Odontoid Fractures: Evaluation and Management

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Abstract

Fractures of the odontoid process are uncommon injuries. Fracture displacement, compromised blood supply, comminution, and iatrogenic distraction have all been implicated in the reported high rates of nonunion. Plain radiography, polytomography, and computed tomography are all useful in delineating the fracture pattern. Magnetic resonance imaging has been recommended for evaluating associated ligamentous injuries and may be helpful in detecting occult cervical spine fractures. Type I fractures are avulsion fractures of the tip of the odontoid process. These rare injuries require only external immobilization with an orthosis if there is no associated ligamentous injury. Type II fractures occur at the junction of the odontoid process and the body of the axis. These are the most common odontoid fractures and are associated with a high incidence of nonunion. Nondisplaced fractures should be treated with halo immobilization for 8 to 12 weeks, with careful clinical and radiographic monitoring. Displaced fractures should be considered for operative treatment, either with atlantoaxial arthrodesis or anterior screw fixation. Type III fractures, which extend into the body of the axis through cancellous bone, are treated with closed reduction and halo immobilization.

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Fractures of the odontoid process were first reported at the beginning of this century and continue to challenge the treating physician. In the early literature, nonunion rates of up to 88% were reported, with no clear consensus on optimal treatment methods.[1,2] It is now recognized that odontoid fractures are uncommon injuries, accounting for 7% to 14% of all cervical spine fractures.[3] They usually occur in one of two major patient populations. The first group is composed of young persons who sustain high-energy fractures, often associated with alcohol use and motor vehicle accidents.[4] It is not surprising that multiple associated injuries are not uncommon in this group. The second group is composed of elderly persons. In this group, odontoid fractures often occur after low-energy forward falls in which the forehead strikes an object, resulting in a hyperextension injury with a posteriorly displaced fracture.[4] Associated trauma is uncommon.

Basic Science

Anatomic factors play an important role in the etiology and treatment outcome of odontoid fractures. The odontoid process projects superiorly from the body of the axis. Its tip arises embryologically from the fourth occipital sclerotome along with the occipital condyles and the rim of the foramen magnum. The first cervical sclerotome gives rise to both the body of the atlas and the base of the odontoid process. The base migrates caudally to fuse with the body of the axis, which arises from the second cervical sclerotome.[5]

The blood supply to the odontoid process has been implicated as one of the most important factors in the high rate of nonunion associated with specific fracture patterns.[6] An arterial arcade in the region of the apical ligaments is created by branches of the vertebral arteries between the second and third cervical vertebrae. A second network of vessels arising from the ascending pharyngeal arteries anastomoses with this arcade caudal to the alar ligaments.[6,7] Type II fractures, which occur at the base of the odontoid, are thought to disrupt this anastomosis, resulting in a high rate of nonunion.[6]

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Histomorphometric analysis of cadaveric odontoids has revealed that the mean volume of trabecular bone at the base of the odontoid is 55% of that of the axis and the odontoid process itself.[8] Furthermore, cortical thickness at the base is one third that of the odontoid process itself. These data suggest that this anatomic area may be at increased risk for fracture.[8]

The mechanism by which odontoid fractures are created has been well studied. Mouradian et al[3] were able to produce fractures of the odontoid process in the laboratory. They found that forward flexion tended to produce fractures extending into the body of the axis, while lateral loading produced fractures at the base of the odontoid. On the basis of clinical data from a multicenter study, Clark and White[9] reported that flexion is the primary mechanism of injury in 80% of odontoid fractures. In a flexion load, the transverse ligament is forced against the posterior aspect of the odontoid, resulting in anterior displacement of the odontoid. An extension force reportedly causes the remaining 20% of fractures.

The injury mechanism is impingement of the anterior ring of the atlas on the anterior odontoid, which results in posterior displacement. As mentioned previously, this frequently occurs in elderly persons when a forward fall causes the forehead to strike an object.[3,4]

Clinical Presentation

Patients with odontoid fractures usually present with severe high cervical pain that may be referred to the occipital region and a history of trauma. Muscle spasms and restricted range of motion are frequent findings in the physical examination. In nondisplaced fractures, however, the clinical symptoms may be mild. Neurologic involvement has been found to occur in 18% to 25% of patients and may range from tetraplegia to motor and sensory disturbances involving the upper limb due to injury to one or more cervical nerve roots.[9,10] Damage to the greater occipital nerve is the neurologic lesion most commonly reported.[11] In cases involving blunt trauma to the face and head, a thorough evaluation of the entire cervical spine is necessary, particularly when the patient is obtunded or intoxicated.

