar. They found that patients treated with a HV were over 4 times more likely to have pneumonia (34% vs 8%), 5 times more likely to suffer cardiac arrest, and twice as likely to have any complication as the non-HV cohort. While the authors did not directly compare the HV group to the cervical collar group, the high rate of complications reported by these authors is concerning, especially because the HV and non-HV cohort were well matched for injury severity scores, Glasgow coma scale, and preexisting comorbidities. An earlier report from the same group went so far as to call HV a "death sentence" in the elderly.[54] In this study, the authors compared 45 old patients (age >65) to young patients with odontoid fractures treated with HV. The old patients had a 40% mortality rate compared to 2% in young patients; there was no difference between the old and young patients treated with a collar or with surgery.

More recent data, however, suggest that HV may be used successfully in appropriately selected patients.[55,56] Van Middendorp et al[56] reported a mortality rate of 6% in a series of 239 patients treated with HV. Similarly, Platzer et al[57] reported a 4% mortality rate and a 17% morbidity rate in their retrospective review of 102 patients treated with HV. Other studies in elderly patients have also reported increased osseous union and better long-term outcomes in elderly patients treated with this technique.[58,59] All of these data provide level III or IV evidence.

Cervical Collar Immobilization

Odontoid fractures may also be treated using semi-rigid cervical collars (Philadelphia, Aspen, Miami-J) or cervicothoracic braces (Minerva). Using this strategy, treatment success for type II odontoid fractures also averages just under 75% (Table 1). While cervical collars are generally well tolerated without a risk for serious adverse events, the increased motion may theoretically increase the risk of nonunion. Unfortunately, the data comparing cervical collars to HV are of poor quality. Sime et al[23] performed a systematic review and found that HV was more successful at achieving long-term stability at C1-C2. Patients treated with HV had a significantly higher rate of airway complications.[23] Waqar et al[25] also performed a systematic review of the available literature finding no differences in treatment success.

What is a Nonunion? Defining Success in a Geriatric Patient

Original research published by Anderson and D'Alonzo[11] and others[15,21,37,42,60] have classically defined osseous union of the odontoid as a measure of successful treatment for odontoid fractures. Given, then, that the risk of nonoperative odontoid fracture management is nonunion, particularly in the elderly, it behooves us to understand the consequences of this arguably "undesirable" outcome.

In a series of 14 patients of age greater than 80, Hanigan et al[34] observed an in-hospital mortality rate of 35.7%. In the remaining 9 patients (6 type II and 3 type III), there were 4 nonunions (3 type II and 1 type III). One of the nonunion patients died during the follow up period from a cerebrovascular accident (CVA), but the other 3 returned to routine activity without neurological sequelae.[34] This led the authors to conclude that a stable fibrous union was well tolerated in the geriatric population.

Ryan et al[37] also reported only 23% rate of union in series of 30 elderly patients (aged >65). Of the 19 patients demonstrating nonunion only 5 subsequently underwent spinal fusion for reasons not disclosed. The majority of their cohort (n = 14; 74%) had few complaints, were neurologically intact, and did not require further stabilization.[37] As with Hanigan and colleagues,[34] these authors also concluded that achieving primary union was not necessary for acceptable outcomes in the elderly.

Seybold et al[61] also reported good to excellent outcomes in all patients over 65 in whom a stable C1-C2 could be obtained regardless of odontoid union. Most recently, Koech et al[58] found that conservative management of type II odontoid fracture

TABLE 1. Existing Series Discussing the Treatment of Odontoid Fractures, Divided by Type and Treatment Modality

