Atlantal lateral mass screws for posterior spinal reconstruction

Technical note and case series

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Object. A variety of techniques may be used to achieve fixation of the upper cervical spine. Transarticular atlantoaxial screws, posterior interspinous cable and graft constructs, and interlaminar clamps have been used effectively to achieve atlantoaxial fixation. Various anatomical factors, however, may preclude the successful application of these techniques. These factors include aberrant vertebral artery anatomy, irreducible atlantoaxial subluxation, exaggerated cervicothoracic kyphosis, and the absence of the osseous substrate for fixation. In these cases, an alternative method of fixation must be performed. The authors present an alternative method to achieve fixation of the atlas in which lateral mass screws can be applied to atlantoaxial and occipitocervical fixation.

Methods. Between February 1998 and November 2001, eight patients who ranged in age from 16 to 74 years underwent posterior fixation for upper cervical instability. Diagnoses included C-2 metastatic disease in two patients, irreducible odontoid fractures in two patients, atlantoaxial subluxation in two patients, and transverse ligament synovial cyst in two patients. Various anatomical factors precluded transarticular atlantoaxial screw fixation in seven patients. One patient with a highly unstable spine due to a C-2 metastasis and pathological fracture underwent occipitocervical fusion.

Atlantocervical fixation was achieved in seven patients by using varying constructs incorporating C-1 lateral mass screws. Occipitocervical fixation was achieved in one patient by incorporating C-1 lateral mass screws as an additional fixation point. A total of 14 C-1 lateral mass screws were placed in eight patients. There were no intraoperative complications. In all patients rigid fixation was achieved as demonstrated on postoperative radiographs. One patient died on postoperative Day 9 of aspiration pneumonia. At a mean follow-up time of 7.4 months, rigid fixation was maintained in all patients.

Conclusions. Atlantal lateral mass screws can be used to provide a safe and efficacious means of achieving atlantoaxial fixation when anatomical constraints preclude the use of a more traditional procedure. Atlantal lateral mass screws may also be incorporated in occipitocervical constructs to provide additional fixation points which may prevent construct failure.

KEY WORDS • atlas • lateral mass screw • posterior cervical fixation • atlantoaxial stabilization

A variety of techniques exist for fixation of the upper cervical spine. We describe a method for inserting screws into the lateral mass of the atlas to achieve posterior cervical fixation. This technique was recently described by Harms and Melcher as an alternative method to achieve atlantoaxial fixation. In this report we describe our experience using C-1 lateral mass screws to achieve posterior cervical fixation.

Atlantal lateral mass screws may be used to provide additional fixation points in occipitocervical constructs, possibly increasing resistance to construct failure in the cervical spine without increasing the number of cervical levels fused. Additionally, C-1 lateral mass screws may be used as a supplement to or substitute for other forms of atlantoaxial fixation. Techniques for achieving atlantoaxial fusion include posterior interspinous fusion with sublaminar cables and iliac crest bone graft, \(^6\) C-1–2 transarticular screw fixation, \(^1,5,6,7,16\) and interlaminar clamp fixation. \(^1,13\) Although each of these methods has been successfully used to achieve atlantoaxial fusion, anatomical factors may exist in certain cases that preclude their use. Interspinous fusion at C1–2 with sublaminar cables or interlaminar clamps cannot be performed if the posterior elements of C-1 or C-2 are absent or disrupted. Atlantoaxial transarticular screws cannot be placed successful-
ly in the presence of a medially located VA, irreducible subluxation, severe cervicothoracic kyphosis, or destruction of the C-2 pars interarticularis. In these cases constructs incorporating C-1 lateral mass screws may be used to achieve fixation. We present a small case series in which C-1 lateral mass screws were used to achieve atlantoaxial fixation when anatomical characteristics precluded the use of traditional fixation methods. Also included in this series is one case in which C-1 lateral mass screws were used to provide additional fixation points for occipitocervical fusion.

