The Journal of Turkish Spinal Surgery
2009; 20 (3): 59-70

CASE REPORT / *OLGU SUNUMU*

OCCIPITOCERVICAL FIXATION AFTER TRANSORAL RESECTION OF UPPER CERVICAL AND CRANIOCERVICAL JUNCTION PATHOLOGIES: CLINICAL EXPERIENCE IN 6 CASES

ÜST SERVİKAL VE KRANİOSERVİKAL BİLEŞKE PATOLOJİLERİNİN TRANSORAL REZEKSIYONU SONRASI OKSİPİTOSERVİKAL FİKSASYON: 6 OLGUDAKİ KLİNİK DENEYİMİMİZ

Fatma ÖZLEN*, Mustafa Onur ULU, Lale Şaşmaz HANCI***, Galip Zihni SANUS******

SUMMARY:

The transoral approach provides direct access to the upper cervical vertebrae and the craniocervical junction (CCJ) pathologies. However, this approach causes additional destruction to the normal anatomical structures and interferes with normal stability of the CCJ, which also warrants occipitocervical (OC) fixation in most of the cases. Different technique of OC fixation has been described previously. In this study, we retrospectively evaluated the clinical results of 6 consecutive patients (male/female: 3/3; mean age:49) with upper cervical and CCJ pathologies (chordoma in 3 patients, pannus formation secondary to rheumatoid arthritis in 2 patients and malpositioned type II dens fracture in 1 patient) who were operated via transoral resection and subsequently underwent rigid posterior OC fixation with cervical laminar hooks and occipital screws (Vertex™ Reconstruction System; Medtronic, Sofamor Danek). The patients were followed up in a mean time of 31 months (range 14-48 mo). Except for one patient, pain relief was achieved in all patients with preoperative complaint of neck pain. In 3 of the 4 patients with preoperative neurological compromise, the neurological status was improved and none of the patients showed neurological detoriation postoperatively. The integrity of the construct was maintained in all the patients for the duration of the follow-up period and there were no instrumentation failure.

In conclusion, transoral decompression of upper cervical spine pathologies necessitates safe and effective stabilization of the CCJ. Rigid OC fixation with sublaminar hooks and occipital screws provided immediate stability of the CCJ with favorable postoperative fusion rates and clinical outcomes.

Key Words: *Cervical spine, craniocervical junction, occipitocervical fixation, transoral resection*

Level of Evidence: *Level IV, Case Report*

(*) M.D., Attending Neurosurgeon, Istanbul University, Cerrahpasa Medical Faculty, Department of Neurosurgery, Istanbul, Turkey
(**) M.D., Attending Neurosurgeon, Sakarya ToyotaSA State Hospital, Department of Neurosurgery, Sakarya, Turkey
(***) M.D., Attending Neurosurgeon, Metin Sabanci Baltalimani State Hospital, Department of Neurosurgery, Istanbul, Turkey
(****) M.D., Associate Professor, Istanbul University, Cerrahpasa Medical Faculty, Department of Neurosurgery, Istanbul, Turkey

Corresponding Address: *Doç. Dr. Galip Zihni SANUS. Cerrahpasa Tıp Fakültesi, Nöroşirürji Anabilim Dalı 34301 Cerrahpaşa / İstanbul*
Phone : *+ 90 (212) 414 30 00 (22455)*
e-mail: *galipzihnisanus@yahoo.com*

ÖZET:

Transoral yaklaşım, üst servikal omurga ve kranioservikal bileşke (KSB) patolojilerine direkt ulaşım sağlamaktadır. Buna karşın bu yaklaşımla normal anatomik yapılara da ek zararlar verilmekte, KSB'nin normal stabilitesi bozulmakta ve birçok olguda oksipitoservikal (OS) fiksasyon gereksinimi doğmaktadır. Farklı OS fiksasyon teknikleri tanımlanmıştır. Bu çalışmada çeşitli üst servikal ve KSB patolojileri (3 olguda kordoma, 2 olguda romatoid artrite sekonder pannus, 1 olguda malpozisyone tip II dens fraktürü) bulunan ve transoral rezeksiyon sonrası servikal lamina kancaları ve oksipital vidalar kullanılarak (Vertex™ Reconstruction System; Medtronic, Sofamor Danek) OS fiksasyon uygulanan ardışık 6 hastanın (erkek/kadın: 3/3; ortalama yaş: 49) verileri retrospektif olarak incelenmiştir. Olgular ortalama 31 ay süreyle (aralık 14-48 ay) takip edilmiştir. Bir olgu haricinde preoperatif boyun ağrısı şikayeti bütün olgularda düzelmiştir. Preoperatif nörolojik defisiti olan 4 olgunun 3'ünde postoperatif olarak iyileşme sağlanmış ve hiçbir olguda postoperatif nörolojik kötüleşme görülmemiştir. Takip sürecinde fiksasyon sisteminin bütünlüğü korunmuş olup, enstrümentasyon bozukluğuna rastlanmamıştır.