References	Total, failure rate (failure/total, N, % failure)	Failures by Treatment: Traction ± collar/vest	HV	Minerva/SOMI[a]	Collar[b]
Anderson et al, 1974[11]	0/2 (0%)	0/2			
Ryan et al, 1993[37]	0/1 (0%)	0/1			
Chiba et al, 1996[83]	0/2 (0%)	0/2			
Greene et al, 1997[33]	0/2 (0%)		0/2		
Totals	0/7 (0%)	0/5 (100%)	0/2 (100%)		
Anderson et al, 1974[11]	8/24 (33.3%)	8/24			
Marar et al, 1976[84]	15/24 (62.5%)	15/24			
Ekong et al, 1981	6/12 (50.0%)		6/12		
Ryan et al, 1993[37]	18/24 (75.0%)	5/5	5/9	2/4	6/6
Wang et al, 1984[85]	5/12 (41.7%)		1/5		4/7
Clark et al, 1985[15]	10/41 (24.4%)		8/38		2/3
Pepin et al, 1985[42]	7/13 (53.8%)				
Dunn et al, 1986[31]	19/59 (32.2%)		19/59		
Hadley et al, 1985[41]	8/31 (25.8%)		5/23	2/6	1/2
Hanssen et al, 1987[36]	3/12 (25.0%)		2/10	0/3	1/2
Lennarson et al, 2000[29]	11/33 (33.3%)		11/33		
Lind et al, 1987[60]	1/9 (11.1%)		1/9		
Govender et al, 1988[21]	5/19 (26.3%)	5/19			
Govender et al, 2000[20]	50/109 (45.9%)			50/109	
Bucholz et al, 1989[86]	2/17 (11.8%)		2/17		
Polin et al, 1996[30]	7/35 (20.0%)		4/16		3/19
Seybold et al, 1998[61]	7/28 (25.0%)		7/23		0/5
Muller et al, 1999[40]	9/40 (22.5%)		3/21		6/19
Kuntz et al, 2000[79]	4/10 (40.0%)		4/8		0/2
Koech et al, 2008[58]	1/42 (2.4%)		0/32		1/10
Butler et al, 2010[87]	0/12 (0.0%)		0/6		0/6
Lewis et al, 2011[88]	23/47 (48.9%)		12/30		11/17
Seljeskog 1978[89]	2/27 (7.4%)	1/12	1/15		
Greene et al, 1997[33]	25/88 (28.4%)		NR/5	NR/9	NR/81
Schweigel, 1987[90]	7/42 (16.7%)		3/20		
Stoney et al, 1998[35]	4/22 (18.2%)		4/22		
France et al, 2012[91]	2/15 (13.3%)		2/15		0/9
Patel et al, 2015[92]	5/39 (12.8%)		3/16		2/23
Totals	252/886 (28.4%)	34/84[c] (40.5%)	103/439[c] (23.5%)	54/122[c] (44.3%)	37/130[c] (28.5%)
Anderson et al, 1974[11]	1/13 (7.7%)	1/13			
Marar et al, 1976[84]	0/2 (0.0%)	0/2			
Ekong et al, 1981[93]	1/5 (20.0%)		1/5		
Wang et al, 1984[85]	0/12 (0.0%)		0/2		0/10
Clark et al, 1985[15]	6/26 (23.1%)		2/16		4/10
Pepin et al, 1985[42]	2/13 (15.4%)				
Dunn et al, 1986[31]	0/15 (0.0%)		0/15		
Lind et al, 1987[60]	0/1 (0.0%)				
Hanssen et al, 1987[36]	0/14 (0.0%)		0/14		
Govender et al, 1988[21]	0/15 (0.0%)	0/15			
Bucholz et al, 1989[86]	0/9 (0.0%)		0/9		
Greene et al, 1997[33]	1/69 (1.4%)		NR/67	NR/2	
Govender et al, 2000[20]	0/74 (0.0%)			0/74	
Polin et al, 1996[30]	0/18 (0.0%)		0/5		0/13
Seybold et al, 1998[61]	1/21 (4.8%)		1/21		
Muller et al, 1999[40]	1/14 (7.1%)		0/8		1/6
Patel et al, 2015[92]	0/15 (0.0%)		0/8		0/7
Totals	13/336 (3.9%)	1/30[c] (3.3%)	4/103[c] (3.9%)	0/74[c] (0.0%)	5/46[c] (10.9%)

[a]SOMI: Sterno-occiputomandibular immobilizer or Minerva Brace.
[b]Includes all rigid cervical, collars, typically Philadelphia collars, Miami J, and/or Aspen Collars.
[c]Totals may not equal, the column on the left as the modality of treatment was not always specified.