CLINICAL MATERIAL AND METHODS

Patient Population

Eight patients with cervicomedullary compression or atlantoaxial instability were treated surgically between February 1998 and November 2001. They ranged in age from 16 to 74 years; there were five women and three men. Preoperative diagnoses included C-2 metastasis in two, irreducible odontoid fracture in two, atlantoaxial subluxation in two, and transverse ligament synoval cyst in two patients. Posterior atlantoaxial fixation was planned in seven patients, one of whom had undergone a transoral resection of the odontoid prior to posterior fusion. In one patient with a C-2 metastasis and pathological fracture, an occipitocervical fusion was planned because the atlantoaxial complex was highly unstable. Atlantoaxial screw fixation was chosen as the initial fixation procedure when preoperative imaging studies revealed no anatomical factors contraindicating screw placement. All procedures were performed using intraoperative lateral fluoroscopy or CT-guided frameless stereotaxic navigation (Stealth Station; Sofamor Danek, Memphis, TN). Autogenous iliac crest bone graft was harvested via a separate posterior iliac crest incision and used for arthrodesis.

Surgical Technique

The patient is positioned prone using a Mayfield head holder (OMI, Inc., Cincinnati, OH). The neck is kept neutral with the head in the “military tuck” position. The arms are tucked in at the sides and the shoulders retracted caudally using tape. A midline incision is made, extending from the inion to C-3 if atlantoaxial fixation is planned. The incision is extended inferiorly as indicated by the planned procedure. A bilateral subperiosteal dissection of the paraspinal musculature is performed to expose the lateral marginals of the facet joints at the C2–3. Dissection is continued laterally over the posterior arch of C-1, exposing the VA in the vertebral groove on the C-1 arch. Bipolar cautery and hemostatic agents such as gelfoam and fibrillar collagen are used to control bleeding from the perivertebral venous plexus. The C-2 nerve root is identified and mobilized inferiorly. The lateral mass of C-1 inferior to the C-1 arch is exposed. The medial wall of the lateral mass is identified using a forward-angle curette to identify the medial limit of screw placement. The medial aspect of the transverse foramen can also be identified and serves as the lateral limit for screw placement. The entry point for screw placement is identified 3 to 5 mm lateral to the medial wall of the lateral mass, at the junction of the lateral mass and inferior aspect of the C-1 arch (Fig. 1). The entry point may be varied depending on the distance between the medial wall of the lateral mass and the C-1 transverse foramen. A high-speed drill with a 3-mm round burr is used to remove a small portion of the inferior aspect of the C-1 arch overlying the entry point, to create a recess for the screw head and plate or rod (Fig. 2 upper left). An assistant retracts the C-2 nerve inferiorly and protects the VA with Penfield dissectors or similar instruments during drilling and screw placement. Using fluoroscopy or image guidance a 3-mm drill bit and guide are used to drill a hole with 10 to 15° of medial angulation to penetrate the anterior cortex of C-1 (Fig. 2 upper right). On lateral fluoroscopic imaging the drill is aimed toward the anterior tubercle of C-1, so that the drill penetrates the anterior cortex of the lateral mass midway between the superior and inferior facets of C-1 (Fig. 2 lower left). The hole is tapped using a 3.5-mm tap. If lateral mass plates are used, an appropriate-sized plate is selected and contoured, after which a 3.5-mm screw is placed through the plate (Fig. 2 lower right). Caudal fixation points are then finalized. If a polyaxial screw/rod system is used, all screws are placed (Fig. 3 left), after which an appropriate sized and contoured rod is secured. In both cases an appropriate-screw length is selected to achieve bicortical fixation.

Once instrumentation placement is completed, decompression is performed if necessary. Finally, fusion is performed. Posterior arthrodesis with sublaminar cable and interspinous bicortical autograft is performed if the laminae

Fig. 1. Intraoperative photograph demonstrating C-1 entry point and anatomical landmarks. The dura mater has been exposed between C-1 and C-2, and the perivertebral venous plexus has been coagulated. The left greater occipital nerve is retracted inferiorly. The medial aspect of the C-1 transverse foramen and the VA in the vertebral groove of C-1 are demonstrated. The entry point lies at the junction of the C-1 lateral mass with the inferior aspect of the C-1 posterior arch midway between the transverse foramen and the medial wall of the lateral mass.
of C-1 and C-2 are preserved (Fig. 3 right). Otherwise, lateral arthrodesis is performed by carefully decorticating the exposed surfaces of the C1–2 joints by using a high-speed drill and then packing cancellous iliac crest autograft over these joints. A hemovac drain is placed prior to wound closure.