Sonuç olarak üst servikal omurga patolojilerinin transoral yaklaşımla rezeksiyonu sonrası KSB'nin güvenli ve etkili bir şekilde stabilize edilmesi gerekmektedir. Sublaminar kancalar ve oksipital vidalar kullanılarak uygulanan rijid OS fiksasyon, tatminkar postoperatif füzyon ve klinik sonuçla beraberdir.

Anahtar Kelimeler: *Kranioservikal Bileşke, Servikal Omurga, Oksipitoservikal Fiksasyon, Transoral Rezeksiyon*

Kanıt Düzeyi: *Düzey IV, Olgu Sunumu*

INTRODUCTION:

Occipitocervical (OC) instability is a challenging disorder with potentially life-threatening consequences. It is most commonly seen secondary to traumatic events which involve upper cervical vertebrae and the main structures of the craniocervical junction (CCJ) namely the atlantooccipital joint, the occipital condyles, the atlas, and the axis. Survivors are prone to suffering repeated luxations and often suddenly die of complications related to such instability. Patients with nontraumatic upper cervical instabilities, on the other hand, usually present with progressive neurological deterioration, which may be due to the compression of the upper cervical cord, medulla, and / or lower brainstem [10,32]. Infections, inflammatory diseases such as rheumatoid arthritis (RA), metabolic disorders, congenital malformations and tumors constitute the most common pathologies in this group [5,11,15,32]. Whether they require surgical decompression or not the common denominator for both groups is the need for permanent fixation. Although in the majority of the patients with upper cervical instability the fusion can be acquired via posterior C1-C2 fixation, in conditions where there is concomitant OC instability, severe C1-C2 luxation, tumor invasion, spinal cord compression or opening of the posterior CCJ, OC fixation is indicated [9-11,27].

The transoral approach provides direct access to the upper cervical vertebrae and the CCJ. The most common indications for this approach have been the resections of the odontoid process, basilar invagination caused by rheumatoid arthritis, and tumors involving the CCJ [7,17-18]. This approach causes additional destruction to the normal anatomical structures and interferes with normal stability of the CCJ, which also warrants OC fixation in most of the cases. Different techniques of OC fixation have been described previously [2,4-5,8-9,12-13,19, 25-30,33,34]. In this study, we retrospectively evaluated the clinical results of 6 consecutive patients with upper cervical and CCJ pathologies, who were operated via transoral resection and subsequently underwent rigid posterior OC fixation with cervical laminar hooks and occipital screws.

MATERIAL AND METHODS:

Between February 2004 and March 2008, 6 consecutive patients (male / female: 3 / 3; mean age: 49) underwent OC fusion surgery after transoral resection of upper cervical and CCJ pathologies at Cerrahpasa Medical Faculty, Department of Neurosurgery. The preoperative diagnosis were chordoma in 3 patients, pannus formation secondary to RA in 2 patients and malpositioned type II dens fracture in 1 patient. All patients were evaluated preoperatively by anteroposterior and lateral radiographs of the OC region, including flexion-extension views to assess stability. The extent of ventral compression of the cervicomedullary region was assessed by magnetic resonance imaging (MRI) in all patients. For determining the bony anatomy of CCJ structures all patients underwent multislice computerized tomography (CT) scanning with sagittal and coronal reconstructions. The characteristics of the patient population are summarized in Table-1.