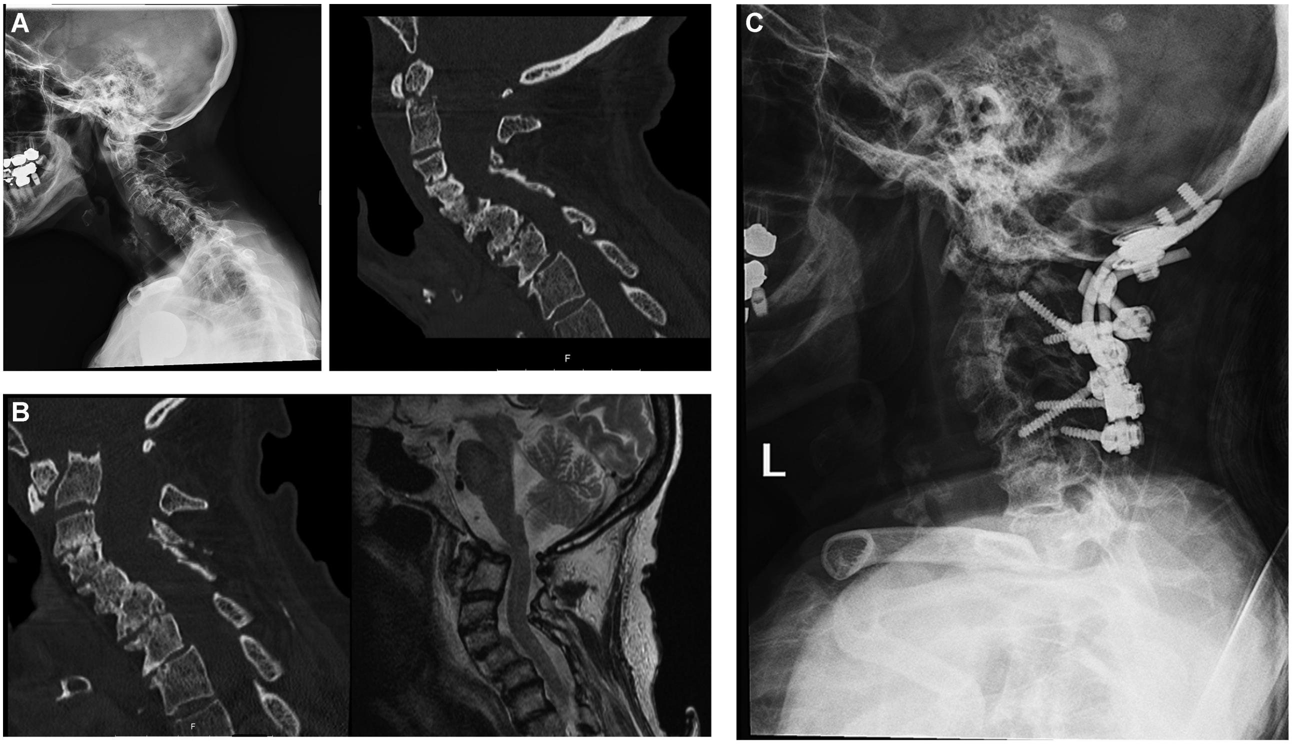

FIGURE 3. **A**, *Lateral cervical radiographs and CT scan of an 80-yr-old female with a Type II odontoid fracture. The patient elected to proceed with conservative management and was followed with radiographs periodically.* **B**, *The patient unfortunately did not unite this fracture. Approximately 18 mo after her initial diagnosis, she was noted to have superior migration of the C2 body with severe canal stenosis at the foramen magnum.* **C**, *She developed progressive neurological deficits and was treated with a posterior spinal fusion from the occiput to C6.*

resulted only in a 40.5% union rate (on CT scans) but that 97.6% of patients achieved stability at C1-C2 by 2-yr follow-up.