Diagnosis

The presence of an odontoid fracture is confirmed by radiographic studies. Care must be taken to protect the head and neck from further injury during the examination. The initial evaluation consists of anteroposterior, lateral, and open-mouth views in the neutral position. If the fracture is not well visualized, polytomography may be required to delineate the fracture pattern further.[12] Thin-section computed tomography (CT) with sagittal (and in rare instances three-dimensional) reconstruction may also be helpful. In the case of nondisplaced fractures, if the fracture line is parallel to the plane of the CT section, it may be missed even with reconstructions.[13] In the awake, alert patient, active flexion-extension plain films are recommended to evaluate any associated ligamentous instability. In the obtunded patient, physician-supervised fluoroscopic evaluation may be necessary.

The differential diagnosis of acute odontoid fractures includes os odontoideum. In an os odontoideum, the ossicle is small and round with smooth edges and is separated from a hypoplastic odontoid by a wide gap.[14] This gap usually extends above the level of the superior facets.[15]

Injuries to the ring of the atlas may accompany odontoid fractures. However, isolated atlas fractures and atlas fractures in combination with other cervical injuries are far more common than the combination of odontoid and atlas fractures. Some authors have stated that one third of all atlas fractures occur in combination with odontoid fractures.[4,16,17] Levine and Edwards[18] noted that this association is more likely in atlas fractures that consist of bilateral posterior-arch fractures. The presence of any upper cervical spine lesion warrants a thorough workup of the entire cervical spine because of the high rate of associated fractures.[16,19,20]

The use of magnetic resonance imaging has recently been described for the evaluation of the transverse atlantal ligament in patients with fractures of the odontoid process. In a series of 30 patients with odontoid fractures, Greene et al[21] noted three instances of rupture of the transverse ligament. All three patients had type II fractures. It is essential that injuries to the transverse ligament be recognized early. If not, atlantoaxial instability will persist even after successful healing of the odontoid fracture and will require atlantoaxial arthrodesis for stabilization.

Classification

Several classifications of odontoid fractures have been proposed. The most commonly used is that of Anderson and d'Alonzo.[22] Their classification is based on the level of the fracture (Fig. 1) and has been found to be predictive of the risk of nonunion.[23]

Type I fractures are avulsion fractures of the tip of the odontoid process. These injuries are rare. The transverse ligament and one alar ligament remain attached to

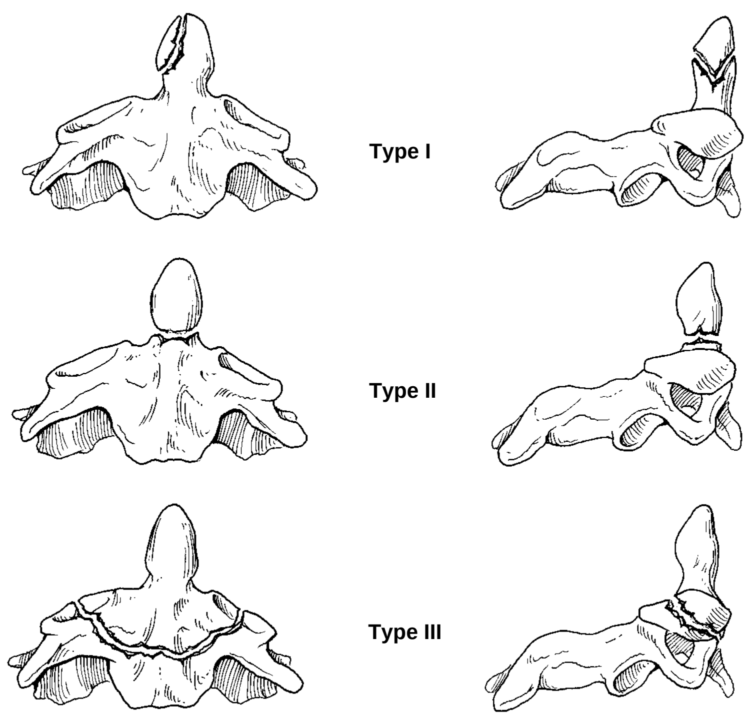

Fig. 1 The Anderson and d'Alonzo classification.[22] Type I fractures are avulsion fractures of the tip of the odontoid process. Type II fractures occur at the junction of the odontoid process and the body of the axis. In the type III pattern, the fracture extends into the body of the axis through cancellous bone.

