Clinical Article

Surgical Treatment of Craniovertebral Junction Instability : Clinical Outcomes and Effectiveness in Personal Experience

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Objective : Craniovertebral junction (CVJ) consists of the occipital bone that surrounds the foramen magnum, the atlas and the axis vertebrae. The mortality and morbidity is high for irreducible CVJ lesion with cervico-medullary compression. In a clinical retrospective study, the authors reviewed clinical and radiographic results of occipitocervical fusion using a various methods in 32 patients with CVJ instability.

Methods : Thirty-two CVJ lesions (18 male and 14 female) were treated in our department for 12 years. Instability resulted from trauma (14 cases), rheumatoid arthritis (8 cases), assimilation of atlas (4 cases), tumor (2 cases), basilar invagination (2 cases) and miscellaneous (2 cases). Thirty-two patients were internally fixed with 7 anterior and posterior decompression with occipitocervical fusion, 15 posterior decompression and occipitocervical fusion with wire-rod, 5 C1-2 transarticular screw fixation, and 5 C1 lateral mass-C2 transpedicular screw. Outcome (mean follow-up period, 38 months) was based on clinical and radiographic review. The clinical outcome was assessed by Japanese Orthopedic Association (JOA) score.

Results : Nine neurologically intact patients remained same after surgery. Among 23 patients with cervical myelopathy, clinical improvement was noted in 18 cases (78.3%). One patient died 2 months after the surgery because of pneumonia and sepsis. Fusion was achieved in 27 patients (93%) at last follow-up. No patient developed evidence of new, recurrent, or progressive instability.

Conclusion : The authors conclude that early occipitocervical fusion to be recommended in case of reducible CVJ lesion and the appropriate decompression and occipitocervical fusion are recommended in case of irreducible craniovertebral junction lesion.

KEY WORDS : Craniocervical junction instability · Occipitocervical fusion · Spinal instrumentation.

INTRODUCTION

Instability of the craniovertebral junction (CVJ) and the atlantoaxial complex is associated with difficult diagnostic and therapeutic problems due to their complex anatomical structures and biomechanical characteristics. These injuries may cause immediate fatality or delayed deterioration of neurological function[6,7]. Many authors report excellent results from occipitocervical fixation by using various internal fixation instruments, including wire-rod system and screw-plate system, which are currently widely used. The goals of internal fixation are to achieve anatomic alignment, to protect the neural elements, to stabilize the spine while preserving the motion of normal elements and to produce a "functional decompression". We reviewed our clinical experience of 32 patients to evaluate clinical outcome, complications and effectiveness of occipitocervical instrumentation (wire and screw system) with CVJ instability. Additionally, we took account of relevant reports and made decision-making tree for such cases.

MATERIALS AND METHODS

From 1998 to 2009, 32 patients underwent occipitocervical internal fixation surgery in the neurosurgical department of our institution. Their medical records and imaging studies were retrospectively reviewed. They had been followed up for a mean of 38 months (range, 3-60 months) years. Eighteen males and 14 females, with a mean age of 48.8 years (range,

18-68 years) were included as patients. The causes of CVJ instability were trauma (14 cases), rheumatoid arthritis (8 case), assimilation of C1 (4 cases), basilar invagination (2 cases), upper craniovertebral junction metastatic disease (2 cases), and miscellaneous (Arnold-Chiari Malformation 1 case, Os odontoideum 1 cases). Each patient underwent preoperative radiological evaluation of X-ray, CT scan and MRI of the CVJ region. Instability of the CVJ was diagnosed if atlantodental interval was shifted by more than 3 mm in dynamic X-ray and if pathologic movement with neurological symptoms (subjective and objective) were present. In patients who had severe trauma, dynamic X-ray was not performed in order to avoid pain and to prevent neurological deterioration. Treatment was chosen considering a number of different factors, including the general medical condition of the patient, the severity and location of the fracture, compression of the spinal cord, degree of instability and the
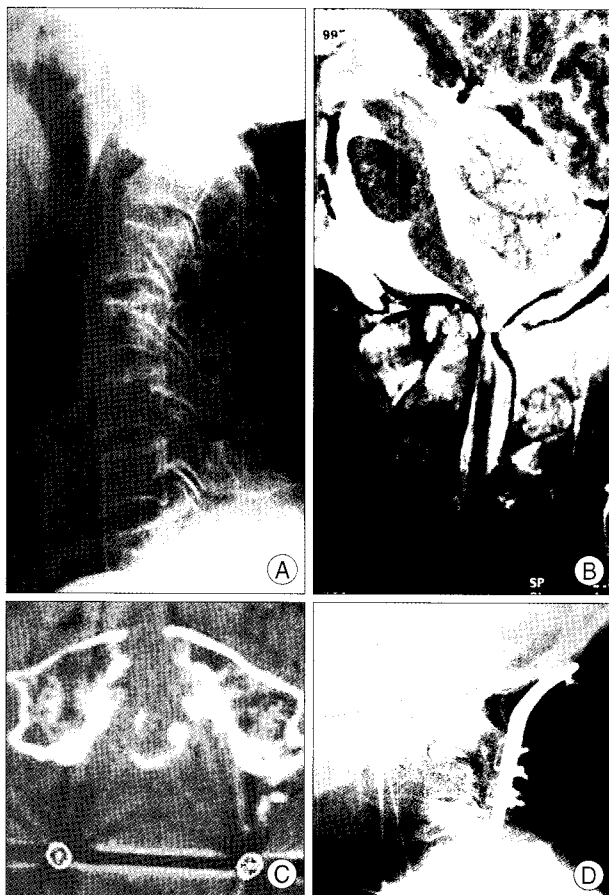