Hart and colleagues[16] described nonoperative management of chronic, mobile nonunion in 5 elderly patients with odontoid fractures. Displacement through the mobile fracture site averaged 4.5 mm at initial presentation (range 1-9 mm).[16] All were managed successfully without surgery. Raudenbush and Molinari[62] attempted to perform a long-term follow-up of 30 geriatric patients (>70 yr) with nonunion following an odontoid fracture. In their cohort, 68% of patients (n = 23) had died on average 3.8 yr after injury (range 2 mo-9.42 yr). Causes of death were related to medical comorbidities rather than spinal instability. Seven patients were available for minimum 4-yr follow-up. Despite 5 of the 7 patients having a mobile nonunion, there was no difference in neck disability index (NDI) or pain scores compared to an age- and sex-matched control cohort.

Joestl et al[59] also described the treatment of 44 patients over age 65 with a nonunion following an odontoid fracture. In this cohort, they found that nonoperative management was an acceptable treatment option with satisfactory clinical outcomes in 100% of patients despite a low rate of osseous union of the dens.

While the above data are largely level IV evidence, they are in agreement with the unpublished experience of the current authors and indicate that an osseous union is not a prerequisite to obtain and maintain satisfactory clinical outcomes in a geriatric patient population.[34,37,58,61,63] When counseling patients about nonoperative care, it remains important to inform patients about the possibility of symptoms associated with nonunion including neck pain, and at least a theoretical concern of myelopathy from translation at the C1-C2 joint (Figure 3).[64,65] Acute spinal cord injury from future falls is also a consideration, but is likely balanced by the risk of acute spinal cord injury or death as a result of surgery.[66] It is our view that a stable nonunion or even an asymptomatic mobile nonunion (provided proper follow-up and surveillance) can be not only an acceptable but perhaps a superior outcome in a geriatric odontoid fracture population compared to the morbidity and mortality associated with surgery.

Operative Management

Anterior Approach

Anterior screw fixation of the odontoid was first described by Böhler.[67] This technique provides immediate stability to the fracture fragments and preserves motion at the C1-C2

TABLE 2. An Overview of Techniques Available for Posterior C1-C2 Fusion

Posterior technique	Fixation	Comments
Gallie fusion	Sublaminar wire around C1 looped around spinous process of C2 with notched iliac crest autograft	Requires an intact posterior arch
Brooks–Jenkins fusion	Sublaminar wire around both axis and atlas with iliac crest autograft	Requires intact posterior arch
		Longer sublaminar wires may compress cord in a “clothesline” fashion
Interlaminar clamp	Modification of Brooks–Jenkins without sublaminar wires	Requires intact posterior arch of C1
Transarticular screws	Screws placed across C1-2 joints	Offers immediate stabilization with rigid fixation. Vertebral artery is at risk with this technique.
Rigid screw fixation	C1: lateral mass screws	C2 nerve root may be identified and can be protected or sacrificed when placing C1 lateral mass screws. Large pedicles at C2 make placing pedicle screws relatively safe.
	C2: pars screw, pedicle screw or laminar screw	Rigid fixation
		Laminar screws require an intact posterior arch

joint. Compared to posterior approaches, additional advantages of anterior fixation include ability to apply direct pressure on the odontoid or on C2 for intraoperative reduction, a shorter operative time,[17,68] obviated need for graft harvesting, shorter hospital stay,[68] and reduced need for postoperative immobilization.[17,68]

