The purpose of this study was to assess the feasibility and radiographic indications of using the subaxial anterior approach for decompression and fusion at C2. Anterior exposure at C2 was difficult and associated with increased morbidity. The subaxial anterior approach is easy and familiar to spine surgeons but did not provide satisfying exposure in all patients. This article describes a series of patients undergoing anterior surgery involving C2 through the subaxial anterior approach.

Patients were selected based on lateral extension radiographs showing a mandibular angle higher than the C3 upper endplate. Forty-two patients (29 men and 13 women) with average age of 45 years and an average follow-up of 9.7 months were reviewed. Etiologies included Hangman's fracture (n=35), traumatic disk herniation at C2-C3 (n=1), C3 fracture (n=2), ossification of the posterior longitudinal ligament (n=2), and tumor (n=2). Single-level discektomy (n=36) and corpectomy (n=6) were performed. Exposure was satisfactory, and operations went smoothly in all patients except in 1 man with a muscular neck. One (2.4%) postoperative complication of choking and trouble swallowing liquids was observed and diminished in 3 months with no treatment. Pre- and postoperative Japanese Orthopaedic Association scores were 13.86±2.25 and 16.50±0.76, respectively, with an improvement rate of 85%±24% in 14 patients who had preoperative neurological dysfunction. A fusion rate of 100% was achieved. The subaxial anterior approach may be simple and safe for exposure at C2 in select patients. Complicated exposure, such as the transoral or retropharyngeal approach, should be avoided in these patients.

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The cervical subaxial anterior approach is one of the most commonly used spinal approaches. The subaxial anterior approach was first used for the resection of the esophageal diverticula in the 1950s. It is also called Smith-Robinson approach because they adopted this approach for anterior cervical decompression and fusion.

The subaxial anterior approach is optimal for spine surgery at C3-C7. Extending this approach above C3 is difficult and associated with increased morbidity. Therefore, various surgical techniques were developed to address this issue.

Fang and Ong reported the transoral approach in 1962. It is designed to directly expose the atlas and axis, but the surgical corridor is relatively narrow. Thus, the transoral approach has the major shortcoming of limited operative space. By further splitting the tongue and mandible (transmandibular approach), clivus to C3 could be exposed. Without resecting the tongue, the transoral approach could reach C2-C3.

The retropharyngeal approach was first reported by Stevenson et al. for the treatment of a clival chordoma as a combined T incision and transcervical retropharyngeal approach in 1966. Andrade and MacNab reported this approach in their series of performing spinal arthrodesis from the atlas to the lower cervical spine. McAfee et al. modified this technique to the currently widely used version by including resection of the submandibular gland and transection of the digastric muscle. It then became the most commonly used approach for exposing C2. Although it provided satisfactory exposure of C1-C3, the retropharyngeal approach is unfamiliar to spine surgeons. Wide resection of normal organs or nerves is adopted, resulting in a high complication rate and long operative time. The approach-related complications included hypoglossal nerve paresis, salivary fistula, traction injury to the facial nerve, carotid artery occlusion, and carotid artery injury.

Although the subaxial anterior approach is usually used for exposing C3 and lower levels, it is easy to perform and familiar to spine surgeons. The technique was applied for C2 by some surgeons and achieved satisfying results. However, it is not feasible for all patients.

They noticed that the size of the mandible influenced the use of the subaxial anterior approach to expose C2. They usually perform anterior surgery using the subaxial anterior approach in patients with a small mandible and perform posterior surgery in patients with a large mandible. A small mandible was defined as a mandibular angle above the C3 upper endplate on lateral extension radiographs. They believed that decompression of the C2-C3 disk required direct sight into the disk space to ensure no residue of compression was preserved. If the chin extended over the C2-C3 disk, it would be a hurdle for removing the C2-C3 disk (Figure 1). In the current study, 42 patients with a small mandible underwent anterior surgery with the subaxial anterior approach. To the authors’ knowledge, the influence of the mandible on anterior exposure of C2 us-
ing the subaxial anterior approach has not been reported.