RESULTS

Fourteen C-1 lateral mass screws were placed in eight patients (Table 1). These screws were incorporated into several different constructs by using lateral mass plates (Axis; Sofamor Danek) or a polyaxial screw/rod system (Vertex; Sofamor Danek) to achieve atlantoaxial fixation in seven patients and occipitocervical fixation in one patient. There were no intraoperative complications and no VA injuries. One patient died on postoperative Day 9 of complications related to aspiration pneumonia. The remaining patients were immediately mobilized postoperatively in hard cervical collars, which were worn for 3 months. Immediate rigid fixation was achieved in all patients. There were no cases of hardware failure or screw pullout. The follow-up period ranged from 9 days to 18 months (mean 7.4 months). Osseous fusion was documented in two patients on 9- and 18-month follow-up radiographs, respectively, and in four patients delayed postoperative flexion–extension radiographs demonstrated construct stability.

CASE ILLUSTRATIONS

Case 1

This neurologically intact 16-year-old woman was referred for management of a Type II odontoid fracture. She had sustained the fracture 2 months earlier in a motor vehicle accident and had been treated with external immobilization by the referring physician. She was referred after postimmobilization radiographs revealed a 1-cm subluxation at C1–2 (Fig. 4 upper). After 3 days of halo traction, radiographs demonstrated minimal reduction of the subluxation, and she was taken to the operating room to undergo internal fixation. Intraoperative attempts to reduce the fracture under fluoroscopic guidance were unsuccessful. Internal fixation was achieved using a polyaxial screw/rod system with C-1 lateral mass screws and C-2 pars screws, supplemented with interspinous iliac crest autograft and sublaminar cable. The patient underwent immobilization therapy postoperatively in a hard cervical collar. Postoperative radiographs revealed solid fixation at C1–2 (Fig. 4 lower). The patient is neurologically intact at 3 weeks follow up.

Case 2

This 34-year-old man presented to the emergency department with severe neck pain and midline neck tenderness at C-2 after falling. There was no neurological deficit. Plain radiographs revealed an anteriorly displaced odontoid fracture (Fig. 5 left). Coronal and sagittal reformatted CT scanning demonstrated a Type III odontoid fracture involving the left C-2 pedicle. Magnetic resonance imaging revealed no neural compression. The fracture could not be reduced by halo traction. Stereotactic image-guided placement of C1–2 transarticular screws was attempted. Intraoperative attempts at fracture reduction were unsuccessful, and C1–2 screws could not be placed. Bilateral C-1 lateral mass screws, C-2 pars screws, and C-3 lateral mass screws were inserted. Fixation was achieved with lateral mass plates followed by C1–2 interspinous fusion with iliac crest autograft. The patient’s neck pain resolved, and flexion–extension radiographs obtained 9 months postoperatively demonstrated no motion and a solid osseous fusion (Fig. 5 right).

DISCUSSION

We have described a technique to achieve solid fixation

Fig. 2. Diagram. Upper Left: A high-speed drill is used to start a pilot hole at the entry point. The inferior aspect of the posterior arch has been drilled away to create a recess for the screw head. Upper Right: Axial view demonstrating medial angulation and bicortical purchase of the C-1 lateral mass screws. Lower Left: Lateral view of C-1 lateral mass screw/C-2 pars interarticularis screw construct with lateral mass plate. The tip of the C-1 screw is equidistant from the superior and inferior facets of C-1. Lower Right: Completed unilateral construct in which C-1 lateral mass screw and C-2 pars interarticularis screw were used with a lateral mass plate.