Fig. 1. A 65-year-old woman presented with progressive quadriparesis for 10 years. A : Lateral radiograph of the CVJ shows assimilation of the atlas and absent posterior elements of the C1. B : Preoperative craniovertebral junction MRI shows the assimilation of the C1 and the spinal cord signal change consistent with occipital foramen stenosis. C : Postoperative axial reconstructed CT scan shows a removal of the anterior arch of C1 and dens of C2. D : She underwent occiput-to-C2 fusion with wire-rod fixation. Postoperatively, her neck pain and myelopathy had improved significantly on follow-up examination. CVJ : craniovertebral junction.

neurological status. If there was cervical spinal mal-alignment, we attempted first to reduce the dislocation using cervical traction except ocipitocervical dislocation case. Cervical MRI was performed to evaluate spinal cord compression. In patients with malpositioning of the dens with anterior compression of the spinal cord, and failure of reduction with concomitant neurologic deficits, a trans-oral decompression with resection of the dens was performed as first-stage surgery, prior to the posterior OC fusion (Fig. 1). The need for a laminectomy was evaluated based on the clinical findings of either cervical myelopathy or radiculopathy, and the presence of spinal cord compression on MRI. If posterior decompression of the spinal cord was necessary, posterior decompression was performed at the same surgery as the fusion procedure. All patients underwent fusion with titanium contoured U-shaped rod and Songer titanium sublaminar wire or titanium alloy rod and screw. We used various instrumentation techniques, depending on the spinal level. Anteroposterior and lateral radiographs were taken immediately after surgery and monthly for at least 6 months, and a hard cervical collar was worn for at least 3 months postoperatively.

Autologous iliac crest (29 patients) and calvarium (1 patient) allograft were harvested, and the exposed bone on C1 and C2 was decorticated prior to graft placement. The graft was carefully fashioned to fit precisely to the prepared decorticated posterior surface of C1 and C2. Patients were then followed on outpatient clinic. All patients underwent both anteroposterior/lateral/dynamic plain radiography and cervical CT scan to assess screw placement and fusion rate. Fusion was assessed principally by CT scans. Fusion was assessed by dynamic plain radiography of patients who could not take the CT scan during the follow up period. Satisfactory fusion was defined as successful if two criteria were met : 1) the presence of a homogeneous fusion mass visualized between the graft and bone on CT scans; 2) there was no pathological movement between the fused motion segments in flexion and extension views of cervical X-ray study. Clinical conditions before and after the surgery were assessed using the Japanese Orthopaedic Association (JOA) score[17]. The JOA score was assessed before the operation, at discharge, after 1 month and 6 months and finally at the most recent follow up. The total JOA score assessed motor and sensory functions of four extremities and sphincter, which amounts to a total of seventeen points (Table 1). The neurologic recovery rate was calculated as follows : (postoperative JOA score-preoperative JOA score)/(full score-preoperative JOA score) × 100. Neurological recovery rate was ranked as excellent (75-100%), good (51-74%), fair (25-50%), poor (0-24%), or worse (< 0%). Comorbidity and complications were recorded to assess the risk of surgery.