The disadvantages of the anterior screw placement include difficult intraoperative imaging in osteopenic patients, dysphagia,[69] respiratory-related complications,[17] and osteopenia leading to instrumentation failure. The odontoid screw enters the inferior body of C2 from anteriorly within the C2/3 disc space. It is aimed rostrally toward the odontoid apex where the tip of the screw(s) should penetrate the thick cortical cap where the majority of biomechanical strength is derived.[67] In geriatric patients, osteoporosis can predispose to screw failure, primarily, especially from the head of the screw cutting into the body of C2 anteriorly and superiorly.[70] Although biomechanical[71,72] and clinical data[73,74] suggest that there is only limited benefit to placing 2 screws, we agree with others that 2 screws may help to avoid this complication.[71] Proper positioning of the screw heads within the C2/3 disc space also helps to prevent screw migration.

Relative contraindications to anterior screw fixation include fracture comminution, oblique anterior fractures, fractures with nonreducible displacement, chronic fractures (greater than 6 mo old),[74] and anatomic/body habitus considerations.[69] It can be difficult to place these screws along the correct trajectory (and engage the cortical bone at the tip of the dens) in patients with cervical spondylosis and kyphosis, barrel chests, and/or short necks.[69]

While most of the existing data on odontoid screw fixation include both young and old patients,[22] there are a few recent studies focusing on a geriatric population. Harrop et al[17] reported on a series of 10 elderly patients with type II fractures treated with an anterior odontoid screw placement followed by immobilization in a brace or collar. The majority of fractures in this series were initially displaced (mean 6.6 mm) most of which were in a posterior direction. They reported 1 case of non-union requiring posterior C1-C2 fusion and 1 case of delayed union in a patient with osteopenia. There were 2 respiratory complications including a patient who died from pneumonia.

Dailey et al[69] reported on 57 patients over 70 yr of age with type II or type III odontoid fractures treated with an anterior odontoid screw (3-62 mo of follow-up).[69] Eighty percent of patients achieved fracture stability (fibrous or osseous union). Stability was more consistently achieved using 2 screws (96%) compared to 1 (56%). However, high rates of postoperative dysphagia were reported with 35% of patients needing temporary diet modification or a nasogastric tube after surgery.

Joestl et al[75] compared anterior screw fixation to HV immobilization in 80 patients with type II fractures. All patients were aged >65 and were considered to have “increased risk for anesthesia.” The authors found a higher bony fusion rate in the anterior screw cohort (90%) compared to HV (77%). The anterior screw group also had less pain, better functional outcomes, and less psychological distress. Although there was comparable morbidity and mortality between the 2 groups, the authors did not report the incidence of dysphagia following surgery.

Posterior Approach

Posterior approaches for fractures of the odontoid rely on arthrodesis of C1-C2. While the earliest descriptions of posterior cervical fusion described wire stabilization of C1-C2 with a notched piece of autograft iliac bone, techniques of today have evolved significantly. Modern techniques for fusion of C1-C2 include transarticular screws at C1-C2, lateral mass screws in C1 with pedicle or interlaminar screws at C2. A detailed review of the techniques for C1-C2 arthrodesis is beyond the scope of this chapter but is summarized in Table 2.

The principal advantage of a posterior approach is that it allows for a more predictable outcome. Because the procedure relies on fusion of the posterior elements vs healing of a displaced fracture with questionable vascular supply, the reported success rates with this technique are high. Scheyrer et al[76] compared a series of 17 patients treated with anterior odontoid screw vs posterior fusion. They reported a nonunion rate of 77% in the anterior screw cohort compared to a 93% fusion rate in the posterior C1-2 fusion cohort. This nonunion rate is surprisingly high compared to the experience of others and raises concern about the surgical technique employed. Nonetheless, Molinari et al[77] similarly reported a 100% fusion rate using C1 lateral mass screws and C2 pars interarticularis or translaminar screws in a series of 25 elderly patients with type II odontoid fractures. Frangen et al[78] also reported a 95% fusion rate using C1-2 transarticular screw fixation (Magerl and Seeman) in conjunction with a Sonntag or modified Gallie fusion for elderly patients with type II odontoid fractures.