**MATERIALS AND METHODS**

**Case Series**

Between 2002 and 2009, the data of 42 patients (29 men and 13 women) with an average age of 45 years (range, 14-72 years) undergoing cervical anterior decompression and fusion with at least 6 months of follow-up were reviewed (Table). Etiology included Hangman’s fracture (n=35), traumatic disk herniation at C2-C3 (n=1), C3 fracture (n=2), ossification of the posterior longitudinal ligament (OPLL) (n=2), and tumor (n=2). Surgical indication for Hangman fracture was unstable fracture (type II and III, according to Levine’s classification24; n=24) or failed conservative treatment (n=11), as the current authors previously reported.29 Combined injury included head injury (n=10) other spinal fracture (n=2), extremity fracture (n=6), and inner organ injury (n=2). Combined morbidity included hypertension (n=8), diabetes mellitus (n=3), and ankylosing spondylitis (n=1).

Complications and neurological status were recorded. Neurological function was evaluated with the Japanese Orthopaedic Association score pre- and postoperatively. Fusion was considered achieved when bridging trabeculae were seen on postoperative computed tomography scans or radiographs.

**Surgical Technique**

Preoperatively all patients performed neck extension exercises under doctors’ supervision. In patients with a fracture, neck extension was performed under constant traction.

Nasotracheal intubation was performed while patients were conscious. Then, the patient was placed in the supine position with the neck in full extension (Figure 2). Anesthesia was administered after intubation and positioning. A standard transverse or vertical incision was used for the lower cervical spine. The transverse incision was usually located midway between the angle of the jaw and the thyroid cartilage. A wide subcutaneous release was made. Fascial dissection was made between the omohyoid and sternohyoid just below the hyoid. The superior thyroid artery usually crosses this field at C3.30 It could be released and drawn caudal to expose C2-C3 or drawn cephalic to expose the lower cervical spine.

Two C-shaped celiac retractors were then placed to draw the tracheoesophageal bundle and carotid vessel to the lateral sides. The soft tissue was simultaneously pulled cranially by a retractor to expose the midportion of C2. The retractors may be stopped by the mandibular arch when they pull cranially. Turning it into an oblique position will help expose more of the front portion of the C2 body (Figure 3). With satisfactory exposure, decompression and instrumentation were performed routinely as it was performed at the lower cervical spine. A cage or tricortical iliac crest was used for arthrodesis. An anterior constrained plate was generously used.

Patients were allowed to walk with a Philadelphia collar 1 day postoperatively. The hard collar was used for 4 to 8 weeks depending on the patient’s general condition and the surgeon’s experience.

**RESULTS**

Single-level disectomy of C2-C3 (n=36) or corpectomy of C3 (n=6) were performed. A cage was used for 34 patients, autogenous tricortical iliac graft in 2, and titanium MESH in 6. Exposure was acceptable, and operations went smoothly in all patients except 1 man with a muscular neck. The incision could barely be drawn cranially with under largest dose of atracurium he could take. Anterior decompression and instrumentation were...
achieved through an oblique working tunnel with difficulty.

No permanent neurological deterioration was observed during an average follow-up of 9.7 months (range, 6 months-3 years). One approach-related complication, choking and trouble swallowing liquids, was observed in 1 (2.4%) patient and diminished in 3 months with no treatment. Neurological improvement was observed in 14 patients who had neurological dysfunction preoperatively. Pre- and postoperative Japanese Orthopaedic Association scores were 13.86±2.25 and 16.50±0.76, respectively, with an improvement rate of 85%±24%.

No patient underwent a secondary operation during follow-up. A fusion rate of 100% was achieved.

**DISCUSSION**

Both anterior and posterior approaches can be used to treat lesions at C2. Because of the complex anatomic feature of the upper cervical spine, arthrodesis was predominately achieved with a posterior approach.24,27,31-34 The posterior approach was preferred for its simple exposure that avoids major visceral and vascular structures, and thus, its lower complication rate.16,24,26,27,35,36 Segmental fixation of C2-C3 was widely adopted due to its reserved neck rotation by sparing atlantoaxial articulation.27,37,38 However, using transpedicle screws poses the risks of intraoperative neurological and vascular injuries. Placement of a C2 transpedicle screw has an injury rate to critical structures between 11% and 66% in its early application.39-41 The intrusion rate has decreased to 6.6%, and a total surgical complication of 12.5% was reported.42 Another shortcoming of the posterior approach is postoperative axial pain.