the odontoid; thus, the fracture is stable.[22] Although there is some disruption of the apical arcade, most of the blood supply to the odontoid process remains intact.[6]

Type II fractures occur at the junction of the odontoid process and the body of the axis. This is the most common type of fracture pattern and is associated with a high risk of nonunion.[9,10,22] The blood supply to the odontoid is frequently disrupted,[6] and the fracture is often unstable due to the ligamentous attachments to the separated proximal fragment.[23]

Hadley et al[24] proposed a subclass of type II fractures with comminution at the base of the odontoid, termed type IIA fractures. Inability to maintain adequate reduction with external immobilization was found with all type IIA fractures in their series, regardless of the amount of initial displacement. In that study, the 3 type IIA fractures accounted for 5% of the 62 type II fractures encountered. The authors considered type IIA fractures to be inherently unstable injuries and recommended early surgical stabilization with atlantoaxial arthrodesis.

In the type III pattern, the fracture extends into the body of the axis through cancellous bone. The blood supply to the odontoid process is intact, and the fracture is generally stable after reduction and placement of a rigid orthosis.[6,23]

Treatment

Type I Fractures

Type I fractures retain most of their ligamentous support and are therefore stable. These injuries usually heal uneventfully with simple immobilization in a rigid collar.[22] However, Eismont and Bohlman[25] described a type I fracture in association with an occipitocervical dislocation. This rare combination of injuries highlights the importance of evaluating associated soft-tissue injuries.

Type II Fractures

Management of type II fractures remains highly controversial. The reported nonunion rate with nonoperative treatment ranges from 15% to 85%.[9,22,26] Several investigators have reported that the degree of initial fracture displacement is the most important factor in determining the success of nonsurgical management.[24,27] For example, one study[9] showed a 69% nonunion rate for fractures displaced 6 mm or more, compared with a nonunion rate of 10% for fractures displaced less than 6 mm. Nondisplaced type II fractures may be managed nonoperatively with halo immobilization but must be followed closely for signs of healing or further displacement. In cases of multiple trauma, surgical stabilization may be indicated to allow early patient mobilization.[28] Most authors currently recommend primary surgical management for type II fractures if there is more than 4 to 5 mm of displacement, because of the high rate of nonunion when these fractures are treated with external immobilization.[9,22,24] Surgical management is also recommended for type IIA fractures.

Atlantoaxial Arthrodesis

Surgical options include various techniques of atlantoaxial arthrodesis. Brooks-type wiring and transarticular screw fixation are two of the more commonly used methods. The Brooks fusion technique consists of sublaminar wiring of C1 and C2 compressing wedges of tricortical bone graft placed between the neural arches of the two vertebrae. We believe this is the optimal technique if wiring is chosen.[29] Fusion rates as high as 95% have been reported.[9,22] Transarticular screw fixation has also been reported to facilitate atlantoaxial arthrodesis, but it is a technically demanding technique.

The Gallie technique can also be used. It has the relative advantage of avoiding passage of sublaminar wires at C2. However, this technique tends to displace the dens fragment posteriorly with respect to the body of C2, which may not be optimal for reduction.

Anterior Screw Fixation

An alternative to atlantoaxial arthrodesis is anterior screw fixation of the odontoid (Fig. 2). This procedure has the advantage of preserving atlantoaxial motion with direct osteosynthesis of the fracture, but requires considerable experience in anterior cervical surgery.[28,30] Successful union rates of 88% to 100% have been reported.[30,31] The technique is contraindicated in certain situations. In patients with insufficient bone stock, an alternative method should be used. Patients with combined odontoid fractures and transverse ligament rupture should undergo atlantoaxial arthrodesis instead of anterior screw fixation. If they do not, atlantoaxial instability will persist after the odontoid fracture has healed. A third contraindication is an oblique sagittal fracture in which the fracture line is parallel to the direction of screw placement; interfragmentary compression is not possible in this situation.[30] A relative contraindication is a barrel-chest deformity, which makes placement of the screws technically difficult.