The principal disadvantage of the posterior approach is that fusion of C1-C2 results in the loss of approximately 50% of axial rotation in the cervical spine. While this limitation is significant, it is unclear what the clinical significance of this lost motion means in a geriatric population. The low functional demands of this population may allow them to tolerate loss of axial rotation better than younger patients. The posterior approach may also subject patients to a longer procedure than anterior surgery and therefore increased anesthetic risks.[77] Without a doubt though, in cases of unstable chronic type II odontoid fractures, posterior C1-C2 arthrodesis is required.[68]

Choice of Approach

There are few studies that directly compare an anterior and posterior approach in a geriatric patient population. Schroeder et al[24] performed a systematic review of the treatment of odontoid fractures in the elderly and concluded that there was no risk between short-term and long-term mortality or morbidity between anterior and posterior approaches. However, they tempered their conclusions because of the low level of evidence (all but 1 article was level III or IV).

Patterson et al[68] performed a retrospective review of the National Surgical Quality Improvement Program database (NSQIP) and examined 30-d perioperative outcomes of odontoid stabilization in 141 elderly patients (age > 65).[68] They found that posterior surgeries had longer operative times. Although the 2 types of procedures had equivalent rates of postoperative adverse events, anterior surgery was associated with a significantly higher rate of readmission (RR = 8.95, 2.21-36.29) and rate of revision (RR = 19.51, 2.49-152.62) compared to patients undergoing posterior fusions. The generalizability of this paper was, however, limited by the heterogeneity of the patient population studied and the lack of clinically relevant data fields (osteopenia, fracture pattern, etc) in the NSQIP database. This retrospective database study constitutes level III evidence.

Type II Fractures: Operative vs Nonoperative Management

Several studies of surgical vs nonsurgical management in the elderly have been performed. The largest study on this topic has been performed by AOSpine North America and provides level III evidence.[12] These authors retrospectively reviewed 322 patients with geriatric odontoid fractures and compared 157 conservatively treated patients to 165 operatively treated patients. They found that patients managed nonoperatively had a higher risk of mortality (30-d and final follow-up) when confounding variables such as age, comorbidities, and gender were adjusted for. Their results favored surgical management in this patient population.

Vaccaro et al[19] provide the only level II data on this topic[19] prospectively following 159 geriatric patients treated surgically or with halo immobilization. They showed that patients undergoing surgical treatment for odontoid fractures had better functional outcome measures as measured by the NDI. Unfortunately, this difference in outcome between the 2 groups was small, rendering the clinical significance unclear. A trend toward lower mortality in the surgical group (26% vs 14%) was observed but this difference did not reach statistical significance ($P = .06$). The relevance of this is difficult to ascertain as patients were not randomized and results could be subject to selection bias (ie, the healthiest patients had surgery).

Seybold et al[61] compared operative vs nonoperative management in 28 patients aged over 60 observing that conservative care was associated with higher complication rates. There were, however, no differences in functional outcomes between groups. Kuntz et al[79] performed a retrospective review of 36 patients aged 65 and over treated with C1-2 transarticular screws or nonoperative management with a halo or collar. They reported a significantly higher early failure rate in the nonoperative cohort (50% vs 9%) and similar morbidity and mortality rates between the 2 groups. More recently, Dhall and colleagues[80] reviewed 3847 patients aged 80 yr or older using the National Sample Program of the National Trauma Data Bank from 2003 to 2012. They found that 10.3% of these patients received surgery. Patients undergoing surgery did not have a higher incidence of inpatient mortality, but were more likely to suffer medical complications and be discharged to institutionalized care after their hospital stay. All the above studies offer level III evidence.