Table - 1. The summary of patients who underwent occipitocervical fusion subsequent to transoral resection of upper cervical pathologies

Case #	Age / Sex	Etiology	Symptoms	Preoperative Neurological Status	Follow up / months	Comp.	Postoperative Outcome
1	65 / F	RA	Neck Pain	Quadriparesis	40	T	PR, Same
2	42 / M	Chordoma	None	CN 12 palsy	14	None	Good, improved
3	51 / F	RA	Neck Pain	Quadriparesis	48	Wi	PR, improved
4	27 / M	Chordoma	None	intact	18	None	Neck Pain
5	50 / M	Chordoma	Neck Pain	intact	32	None	PR, Good
6	59 / F	DF	Neck Pain	Right hemiparesia	36	None	PR, improved

Abbreviations: RA: Rheumatoid Arthritis; DF: Dens fracture type II; Comp: Complication; WI: Wound infection; PR: Pain relief; CN: Cranial never; T: Tracheostomy

For all patients, but one, a two-staged operation was planned. In the first session, the patients underwent transoral resection of their pathologies and OC fixation was done in another session. In all patients standard transoral approach without splitting the soft or hard palate was sufficient to decompress the craniocervical region ventrally. There were no peroperative complications. For protecting the spinal cord in the postoperative period until the second session, all patients were placed in a halo vest in the operating room after the first session except for Case #6 who underwent transoral resection and posterior OC fusion in the same session. The patients were intubated orally and extubated within 48 hours after the operation. In one patient (Case #1), secondary tracheostomy became necessary due to postoperative local complications. Nasogastric tube feedings were maintained for the first 5 days. Over several days, it was advanced to a full liquid diet and, subsequently, to a soft diet.

Surgical Technique: Occipitocervical Fusion:

Before OC fixation surgery, the proper cervical curvature is maintained by manipulating the halo vest and satisfactory alignment of CCJ is confirmed by radiological imaging. This step is repeated peroperatively with fluoroscopy before stable fixation. The patients were intubated and prone positioned with their halo vest. A midline incision from occipital protuberance to the level of C7 spinous process was performed. The paravertebral muscles were dissected to expose external occipital protuberance, suboccipital area and cervical laminae. After ligamentum flavum dissection, the interlaminar hooks were placed between C2 and C3 in all patients. C1 is not included in the hardware system for mainly three reasons: 1) since the anterior arc of C1 has been removed via transoral approach, the inclusion of C1 to the hardware system does not seem to be reliable. 2) The attempt to connect its' deeply located posterior arc to the rod, may cause

subluxation of C1 in the axial plane. 3) The thin and weak lamina of C1 makes it impossible to put more than one claw application, which is usually not sufficient especially in long segment constructions. Furthermore, since only one hook can be applied to C1, there is a potential risk of serious cord injury if it gets disconnected in the postoperative period. Subsequently, the rod plates were positioned with an OC bend angle, adjusted for each patient by using both rod holder benders. If there is a need of head extension after the peroperative fluoroscopy control, this can be done by manipulating the halo vest before rigid fixation. However, extension of the head may cause anterior migration of the deeply located posterior arc of C1. In such cases, the relationship of the posterior arc and the dura should be evaluated and the posterior arc can be widely resected if needed. Since the construction begins from the occiput and ends in C3, C1 can safely be left out from the system. The occipital end of the rod plates were fixed before the cervical end with two screws placed on each side of the occipital protuberance (4 screws in total) where the bone is thickest. For all patients, the rod plates were linked at the cervical level using a device for transverse traction (DTT) holder and autologous iliac crest bone graft and Grafton® Putty are packed along the previously decorticated posterior vertebral surfaces to fill in the gaps between the implant and the spine to facilitate the fusion. In cases where two DTT's were placed, placing the hooks over C2 and below C3 and the use of a longer rod can make the construction stronger. A Philadelphia collar was routinely used for postoperative immobilization for 5 weeks. In the follow up period, all patients underwent postoperative radiological investigations including MRI, plain X-ray and CT imaging for evaluating the fusion and the alignment of the hardware.

RESULTS:

The amount of time between two surgery sessions ranged between 0 - 14 days (mean 9,6 days). The mean follow-up period was 31 months (range 14-48 mo). Pain relief was achieved in all patients with preoperative complaint of neck pain. However one patient (Case #4) experienced persistent postoperative neck pain in the follow up period, although postoperative radiological investigations revealed no abnormality. In 3 of the 4 patients with preoperative neurological compromise, the neurological status was improved. None of the patients showed neurological detoriation postoperatively and in only one patient (Case #1) the preoperative neurological deficit persisted despite physical therapy and rehabilitation. One patient experienced superficial wound infection which did not require debridment and resolved with IV antibiotics. The integrity of the construct was maintained in all the patients for the duration of the follow-up period and there were no instrumentation failure. An illustrative case (Case #6) is presented in Figures-1.a-d and 2.a-b.