Table 1. Japanese Orthopaedics Association score for cervical myelopathy

	Japanese Orthopaedics Association Score
I	Motor function of upper extremity
	0 : Unable to eat with either spoon or chopsticks
	1 : Possible to eat with spoon, but not chopsticks
	2 : Possible to eat with chopsticks, but inadequate
	3 : Possible to eat with chopsticks, but awkward
	4 : Normal
II	Motor function of lower extremity
	0 : Impossible to walk
	1 : Need cane or aid on flat ground
	2 : Need cane or aid only on stairs
	3 : Possible to walk without cane or aid, but slow
	4 : Normal
III	Sensory deficit
	A) Upper extremity
	0 : Apparent sensory loss
	1 : Minimal sensory loss
	2 : Normal
	B) Lower extremity
	0 : Apparent sensory loss
	1 : Minimal sensory loss
	2 : Normal
	C) Trunk
	0 : Apparent sensory loss
	1 : Minimal sensory loss
	2 : Normal
IV	Sphincter dysfunction
	0 : Complete urinary retention
	1 : Severe disturbance
	2 : Mild disturbance
	3 : Normal

RESULTS

Clinical results

There were 18 male and 14 female patients with a mean age of 48.8 years (range, 18-68 years). Table 2 shows the clinical data of the 32 patients undergoing CVJ surgery as diagnosed on imaging. Preoperatively, all patients suffered from significant neck pain, stiffness or radiculopathy. Twenty-three patients presented with myelopathy. Seven patients underwent a transoral odontoidectomy for either rheumatoid arthritis (3 patients), congenital anomaly (2 patients), neoplasm (1 patient), basilar invagination (1 patient) immediately prior to posterior fusion. All 7 patients performed posterior fusions after completion of the transoral procedure. Fifteen patients underwent posterior decompression and fusion with rod and wire fixation for trauma (7 patients), rheumatoid arthritis (3 patients), congenital anomaly (3 patients), neoplasm (1 patient) and basilar invagination (1 patient). Five patients underwent a C1-C2 transarticular screw fixa-

tion for rheumatoid arthritis (2 patients) and trauma (3 patients). C1 lateral mass-C2 transpedicular screw fixation was performed to rheumatoid arthritis (1 patient) and trauma (4 patients).

Neck pain improved in all patients and no new instability developed at fusion levels. At the last follow-up examination, 27 patients had a satisfactory fusion and were independent in daily activity.

All nine neurologically intact patients remained same after surgery. Among 23 patients with cervical myelopathy, 18 patients (78.3%) had improvement of the JOA scores at last follow-up. The JOA score of the 23 patients were 11.2 (range, 0-16) before surgery and 22 patient were 13.6 (range, 0-17) at the time of last follow up. According to the disease group, the JOA score for patients with trauma improved from 9.4 to 12.1 with a recovery rate of 38.3%. The JOA score for patients with rheumatoid arthritis improved from 12.4 to 14.4 with a recovery rate of 44.4%. The JOA score for patients with congenital anomaly improved from 14.2 to 15.6 with a recovery rate of 58.2%. The average recovery rate in JOA score was 45.2% (range, 0-100.0). One of the patients, who had an occipitocervical dislocation with quadriplegia due to a motor vehicle accident, died 2 months after the surgery. After receiving OC fusion with C1-2 transarticular screw and wire-rod fixation, the patient had pneumonia and sepsis due to long term use of mechanical ventilator and decreased pulmonary function (Fig. 2). The postoperative course of other survived patients was uncomplicated. After wearing a hard cervical collar for at least 3 months, they were discharged 10 to 21 days after surgery. Neck pain improved in all patients and new instability did not develop at operated levels. There was no further deterioration within 3 months following the operation.

Radiological results

Immediately after the operation, plain cervical X-ray images showed restoration of bone alignment in every patient. Postoperative imaging studies confirmed excellent instrument fixation and no abnormal lesion related to surgery in all patients. Post-operative X-ray at 6 months did not reveal instrument loosening or breakage. Up to 12- or 24-month follow-up, plain radiographs did not show any change in instrument position when compared with the immediate post-operative radiographs. During the follow up period, fusion was assessed by dynamic plain radiographs in 8 patients and 22 patients took postoperative CT scan to assess the fusion. Among 22 patients who took postoperative CT scan, solid fusion was found in 21 patients (95.4%). Among 8 patients who were assessed fusion by dynamic plain radiographs, the fusion could be assumed by the absence of the pathologic

