At our institution, acute combination atlas–axis fractures have been seen in the following types of injuries: 3% of all acute cervical spine, 12% of all acute upper cervical spine, 42% of all acute atlas, and 14.5% of all acute axis fractures.9,11 These combinations have been associated with a higher rate of neurological morbidity than isolated C-1 or C-2 fractures and have required surgical stabilization more often than other breaks.9,11 Nevertheless, approximately three-fourths of all patients with acute combination atlas–axis fractures can be treated successfully with an external orthosis.9 However, patients who are at high risk for nonunion or who have irreducible or recurrent subluxation despite external immobilization require early surgical stabilization and fusion.

Case Report

Examination. This 85-year-old man was admitted to our hospital for treatment of multiple systems trauma after being struck by a car while walking. On arrival, the patient complained of severe pain in his neck and left lower extremity. His injuries included a full-thickness, right frontal scalp laceration with an underlying nondisplaced skull fracture, multiple bilateral broken ribs, a right tibial plateau fracture, and left tibia and fibula fractures. His neurological examination was remarkable only for decreased spontaneous movement in the left lower extremity secondary to pain. A lateral cervical plain radiograph showed multiple posterior C-1 ring fractures and a Type II odontoid fracture with approximately 8 mm of posterior displacement of the dens (Fig. 1 upper left). An open-mouth plain radiograph showed an approximately 9-mm displacement of the left C-1 on the left C-2 lateral mass; the right C-1 and C-2 lateral masses were not well visualized (Fig. 1 upper right). There were no other spinal fractures.

Treatment. A Philadelphia collar was placed on the patient’s neck. A computerized tomography (CT) scan of the upper cervical spine confirmed the cervical fractures observed on x-ray films and also revealed an anterior C-1 ring fracture and a left C-1 anterior tubercle fracture (Fig. 1 lower left). The patient was admitted to the intensive care unit and placed in a halo brace after undergoing closed reduction of the Type II odontoid fracture (Fig. 1 lower right). A cervical magnetic resonance (MR) image showed good alignment of the cervical spine with no spinal cord compression or acute spinal cord injury. Axial multiplanar gradient-echo MR imaging revealed increased signal intensity surrounding the left C-1 anterior tubercle fracture and an otherwise intact transverse atlantal ligament. However, supine and upright lateral cervical spine radiographs displayed persistent atlantoaxial instability despite halo brace immobilization.
Early Complications. The patient’s early hospital course was complicated by respiratory distress requiring intubation. He also developed a compartment syndrome of the left lower extremity that required emergency surgery consisting of fasciotomy and intramedullary rod placement for the fractured tibia. Postoperative hypotension required pulmonary artery catheterization, intravascular volume expansion, and an infusion of dopamine. His cardiac performance improved and he was eventually weaned from the dopamine infusion. His hospital course was further complicated by pneumonia that was treated with antibiotic drugs and aggressive pulmonary cleansing. The patient required prolonged intubation and had recurrent episodes of oxygen desaturation when placed in a partially prone position for chest physiotherapy.

Operation. Once the patient was medically stable, he underwent an anterior odontoid and anterior C1–2 transarticular facet screw fixation to treat his atlantoaxial instability (Fig. 2 upper left and right). The techniques of anterior odontoid screw fixation1–3,5–8,13,15,18,28 and anterior C1–2 transarticular facet screw fixation13,25,31 have been described separately by various authors. Briefly, the patient was placed supine on the operating room table, with his head and neck extended carefully under fluoroscopic monitoring after the halo ring was released from the connecting bars and the anterior halo vest plate was removed. Intraoperative open-mouth and lateral biplanar fluoroscopy was used to guide precise placement of the screws. A transverse incision was made on the right side of the neck at the C5–6 level. A routine approach to the anterior cervical spine was used and the incision was extended superiorly to the C2–3 level. Operative exposure was maintained with a Hardy transsphenoidal retractor. A midline trough was made in the anterosuperior edge of the C-3 vertebral body and C2–3 annulus, and a single large screw was inserted into the dens. Next, the atlantoaxial joints were identified and decorticated with curettes. The grooves between the junctions of the C-2 articular facets and body represented the drill entry points for placement of the C1–2 transarticular facet screws. The cortical bone was penetrated with a bone awl, pilot holes were drilled across each C-2 superior facet into each C-1 lateral mass, and lag screws were inserted. The halo brace was removed and the patient’s neck was placed in a Philadelphia collar.

Postoperative Course. Postoperatively, the patient was weaned from the ventilator and extubated. The remainder of his hospital course was unremarkable and he was transferred to an inpatient rehabilitation service. On 27-month follow-up examination, the patient exhibited a decreased range of motion of his neck but no neck pain. He had moderate muscle atrophy and weakness of the distal left lower extremity due to his orthopedic injuries. He was ambulatory with moderate assistance, a four-leg walker, and a left ankle-foot orthosis. Plain lateral flexion–extension radiographs revealed a solid atlantoaxial osseous union with no evidence of atlantoaxial instability (Fig. 2 lower left and right).