Fig. 3. Lower Right: Completed unilateral construct in which C-1 lateral mass screw and C-2 pars interarticularis screw were used with a lateral mass plate.
of the C-1 lateral mass that can be used in a variety of constructs for varying indications. In our experience, the most common indication for the use of C-1 lateral mass screws is atlantoaxial instability. Although a variety of techniques exist to treat atlantoaxial instability, certain anatomical factors may preclude their application in specific situations. Atlantoaxial interspinous fusion procedures involving either sublaminar cables or interlaminar clamps in combination with iliac crest autograft require the presence of intact posterior elements. These techniques cannot be applied when the C-1 arch or C-2 lamina has been disrupted by trauma, neoplasm, or other pathological processes, or when resection of these elements is necessary to achieve neural decompression. Atlantoaxial transarticular screw fixation is likewise precluded by a variety of factors. In up to 20% of patients, a medially located VA will preclude the safe passage of C1–2 transarticular screws unilaterally. In 3% of patients, VA anatomy will contraindicate the passage of screws bilaterally.10,14 Irreducible C1–2 subluxation will likewise preclude optimum placement of atlantoaxial transarticular screws. In this case, a screw trajectory traversing the articular surfaces of C-1 and C-2 cannot be achieved. Severe cervicothoracic kyphosis may contraindicate C1–2 transarticular screw placement by obstructing the trajectory of the instruments used to insert the screws. Destruction or erosion of the osseous substrate for screw fixation by trauma, neoplasm, or other pathological processes will likewise preclude transarticular screw placement. In these situations occipitocervical fusion may be considered as an alternative means to treat atlantoaxial instability. Occipitocervical fusion may be avoided using C-1 lateral mass screws to achieve atlantoaxial fixation. By avoiding occipitocervical fixation, there is no risk of intracranial bleeding, which may occur when occipital hardware is placed.17 Additionally, range of motion at the occipitoatlantal joint is maintained, which reduces morbidity from craniocervical malalignment that may occur following occipitocervical fusion. The authors of clinical studies have also suggested that avoidance of occipitocervical fusion may decrease the incidence of delayed subaxial subluxations.2,9 In this series we achieved atlantoaxial fixation in seven patients in whom various anatomical characteristics were demonstrated that precluded traditional methods of atlantoaxial fixation. These patients were all immobilized in hard cervical collars, avoiding postoperative halo vest immobilization.

It is likely that C-1 lateral mass screws will also prove to be extremely useful devices for occipitocervical fixation. Atlantal lateral mass screws provide additional fixation points for occipitocervical constructs, possibly increasing resistance to construct failure. This additional integrity of the construct is achieved without having to fuse additional cervical levels, thus preserving cervical motion segments. In the one patient in this series who underwent occipitocervical fixation, we were able to achieve solid C-1 fixation and integration into the occipitocervical construct by using C-1 lateral mass screws. As the use of polyaxial screw/rod systems for occipitocervical fixation becomes more widespread, we anticipate that C-1 lateral mass screws will become more widespread.
mass screws will be used more frequently, because the easily contoured rods used in these systems will allow C-1 screws to be easily incorporated into occipitocervical constructs.

In five of the seven patients in this series who underwent atlantoaxial fixation, C-1 lateral mass screw–assisted constructs were supplemented with a posterior C1–2 fusion in which sublaminar cable and interspinous autograft were used. In recent case series, Dickman and Sonntag\(^3\) reported an 86% fusion rate after interspinous cable and autograft–assisted fusion, whereas Farey, et al.\(^5\) reported a 58% fusion rate. In two smaller series, fusion rates of 100% were achieved using the Brooks method of interspinous fusion, but all patients were immobilized in a halo vest for 3 months postoperatively.\(^1,12\) It is not clear from the present series whether C-1 lateral mass screw constructs will increase fusion rates when applied in addition to interspinous fusion techniques, but it seems likely that the additional rigidity conferred by these constructs should result in improved outcomes. The ability of unilateral C-1 lateral mass screw constructs to increase fusion rates when applied in addition to interspinous fusion techniques, but it seems likely that the additional rigidity conferred by these constructs should result in improved outcomes. The ability of unilateral C-1 lateral mass screw constructs to increase fusion rates when applied in combination with contralateral C1–2 transarticular screws is also unclear. Song, et al.\(^15\) reported a 95% fusion rate after unilateral transarticular screw placement combined with posterior interspinous fusion in patients with high-riding VAs. In the present series, one patient received a unilateral C-1 lateral mass screw construct in combination with a contralateral transarticular screw and interspinous fusion. Again, it seems likely that the supplemental fixation provided by the C-1 lateral mass screw construct will increase rigidity and result in higher fusion rates.