Table 2. Clinical data of the 32 patients undergoing occipitocervical fusion

|		No. of patient
Sex	Male	18
	Female	14
Age		18 - 68 years (mean 48.8)
Follow up period		3 - 60 months (mean 38)
Diagnosis	Trauma	
	Acute C1-2 dislocation	5
	Acute unstable C2 fracture	2
	Acute C1-2-3 fracture dislocation	1
	Acute C1 fracture (unstable Jefferson's fracture)	2
	Occipitocervical dislocation	2
	Old unstable C2 fracture	2
	Rheumatoid arthritis	8
	Congenital anomaly	
	Assimilation of atlas	4
	Arnold-Chiari Malformation	1
	Os odontoideum	1
	Basilar invagination	2
	Tumor	2
Symptom and sign	Neck pain	32
	Myelopathy	23
Operative procedure	Anterior and posterior decompression with occipitocervical fusion	7
	Posterior decompression and fusion with wire and rod	15
	C1-C2 transarticular screw fixation	5
	Occiput-/ C1 lateral mass-C2 transpedicular screw fixation	5
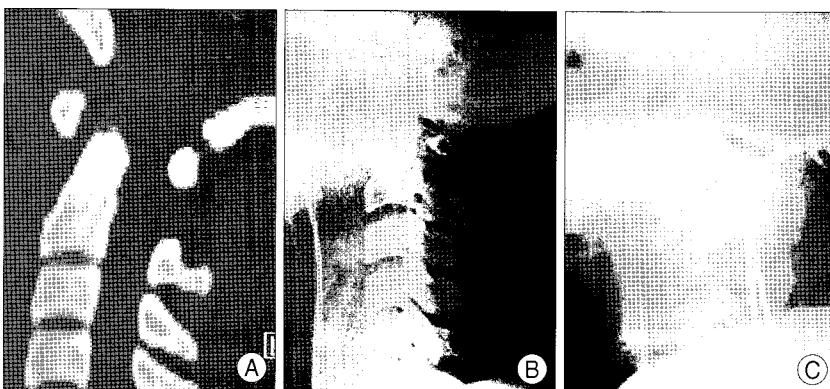
Fig. 2. A 54-year-old woman presented with quadriplegia due to motor vehicle accident. A : Pre-operative sagittial CT scan shows occipitocervical dislocation (Power's ratio : 0.96). B : Preoperative lateral cervical spine radiograph shows atlantoaxial dislocation and 10 mm of anterior translation of C1. C : Post-operative lateral radiograph shows occipitocervical fusion with C1-2 transarticular screw and wire-rod system.

movement in 7 patients (87.5%). True solid fusion rate diagnosed by postoperative CT scan was 95.4%. Failed fusion cases were of 68-year-old female patient with traumatic C1-2-3 dislocation who received an occiput to C4 fusion with screw fixation and of the other 72-year-old female with rheumatoid arthritis who received an occiput to C3 fusion with screw fixation. According to these fusion criteria, overall fusion rate was achieved in 28 patients (93%) and non-union in 2 patients (7%) at last follow-up.

Complication

There were two cases of vertebral artery (VA) injury during operation. In one case, it occured during the C2 tranpedicular screw placement. We placed a screw in a drill hole to control bleeding and underwent unilateral screw placement only to avoid bilateral VA injury resulting in brainstem ischemia (Fig. 3). This patient underwent a CT-angiogram immediately after surgery, which showed complete occlusion of the VA at C2 transverse foramen with some retrograde flow from the contralateral VA. Special attention was paid to the patient after surgery, but no specific treatment was required since the patient showed no symptoms related to the VA injury from the admission to follow up period. In other case, VA was injured during the exposure of the C1 lateral mass. We dissected posterior arch of C1 by using bipolar coagulator and dissected too much of the lateral side. Left vertebral artery was injured by bipolar coagulator tip. We controlled bleeding intra-operatively by using the thrombin-soaked gelform. On immediate angiographic evaluation, there was evidence of VA injury which was occluded by thrombus. Coil embolization of left VA was performed (Fig. 4).

DISCUSSION

Treatment of CVJ instability is challenging field in neurosurgery and is pri-mary indication for OC fusion. The common result is cervicomedullary neural tissue compression with development of symptoms and signs. Patients may present with progressive myelopathy, pain (neck pain, radiculopathy), lower cranial nerve dysfunction, or deformities of the craniocervical region[4,19]. We reviewed 12-year experience of clinical outcome, occipitocervical instrumentation and operative morbidity in treatment of CVJ insta-

bility and lessons we learned are discussed.

Decision making

The indication for fusion in CVJ instability patients, an extensive posterior instrumentation fixation procedure that sacrifices the motion of the occipital and C1-2 complex is still controversial[1,2,12,22-24,29]. In other words, failed fusions were due to use of an inappropriate method of rigid internal fixation or of an improper fusion level. To determine the number of fusion level is one of the most important factors to achieve the complete fusion. Reducibility, status of posterior element and direction of surgical approach should be determined in deciding the level.