Discussion

The surgical management of acute combination atlas–axis fractures is based on the same principles that gov-
pens the management of isolated atlas and axis fractures.\textsuperscript{9,11} Specific treatment recommendations depend on the extent of injury to the atlas, axis, and transverse atlantal ligament. Plain radiographs and thin-section CT scans best delineate the extent of bone injury but do not adequately demonstrate the anatomy of the transverse ligament. Historical criteria for transverse ligament injury such as a widened (> 3 mm) anterior atlantodental interval as seen on lateral radiographs or 7 mm or more of total lateral mass displacement of C-1 on C-2 as seen on open-mouth plain radiographs (Spence’s rule)\textsuperscript{31} are associated with high false-negative rates and therefore do not accurately predict most transverse ligament disruptions.\textsuperscript{10} Currently, axial MR imaging using a high-resolution, thin-slice, multiplanar gradient-echo technique remains the best method for evaluating the integrity of the transverse ligament.\textsuperscript{10,12,10}

Most patients with acute combination atlas-axis fractures can be treated successfully with an external orthosis.\textsuperscript{9,41} However, patients who are at high risk for nonunion or who have irreducible or recurrent subluxation despite external immobilization require early surgical stabilization and fusion. Transverse ligament disruption is an indication for early surgery because the transverse ligament cannot heal.\textsuperscript{10,16,19,22,24,26,29,30,33} In addition, early surgery is indicated for Type II odontoid fractures with 6 mm or more of dens displacement because they have a high rate of nonunion with external immobilization regardless of the patient’s age, direction of dens displacement, or degree of neurological impairment.\textsuperscript{20,21,23,32} Type II odontoid fractures with less than a 6 mm displacement may be treated either with a halo brace or early surgery depending on patient preference. The goals of surgery are to reduce pathological subluxations, restore atlantoaxial stability, preserve normal motion segments whenever possible, and protect the spinal cord and brainstem.

Most patients requiring early surgery can be treated successfully using a posterior operative approach. The procedure of choice depends on the extent of bone injury present. Posterior cervical wiring or Halifax clamp fixation requires intact posterior C-1 and C-2 arches. Posterior atlantoaxial facet screw fixation can be used if the posterior arches of C-1 and C-2 are disrupted but requires intact C-1 lateral masses and C-2 pedicles. If possible, we prefer to use a combination of interspinous wiring \textsuperscript{41} and posterior or atlantoaxial facet screw fixation \textsuperscript{25} because it provides immediate rigid three-point fixation that obviates the need for routine postoperative halo brace immobilization and results in a high rate of osseous union.\textsuperscript{27} Occipitocervical fusion is a salvage procedure for atlantoaxial instability that is used when the atlas cannot be fixated directly to the axis.\textsuperscript{7,17}

Anterior operative approaches may also be used to treat certain unstable combination atlas-axis fractures. Anterior odontoid screw fixation is indicated for treatment of contiguous C-1 Type II odontoid fractures that feature an intact transverse ligament. Anterior transarticular facet screw fixation\textsuperscript{13,25,31} is a salvage procedure for atlantoaxial instability that is used when posterior approaches to C1–2 are impossible, and requires intact C1–2 lateral masses. Potential complications associated with this technique include injury of vertebral artery if the screw trajectory is too lateral and inadvertent occipitocervical fusion if the screws are too long and penetrate the occipitoatlantal joints. The potential disadvantage of all anterior screw fixation techniques is that they cannot be supplemented with bone grafts and therefore require fusion across the fracture site or articular surfaces for long-term stability.

Our patient was admitted for treatment of multiple systems trauma after being struck by a car. He had a Type II odontoid fracture with an approximately 8-mm posterior dens displacement, a C-1 burst fracture with at least a 9-mm displacement of the lateral masses of C-1 on C-2, a left C-1 anterior tubercle fracture consistent with a Type IIB transverse atlantal ligament injury as described by Dickman, et al.\textsuperscript{10} and no neurological deficit. He was placed in a halo brace, and early surgical stabilization via a posterior approach was planned. However, surgery had to be delayed while his hemodynamic instability and lower-extremity injuries were treated. During this time he developed a severe case of pneumonia. He suffered recurrent episodes of O desaturation when placed partially prone for chest physiotherapy, raising concerns about the potential negative consequences of placing him prone for surgical stabilization. He was not considered a candidate for anterior odontoid screw fixation alone because he had a physiologically incompetent and dysfunctional transverse ligament secondary to the left C-1 anterior tubercle fracture. However, odontoid screw fixation was considered essential to achieve and maintain fracture reduction prior to transarticular facet screw fixation because his dens was displaced persistently when the patient was in the supine position. Therefore, he was treated with a combined anterior odontoid and C1–2 transarticular facet screw fixation and a Philadelphia collar. He has developed a solid osseous union and has shown no new evidence of atlantoaxial instability on long-term follow-up evaluation.

Conclusions

We conclude that anterior odontoid and C1–2 transarticular facet screw fixation may be used as a salvage procedure to treat certain patients with acute combination atlas-axis fractures when a posterior approach is not possible.

References

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