It is also unclear whether C-1 lateral mass screw constructs can be used as a stand-alone instrumentation for achieving atlantoaxial fusion in the absence of interspinous fusion or unilateral transarticular screw fixation. Harms and Melcher\(^8\) suggested that temporary C1–2 constructs involving C-1 lateral mass screws may be used in selected cases, including those with rotatory subluxation and young patients with displaced odontoid fractures, allowing preservation of rotation at C1–2 after removal of the temporary instrumentation. In addition, they state that C1–2 fixation with C-1 lateral mass screws eliminates the morbidity associated with passage of the C-1 sublaminar cables. In the present series we treated two young patients with displaced odontoid fractures, adding interspinous cable and autograft to increase construct-related rigidity and provide additional substrate for bone fusion. We believe that odontoid fractures with irreducible subluxation are best treated with C1–2 interspinous arthrodesis in addition to instrumentation to provide optimum rates of long-term fixation. In our experience, the passage of C-1 sublaminar cables can be performed with minimal morbidity when neural compression is not present. In this series two patients were treated with stand-alone constructs because the absence of the C-1 or C-2 lamina precluded interspinous fusion. In both patients follow-up radiographs demonstrated stable constructs. When stand-alone constructs are used, it is important to perform lateral arthrodesis by decorticating the lateral masses and C1–2 joint space, with placement of cancellous autograft laterally. In the future, the decision to use a C-1 lateral mass screw construct without interspinous fusion or contralateral transarticular screw fixation should be considered on a case-by-case basis in the context of the pathological process causing instability, bone quality, and other comorbidities influencing bone fusion, as well as the potential morbidity of the alternative treatment, occipitocervical fusion. Larger studies with long-term follow-up results will be necessary to determine the safety and efficacy of C-1 lateral mass screw constructs.

Harms and Melcher\(^8\) have used a specially modified screw at C-1 with an unthreaded proximal shaft, to reduce the risk of greater occipital nerve irritation as well as screw breakage. In our series we used standard screws.
with threads along the entire shaft. We observed no cases of occipital neuralgia or screw breakage. These results indicate that standard screws may be used at C-1. We believe the risk of greater occipital nerve irritation is small provided there is adequate space caudal to the C-1 screw for passage of the nerve.

The risk of VA injury must always be assessed when placement of lateral mass screws or transarticular screws is planned. In this small case series, there were no VA injuries. To minimize this risk, preoperative CT assessment of the path of the VA is mandatory prior to placement of C-1 lateral mass screws. Magnetic resonance angiography or catheter angiography may be performed to obtain additional information concerning the path and patency of the VAs, although in our experience we have not found this to be necessary. The surgeon must note that the trajectory of the C-1 lateral mass screw is very different from that of lateral mass screws placed in the subaxial cervical spine. Particularly important is that the C-1 screw is placed with a slight medial angulation to avoid the VA laterally and the spinal canal medially. We consider the use of intraoperative fluoroscopy or CT-based image guidance mandatory to place C-1 lateral mass screws safely. Fluoroscopy allows safe placement of bicortical screws under direct visualization, whereas CT-based image guidance provides additional three-dimensional information about the VA and spinal canal. Virtual fluoroscopy may also prove to be a useful adjunct to screw placement.

CONCLUSIONS

The placement of C-1 lateral mass screws provides a useful alternative method to achieve atlantoaxial fixation when anatomical factors preclude the placement of C1–2 transarticular screws. This method achieves immediate rigid stabilization of the atlantoaxial joint and obviates the need for halo vest immobilization. This procedure may be used in certain cases as an alternative to occipitocervical fusion, and may also be used to increase construct-related stability when occipitocervical fixation is performed. Evaluation of the course of the VA with preoperative CT scanning and the use of intraoperative fluoroscopy or image guidance are mandatory when performing this procedure. Placement of C-1 lateral mass screws is a technically demanding procedure that may result in grave VA injury–induced complications if improperly performed. Thus we advocate that this procedure only be performed by surgeons who are highly experienced in the treatment of atlantoaxial instability and who have an intimate understanding of the regional anatomy. The uninitiated surgeon can minimize the possibility of complications during C-1 lateral mass screw placement by first performing this procedure in a cadaveric setting. Biomechanical analysis of this technique should be performed to quantify the strength of the constructs involving C-1 lateral mass screws compared with other fixation methods. Further clinical studies should be performed to determine the safety and efficacy of this technique.