We propose an algorithm for treatment of patients with CVJ disease (Fig. 5). An initial distinction should be made between non-trauma versus traumatic lesion and reducible versus irreducible lesion. We should always take the followings into consideration for specific treatment of CVJ instability.

First is reducibility of the bony lesion. Depending on the reducibility and status of posterior element, the instrumentation is extended upward to the occiput or is extended downward to the C3, C4 fusion (Fig. 6). Incomplete reduction of C1-2 lesion is a statistically significant risk factor for VA injury during the placement of screws instrumentation[14]. In reducible lesions at CVJ, stabilization is paramount to maintain neural decompression. In irreducible lesions, decompression is mandated at the site of encroachment, whether this is anterior or posterior approach. If complete reduction of the C1-2 subluxation is possible, we usually perform C1-2 fusion so that occipital-C1 motion is preserved. If the lesion is irreducible C1-2 subluxation and C1 or C2 posterior element defect (such as fracture and tumor), we recommend OC fusion in this circumstances. However, irreducible C1-2 lesion may necessitate OC fusion for stability.

Second is direction of compression and encroachment. Compressed lesions require decompression at a site where the compression has occurred; these are divided into ventral and dorsal compression states. Anterior decompression (ex, transoral odontoidectomy) results in severe ligamentous and

osseous destruction[3,18]. This procedure alters CVJ anatomy and affects biomechanics of the region. The resultant occiput-C1 and C1-2 hypermobility requires OC fixation (Fig. 1)[6].

Third is the cause of the CVJ instability such as trauma or non-trauma, including congenital, inflammatory and tumor. CVJ instability represents the primary indication of CVJ
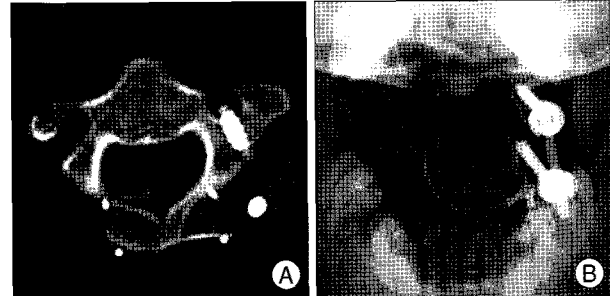

Fig. 3. A 56-year-old male patient had an old, reducible C1-2 subluxation. He had been involved in a motor vehicle accident 6 months previously. A : Postoperative cervical reconstructed axial CT scan reveals a screw penetrating the left vertebra foramen. B : Anteroposterior radiograph demonstrates atlantoaxial stabilization with unilateral transpedicular screws fixation supplemented by sublaminar wire fusion (Sonntag's modified Gallie fusion).
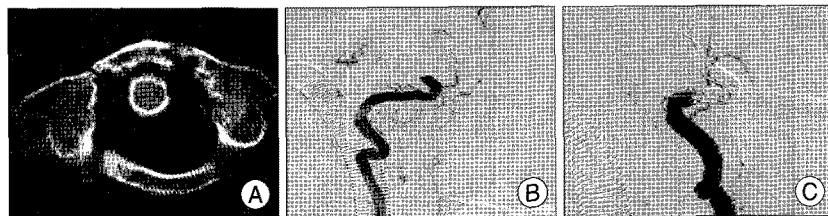

Fig. 4. A 55-year-old male patient had an unstable Jefferson fracture. There was vertebral artery injury during the C1 arch dissection. A : Axial CT scan shows fracture of anterior and posterior arch of C1. B : Immediate angiographic evaluation shows evidence of left vertebral artery injury which was occluded by thrombus. C : Angiogram after coil embolization shows the totally embolized and no flow of left vertebral artery. D : We underwent unilateral screw placement only to avoid bilateral vertebral artery injury.
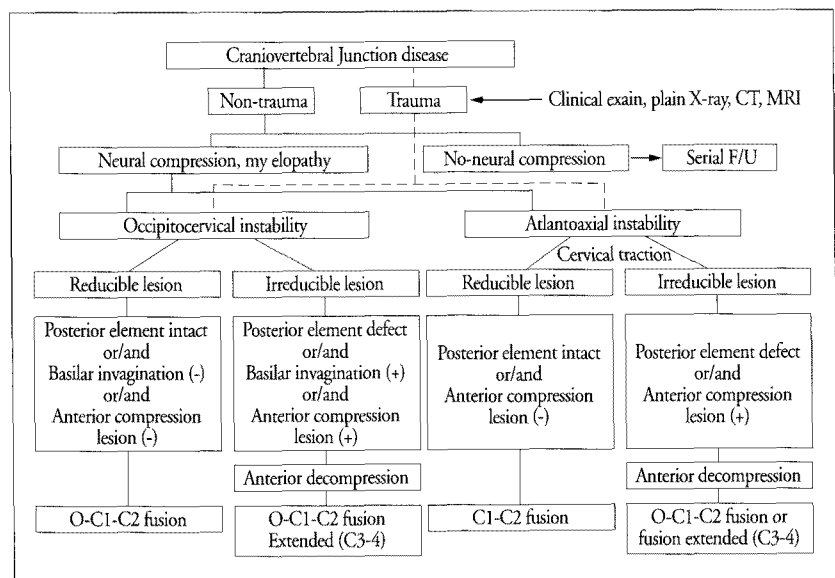