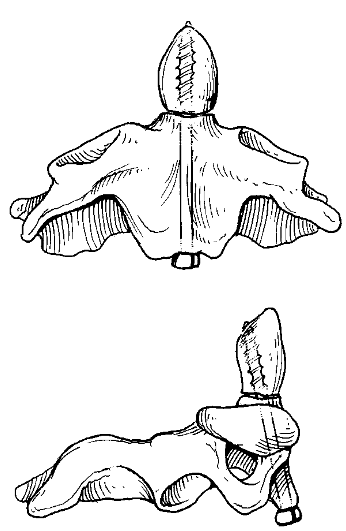

Fig. 2 Anterior screw fixation of the odontoid process with use of a single screw.

Anterior screw fixation may be particularly useful in type II odontoid fractures with concomitant fractures of the ring of the atlas. In this situation, alternative treatment involves an occipitoaxial fusion (with resultant loss of motion) or halo immobilization until the atlas fracture has healed (usually 8 to 12 weeks), followed by atlantoaxial arthrodesis if the odontoid fracture has not yet healed.[28]

Some controversy exists as to whether one or two screws are needed for anterior screw fixation of the odontoid. In a biomechanical study by Sasso et al,[32] no significant differences between the one- and two-screw techniques were found during load-to-failure tests. Graziano et al[33] also found no significant difference between one- and two-screw fixation. They also found one- and two-screw fixation as stiff as primary C1-C2 wiring in torsion and stiffer in bending. It should be emphasized that an anatomic reduction is mandatory for successful screw fixation.

Anterior screw fixation is technically demanding and should be performed only by surgeons experienced in anterior cervical surgery.[28,30] Before surgery, Gardner-Wells tongs are used with skeletal traction to obtain an anatomic reduction. Once the patient is positioned, two image intensifiers are centered on the odontoid at right angles to each other. Adequate clearance of the sternum must be obtained anteriorly to allow for placement of the surgical instruments.

A standard transverse or oblique anteromedial incision is then made at the level of the C5-6 disk space. The platysma is divided in the same direction as the skin incision. The fascial layer overlying the strap and sternocleidomastoid muscles is then divided, and blunt dissection is performed from a point medial to the carotid sheath to the deep cervical fascia. On incision of this fascia, the longus colli muscles are reached. When the vertebral column is readily visible, a radiograph is obtained to confirm the level.

With further soft-tissue dissection (depending on the patient's head position and body habitus), the inferior portion of C2 is reached. The inferior margin of C2 is then rongeured down slightly, facilitating the placement (under biplanar fluoroscopy) of the Kirschner wires. The first Kirschner wire is inserted in the midline from the anterior aspect of the inferior margin of C2, through the central axis of the odontoid, to the apical cortical bone. A second Kirschner wire is inserted parallel to the first for rotational control. A cannulated screw is then inserted over the first Kirschner wire, and the second Kirschner wire is removed. Postoperatively, the patient should wear a hard collar for 6 weeks.

Type III Fractures

Type III fractures occur through the cancellous bone of the body of the axis and are usually stable.[22] They may be managed by reduction with Gardner-Wells tongs or halo traction, with the head flexed for posteriorly displaced fractures or extended for anteriorly displaced fractures. It is generally accepted that subsequent halo immobilization for 3 to 4 months will be required. Fracture healing rates of over 90% can be expected.[22] It should be emphasized that a type III odontoid fracture is not a benign injury. Insufficient immobilization or incomplete reduction may result in nonunion or malunion, with the potential for spinal cord compromise.[9]

Authors' Preferred Treatment

We have no experience with type I fractures. However, in the absence of extensive soft-tissue injury, we recommend immobilization in a hard collar, such as a Philadelphia or Miami J collar, for 6 to 8 weeks.