The anterior approach is an alternative surgical approach for lesions at C2 and is sometimes the only option when disk herniation exists at C2-C3 or OPLL exists at C3, and medullar compression, C3 body fracture, tumor in C3 vertebral body, or a failed posterior arthrodesis.13,21,27,38,43 However, anterior exposure at C2 is often considered complex.6,23,44 Three approaches have been used for anterior surgery: the transoral, retropharyngeal (high cervical), and subaxial anterior approaches. Among these approaches, the retropharyngeal approach may be the most frequently used.11-27 However, the retropharyngeal approach is complicated and involves exposing many nerves and vessels.13 A wide, anatomic dissection of each fascial plane was needed. The facial nerve, submandibular gland, digastric muscle tendon, and hypoglossal trunk should be exposed and carefully handled. To provide a satisfying visualization, Skaf et al16 suggested resecting the submandibular gland.

The subaxial anterior approach was used for treating axis lesions.7,28 Traynelis and Fontes7 reported using intraoperative fluoroscopy and a table-mounted retractor system to perform axis instrumentation in...
46 patients through the subaxial anterior approach. They reported that conditions existed for which the subaxial anterior approach could not provide sufficient exposure. The current authors previously reported a series of Hangman’s fracture treated by anterior decompression and fusion through the subaxial anterior approach and noted that using the subaxial anterior approach for anterior exposure of C2 is challenging in patients with a short, muscular neck. In their experience, the position and size of the mandible affected the results of the subaxial anterior approach. The stretching range of the incision was limited by the chin because the cephalic movement of the retractor was stopped by the mandibular arch. The relationship between the mandible and the cervical spine changes often during neck movement (Figure 4). In extension, the mandible is more cephalic, and the upper cervical spine is exposed more than in other positions. Based on this feature, lateral extension radiographs were used to evaluate the feasibility of the subaxial anterior approach at C2. To avoid spinal cord injury, especially in patients with a fracture, the neck was positioned while the patient was conscious (Figure 5).

The approach-related complication rate was 2.4%, which was lower than that reported by Traynelis (12.9%), who performed the subaxial anterior approach, and lower than those who performed the retropharyngeal approach (range, 12%-20%). The results of the current series proved that the subaxial anterior approach could provide adequate and safe exposure for decompression and instrumentation at C2 in patients with a mandible angle higher than the C3 superior endplate on lateral extension cervical radiographs. However, the subaxial anterior approach may not be limited in these patients.

For patients with a large mandible, the posterior approach may be more promising for lesions involving C2. If anterior surgery became necessary, the retropharyngeal approach may be advantageous. In such cases, the distraction force can be applied mainly to the retropharyngeal space, and the injury to the surrounding soft tissues can be reduced. Therefore, the current authors emphasized the importance of evaluating the feasibility of the subaxial anterior approach in each patient. Further studies are needed to determine the optimal indications for the subaxial anterior approach in patients with a mandible angle higher than the C3 superior endplate.
ryngal approach should be considered. In patients with a small mandible, the subaxial anterior approach provided easy and safe exposure. With satisfactory exposure, discectomy of C2-C3, corpectomy of C3, or both could be performed. Discectomy was usually sufficient for a Hangman's fracture. C3 corpectomy is often required for OPLL. In patients with OPLL, with a large occupying rate (more than 50%), a special technique, microscope, or intraoperative fluoroscopy needs to be adopted.7,49,50

The major shortcoming of the current study was its lack of a paired comparative group. The subaxial anterior approach may also provide enough exposure in some patients with a chin angle lower than the C3 upper endplate. For ethnic reasons, the authors did not test the possibility of using the subaxial anterior approach in patients with a large chin. Animal or cadaver research may partially resolve the problem, with the limitations of different anatomy and loss of flexibility of soft tissue. Muscle tension is another factor that influences exposure, which was not assessed in current study. Patients with strong muscles may not be good candidates for undergoing the subaxial anterior approach, even those with a small mandible.

CONCLUSION

In patients with a mandible angle higher than the C3 superior endplate on lateral extension radiographs, the subaxial anterior approach could provide adequate and safe exposure for decompression and instrumentation at C2. However, using the subaxial anterior approach may not be limited in these patients. In these patients, complex exposure, such as the transoral or retropharyngeal approaches, could be avoided. Preoperative lateral extension radiographs under surgeons' supervision would help find patients who are eligible for undergoing the subaxial anterior approach. Maximum neck extension in positioning facilitates exposure. Nasotracheal intubation and positioning while patients are conscious may avoid spinal cord injury, especially in patients with a fracture.

REFERENCES