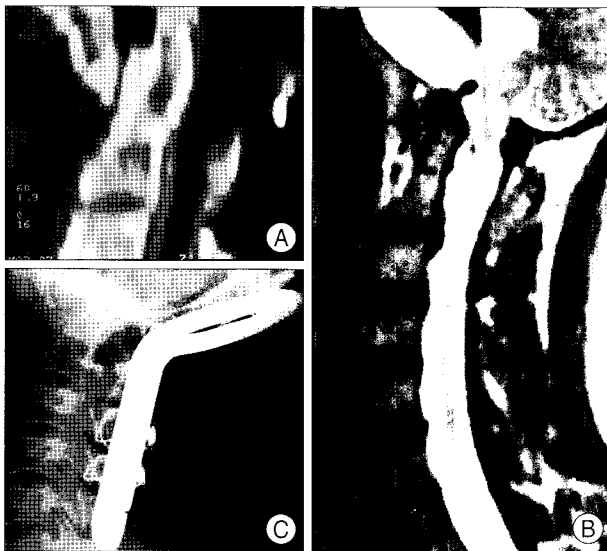**Fig. 5.** Algorithm for treatment of craniovertebral junction disease.

Fig. 6. A 25-year-old female patient who had 7-years history of unsteady gait. A : Sagittal reconstructed CT scan shows the existence of basilar invagination. B : Preoperative MRI scan shows ventral compression of the cervicomedullary junction, associated Chiari-malformation. C : Lateral radiograph shows occiput to C3 fusion with foramen magnum decompression and C1 laminectomy. Postoperatively, she made a good recovery with resolution of her symptoms at last follow-up.

fusion. Traumatic CVJ instability is often encountered in neurosurgical field and the neurological consequences are usually serious and fatal. However, once CVJ instability is confirmed in trauma patients, there should be no limitation in surgery to stabilize CVJ lesion regardless of abscence of neural compression. In cases of non-trauma, it is difficult to decide surgical treatment in children with craniovertebral junction diseases such as Grisel's syndrome, osteogenesis imperfect and allied conditions. If there are no neural compression and osseous instability, re-evaluation with diagnostic procedures aimed at identifying the status of the bony development and neural compromise should be carried out on a yearly basis.

Our experience has shown that this algorithm regarding management of CVJ disease should be followed carefully to avoid unnecessary procedures but nevertheless, it is more important to provide surgical treatment based on different individuals.

Clinical outcomes

The effectiveness of operative procedures reported was demonstrated by the fact that each patient was either stabilized or improved at last follow up. Although there is no standardized grading system to clinically evaluate patients with cervical myelopathy, studies usually employ myelopathy grading system such as the JOA score and the Nurick Scale. In our series, 18 patients (78.3% of patients) experienced an improvement of the JOA scores in their symptoms after the

operation. These results are consistent with the 75% to 95% rate reported in the literature[10].

Significant neurologic improvement (recovery rate > 50%) demonstrated 40% of patients in rheumatoid arthritis, 50% in trauma and 40% in congenital anomaly. These results are consistent with other reports indicating a 30% to 40% significant improvement in myelopathy[4]. Although, it is difficult to make a statistically firm conclusion due to the small sample size, recovery rate in myelopathy seems not to be affected by the fusion methods. Traumatic atlanto-occipital dislocation with survival is rare, as the neurological consequences are usually immediately fatal. In this series, one patient had an occipitocervical dislocation with a quadriplegia and died at 2 month after the operation. Patient had been bedridden for 2 months after surgery. The patient died of pneumonia and sepsis. Non-union associated with pseudoarthrosis occurred in two patients. One patient had a rheumatoid arthritis with C1-C2-C3 subluxation and the other patient had a traumatic C1-C2-C3 dislocation with osteoporosis (T-score : -3.2). In CT scan, there were non-union in bone fusion site probably as a consequence of poor bone quality (osteopenic bone) and slight C1-2 subluxation on dynamic radiographs without neurological impairment. Although pseudarthrosis was observed, two patients were old age (over 65 years old) and had no neurologic symptoms. Thus, we did not perform revision surgery for these 2 patients. We are following these case further, and we will consider fusion surgery if further instrumentation failure and/or neurologic symptoms appear.