Schroeder et al[24] performed a systematic review including the studies above amongst others. They found that operative management of these fractures in the elderly could reduce short-term and long-term mortality without a significant difference in the rate of complications.

Finally, a cost-effectiveness analysis of the various management modalities for type II odontoid fractures found that operative management was more costly but more cost-effective compared to nonoperative management in 65 to 84 yr olds.[81] In the over-84

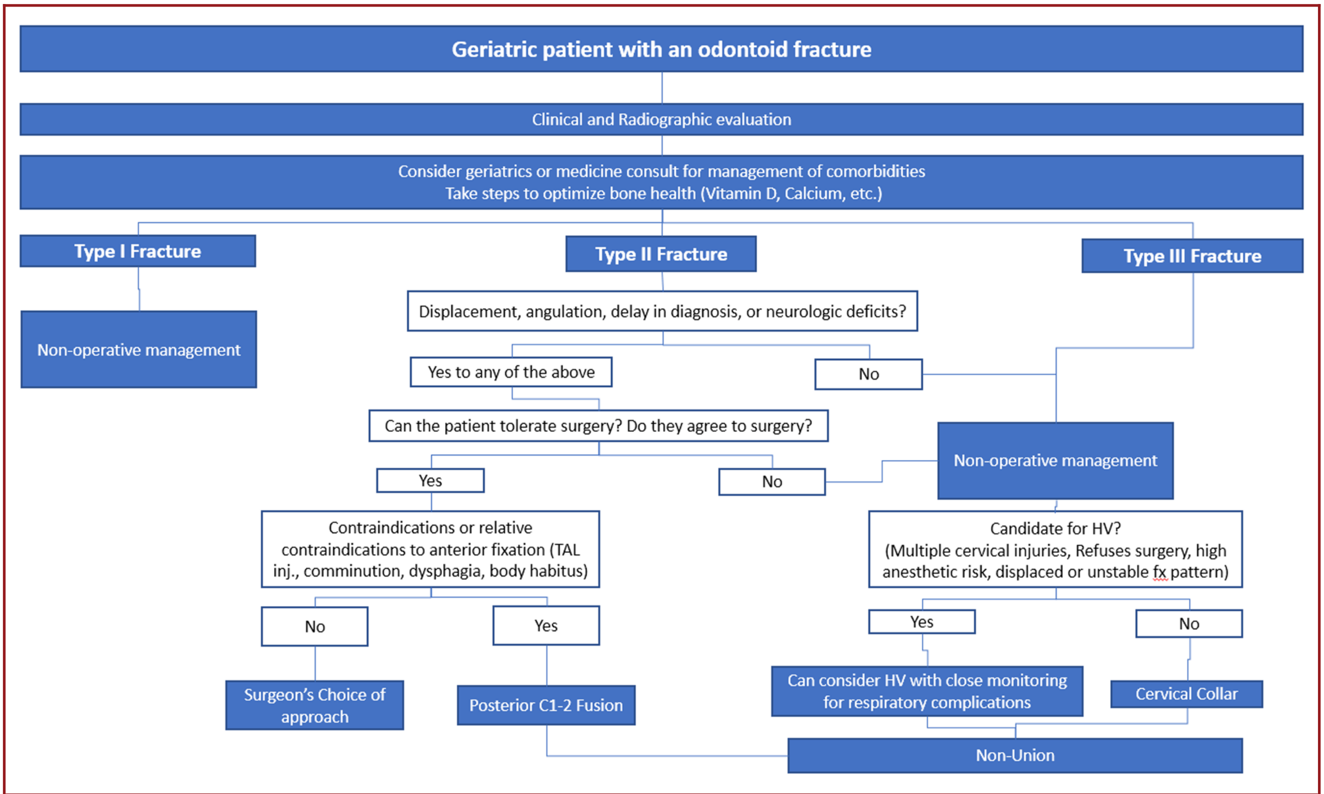

FIGURE 4. *The authors' recommended algorithm for the management of odontoid fractures based on a review of the available evidence and personal experience.*

cohort, nonoperative management was both less costly and more cost effective. However, it should be noted that none of the above studies have satisfactorily addressed the very real potential for selection bias naturally leading surgeons to operate on healthier patients.