We usually manage nondisplaced type II fractures with halo immobilization for 8 to 12 weeks with careful monitoring. Displaced type II fractures are treated with anatomic reduction and single-screw anterior fixation unless contraindicated because of poor bone stock, comminution, associated ligamentous injury, oblique fracture pattern, or body habitus. In these situations, atlantoaxial arthrodesis is recommended.

Type III fractures are generally managed with closed reduction and halo immobilization for 8 to 12 weeks. Again, close monitoring is essential. This may require follow-up CT scans with sagittal reconstruction to confirm that reduction has been maintained.

Nonunions

Nonunions of the odontoid most commonly occur after type II fractures but may also occur after type III fractures. As discussed previously, the precarious blood supply to the odontoid process and the degree of displacement have both been associated with high nonunion rates.[6,24,27] Distraction of the fracture with cervical traction during reduction has also been suggested as a cause of nonunion.[22,27]

Patients with a nonunion may have a wide range of presentations, ranging from nonspecific neck pain to myelopathy.[2] Regardless of symptoms, nonunions are considered by many to be an absolute indication for surgical stabilization because later minor trauma may result in severe neurologic injury or death.[22,27,31]

Atlantoaxial arthrodesis is the most common method of treating nonunion.[22,26,27] Even if the nonunion does not heal, a solid posterior arthrodesis is compatible with a successful outcome.[22,31] Other techniques have also been reported. For example, Böhler[31] reported on 16 patients with nonunions, 12 of whom were treated with combined anterior and posterior bone grafting and stabilization; the other 4 were treated with anterior compression-screw fixation and bone grafting. All patients achieved a solid union without complications. Esses and Bednar[34] also reported on four nonunions treated with anterior screw fixation alone. Union was achieved in all cases, with no complications. Despite these results, experience with anterior screw fixation for the management of nonunions is limited, and further investigation is necessary before it can be routinely recommended for use in this situation.

Odontoid Fractures in Children

Fractures of the odontoid process are among the most common cervical injuries in children, occurring at an average age of 4 years. These are actually physeal injuries of the basilar physis between the odontoid process and the body of the axis. They may be caused by minor falls or other trivial injuries. Patients typically present with restricted motion and neck pain. The odontoid process is almost always angulated anteriorly. Reduction by recumbency in hyperextension followed by rigid immobilization with a halo device results in a high rate of union, making operative treatment unwarranted in most cases.[22,35] The basilar physis closes after the age of 7 to 10 years. Once this has occurred, pediatric odontoid fractures should be treated in the same manner as they are in adults.[35]

In children, as in adults, it may be difficult to distinguish between an acute odontoid fracture or physeal injury and an os odontoideum. The wide gap and smooth, small ossicle should aid in the identification of an os odontoideum. It is likely that most cases of os odontoideum represent odontoid nonunions after unrecognized fractures.[15,22] If an os odontoideum is discovered radiographically and instability is present on flexion / extension views, a posterior atlantoaxial arthrodesis may be necessary. In children under the age of 5 years, the wide radiolucent gap may be confused with the normal epiphyseal line. In this situation, the diagnosis of os odontoideum can be confirmed by demonstrating motion between the odontoid and the body of the axis.[15]

Summary

Fractures of the odontoid process continue to be a difficult injury to manage. Disruption of the blood supply and the degree of displacement play a major role in the treatment outcome. Type I fractures are rare and require immobilization in a hard collar for 6 to 8 weeks.

Treatment of type II fractures remains highly controversial, with reports of high nonunion rates. Nondisplaced type II fractures may be managed in a halo device for 8 to 12 weeks with careful observation, but displaced type II fractures should be considered for surgical stabilization. The type of stabilization used will depend on the surgeon's experience and preference. Atlantoaxial arthrodesis is one option. However, anterior screw fixation, while more technically demanding, allows for preservation of atlantoaxial motion. Young, healthy patients with less than 5 mm of displacement may be candidates for halo immobilization if the treating physician does not have experience with odontoid screw-fixation technique. Type III fractures usually heal after reduction and halo immobilization.

Odontoid fractures in children are physeal injuries that are best treated nonoperatively. Once the physis has closed, they should be treated as they are in adults.

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