Fusion rate

Many investigators have discussed postoperative fusion rates in CVJ patients in whom occipitocervical or atlantoaxial arthrodesis has been performed. Fusion rate of the CVJ lesion is remarkably successful as their reported fusion rates are 75% to 100%[9,20,29]. Surgeons used structural bone graft with sublaminar wires with good results. Fusion rates with internal rod and sublaminar wires were 90% to 100%[2,9]. Grob et al.[10] reported the use of plates and either transarticular screws or subaxial lateral mass screws in occipitocervical fusions with excellent results. Fusion rates with the screw and plate constructs are 90% to 100%[22]. Indeed, all studies have demonstrated very consistent high fusion rates with cervicovertebral junction fixation regardless of fusion met-hods and underlying pathology[29]. In this present study, our overall fusion rate of 93% is similar to that reported in other series involving this procedure. Non-union associated with pseudoarthrosis occurred in two patients. One patient had a rheumatoid arthritis and the other patient had a trauma patient with osteoporosis. Although, this study's numbers are too small to make a firm conclusion, but we have deduced from

our experience in failed fusion cases that sometimes wiring may appear superior to screws in patients with profoundly poor bone condition (e.g., rheumatoid arthritis, osteoporosis) which provide poor support for metal implants. We didn't compare fusion rates according to the wire-rod/screw based construct, disease group or fusion methods separately, because we didn't assess the fusion status of all patients with CT scan but assumed the success of fusion with dynamic X-ray in some patients. Also, this study is limited by study design (retrospective study), variability in patient selection and follow-up, as well as differences in surgical techniques over follow up period.

Wiring or screwing

The highly specialized anatomy of CVJ region have contributed in the development of fusion techniques for stabilization. Fusion procedures at the CVJ region must be capable of withstanding the forces of compression, axial loading, flexion, extension and rotation. Early techniques used stand-alone onlay bone grafting with the use of wires to secure bone grafts. It was not fully sufficient to stabilize until full arthrodesis and was needed to use postoperative halo fixation. Semi-rigid fixation using rod-and-wire techniques with bone grafting was developed and provided immediate stability and demonstrable higher fusion rate compared to previous techniques[25].

Wiring constructs remain as an excellent method for stabilizing the craniovertebral junction and upper cervical spine. When wired to spine and skull, bone struts or metal implants provide reasonably good mechanical stabilization properties with a low incidence of complications. Sonntag and Dickman described the wire-rod technique; they used a grooved titanium fixation rod which was bent into a "U" shape and contoured to fit the cervical curvature (Fig. 6)[25,30]. Rod and wire techniques are associated with lower rates of arthrodesis than rigid screw/rod systems probably due to biomechanical differences[5,16]. Rod and wire techniques often require postoperative halo immobilization and fusion of additional mobile segments for adequate strength, and are associated with complications arising from the passage of sublaminar or suboccipital wires, including dural lacerations and neurological injuries[13,26,28]. Major advantages of rod-and-wire techniques are greater ease of application and decreased risk to neurovascular structures. C1-C2 rod and wire technique is an excellent treatment option in patients with anatomical constraints that limit C1-C2 screw fixation and in young patients with immature spines. Continued development led to the creation of biomechanically superior segmental screw-based constructs for CVJ fusions[13,20].

Screw-based construct is technically demanding and re-quires operative precision and expertise when placing screws in the cervical vertebrae[10,15]. Early screw-based constructs consisted of screw and lateral mass plates[22,24,29]. These constructs provided increased stability and better outcomes when compared with prior instrumentation. The latest generation of fixation devices are polyaxial screw and rods, which can easily be bent in virtue of varying screw trajectories and apply the appropriate occipitocervical angle. Recent biomechanical studies have shown that the screw-based construct is more rigid than the wire-rod construct and reduced the need for external orthoses, but it is rather unclear whether it will result in higher rate of fusion[20,29]. Reports of fusion rate of 80% after wiring and of 94% after screwing do not appear to influence markedly in final clinical results[9]. Complete fusion can be achieved by increased number of wired vertebrae and by external immobilization in wire-rod system.