Treatment Algorithm

Based on our assessment of existing literature and experience, we attempt to provide an evidence-based treatment algorithm for the management of odontoid fractures in the elderly (Figure 4). In most cases, type I and type III odontoid fractures are best managed in a cervical collar. Type II fractures in elderly patients with additonal risk factors for nonunion should be considered for surgical management in view of high mortality rates associated with nonoperative management. The 2013 evidence-based algorithm proposed by Joint Section on Disorders of the Spine and Peripheral Nerves of the American Association of Neurological Surgeons and the Congress of Neurological Surgeons concluded that consideration of surgical stabilization of type II odontoid fractures was supported by level II evidence in patients $\geq$50 yr of age.[82] However, the risks of surgery in an elderly population must be carefully considered on a case-by-case basis. In a frail patient it is important to remember that fibrous nonunion is an acceptable outcome.

Nonoperative management of type II fractures can be accomplished with semi-rigid cervical collars or HV orthoses directed primarily by the patient's overall general constitution. HV immobilization will presdispose to respiratory compromise but has a higher rate of successful healing. In the setting of nonoperative management, long-term (2 yr) follow-up is important to guard against progressive instability and neurological demise. If operative management is undertaken, a posterior approach is the procedure of choice when fracture-related or patient-related factors make an anterior approach challenging. To those who embark on anterior odontoid screw fixation, expertise in anatomy and technique is essential for desirable outcomes.

Finally, the overall poor prognosis for associated morbidity and mortality in the geriatric age group with odontoid fractures underscores the key importance of medical co-management and optimization of bone health following diagnosis.

CONCLUSION

We have attempted to provide a review of the existing literature pertaining to odontoid fractures in the elderly population. While type I and type II fractures can be managed in a collar in most cases, the management of type II fractures is more challenging. Type II fractures with risk factors for nonunion (displacement, comminution, etc) should be considered for surgical management. However, the risks of surgery in an elderly population must be carefully considered on a case-by-case basis; a fibrous nonunion with close follow-up is an acceptable outcome in this population. If operative management is chosen, a posterior approach is preferred when fracture- or patient-related factors make an anterior approach challenging. The high levels of morbidity and mortality associated with odontoid fractures should encourage all providers to pursue medical co-management and optimization of bone health.

Disclosure

The authors have no personal, financial, or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENTS

The authors should be commended for compiling a thorough review of the literature on a growing epidemic in spine surgery: geriatric odontoid fractures. While surgery for patients >80-years-old has been recently shown to be associated with greater morbidity than nonoperative care, it is clear from the 2013 Cervical Spine Trauma Guidelines and other literature that these fractures are difficult to heal without surgery.[1,2] The authors of this study cite a single but relatively large study that showed no increase in morbidity/mortality with halo vest immobilization in the elderly. This is worth noting, but seems to contradict other studies. This review proposes an algorithm that directs halo vest for elderly odontoid fracture patients. The reader should take this into consideration, but bear in mind that halo vest fixation remains quite morbid and potentially fatal to elderly patients. In a high volume spinal program, surgery may have acceptable risk in this population. Overall, the authors should be commended on this study, and we look forward to future high quality prospective data to help answer these questions.

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The authors have carried out a comprehensive review of the literature on the challenging topic of management of odontoid fractures in the elderly. In the present clinical setting, surgeons are often faced with conflicting treatment options with variability of clinical presentation, associated comorbidities, and factors related to the bone morphology making the critical decision to opt for a conservative or a surgical approach, a difficult one. This paper should prove to be useful as a review of the current treatment options available for odontoid fractures, which could potentially aid the clinicians in the decision-making process.

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