Complication

Potential intraoperative complications include excessive venous hemorrhage, neural tissue injury, VA injury, and dural lacerations. Most venous bleeding occur during the exposure of C1 lateral mass or C2 pars interarticularis which can be prevented by maintaining a subperiosteal plane of dissection. Hemostatic agents such as thrombin-soaked Gelfoam, or powdered Gelfoam can be used if necessary. One of the most troubling complications is damage to one or both vertebral arteries. Screw-based (plate or rod) construct has been shown to be an effective for treating atlantoaxial instability. However, despite the increased stability provided by the transarticular screw technique, there is the potential for VA damage and subsequent catastrophic neurological injury. A recent survey of neurosurgeons demonstrated a rate of known VA injury of 2.4% and a suspected injury rate of 1.7% per patient treated[31]. One of the most common anatomical variants that places a patient at greater risk of VA injury is a high-riding transverse C-2 foramen[21]. In other technique of atlantoaxial fixation, lateral mass screws are placed in the atlas which is connected via a rod or plate to the C-2 pedicle or pars interarticularis screws[8,11,27]. Many believe that the risk of VA injury is less with this technique compared with transarticular screw placement. Because an axial screw travels just medial to the transverse foramen using this technique, there is still the potential for VA injury. The potential for VA injury in which the C1-C2 screw fixation technique is used can be minimized with careful screening using preoperative computed tomographic angiogram. If VA injury occurs, the bleeding is initially controlled by placing a screw in the drill hole. Prompt angiographic evaluation is mandated postoperatively. If there is evidence of VA injury, and the injured artery is still partially patent, it should be occluded provided the contrala-

teral vessel normal (Fig. 4). This avoids the later development of an arterial dissection or a pseudoaneurysm or arteriovenous fistula.

The dura may be lacerated during sublaminar passage of the occipital or cervical cables or when occipital burr holes are made. These should be primarily repaired or usually controlled by using glue over the burr hole. Delayed complications include wound infections, loss of reduction, and failure of fusion. The management of wound infection is similar to that of any other postoperative spinal infection. Failure of arthrodesis necessitates surgical re-exploration if there is persistent bony instability.

Lesson we learned

We believe that success of the CVJ fusion depends on avoiding neurovascular structure, especially VA, injury during C1-2 screw placements. Although, number of cases was small and flow up period was short, we have kept key points in mind to improve patient safety, and outcomes and operative efficiency.

First is the patient's positioning. Positioning in disease entity does not differ significantly. However, to keep the patient's position neutrally is important in placing the screw. Surgeons can check the lateral screw trajectory intraoperatively by using fluoroscopy. But, it is difficult to identify patient's midline and to check the screw position using fluoroscopy on anteroposterior view because the patient is placed in radio-opaque head fixation (ex, Mayfield three-point fixation). If patient's position isslightly tilted left or right side, accurate screw placement maybe difficult increas-ing the risk of neurovascular structure injury.

Second is the preoperative planning in detail. Nowadays, 3D-reformatted CT scan provides substantial information of anatomical features of C1/ C2 and pathway of the vertebral artery. Before surgery, we should obtain a clear understanding of the anatomical landmarks essential in determining the starting point for screw trajectory. The screw starting point is measured in millimeters from the mid portion of the C1/C2. The screw trajectory is defined in number of degrees from both the parasagittal plane and the dorsal or ventral position of the screw relative to the VA foramen.

Third is placing the first screw on the most easily approachable and safest side. As a general rule, we start on the "best side" for screw placement so that at least one good screw is inserted as part of the construct. Conversely, if placement with the screw on the more difficult side is attempted first and results in a VA injury, placement of a second screw should not be attempted. This failure to place both screws might result in reduced stability and require postsurgical immobilization.

CONCLUSION

The clinical outcomes of our series show that the occipitocervical fusion with screw and wire system is a safe and effective method for the treatment of CVJ instability. Some may consider that wire-rod construct is "old fashioned", but it still has a major role in spinal surgery. The advantages of the wire-rod device include being technically simple, safe and economical. The screw-rod device offers several advantages, including strong occipital screw purchase, easy contour of the rod to fit the occipitocervical curvature and allowing cervical decompressive procedures. There is no "best" method for occipitocervical fixation. We recommend that the spinal fixation technique should be individually selected based on the location and extent of the injury. Accurate imaging diagnosis and strict patient selection are keys to successful outcome.

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