DISCUSSION:

The CCJ is the most mobile portion of the cervical spine and constitutes two important synovial articulations; namely the atlanto-occipital and atlantoaxial joints. They are both devoid of intervertebral discs and instead

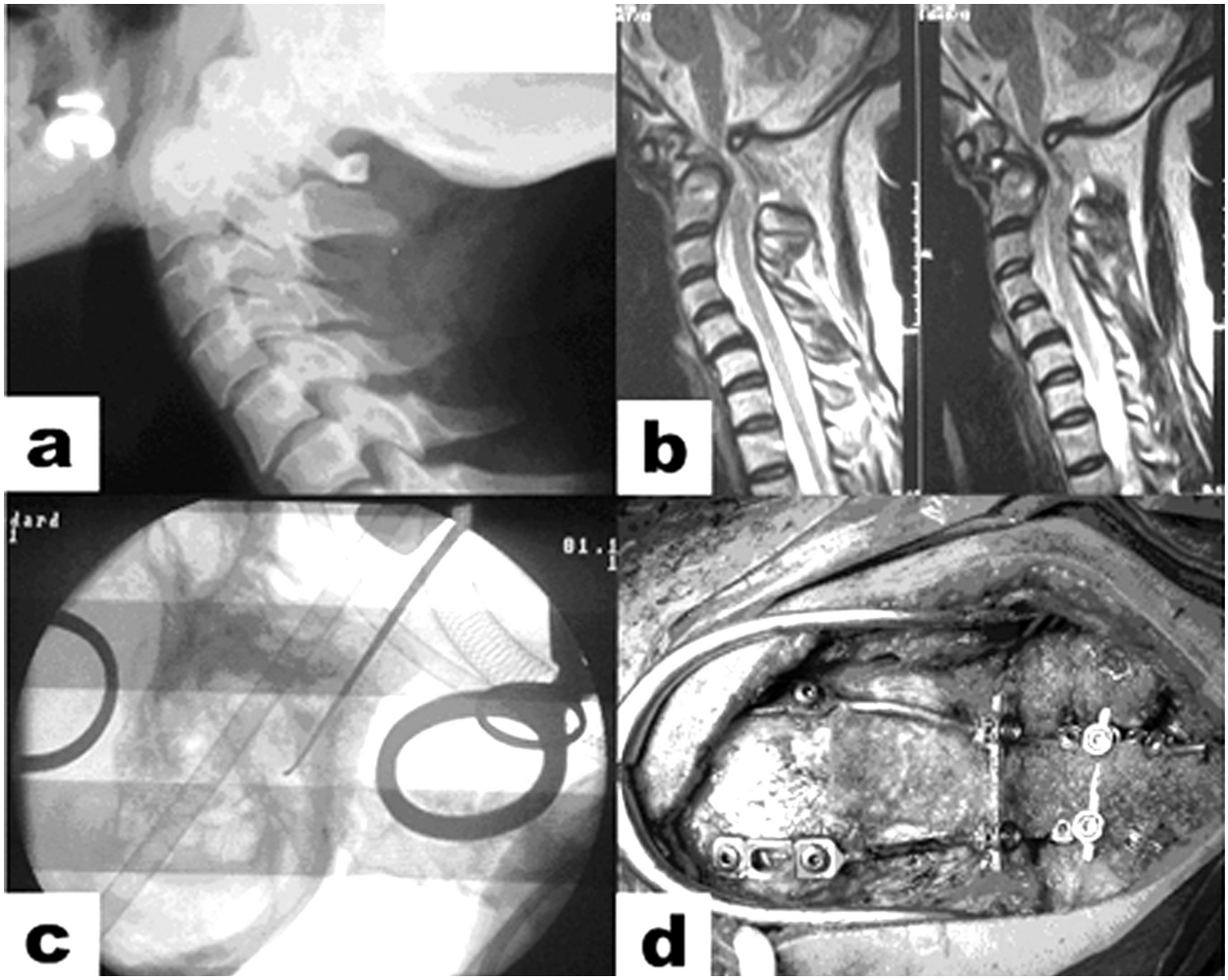

Figure-1. A 59 years old female admitted to our emergency department with the complaint of neck pain after a motor vehicle accident. Neurological examination revealed right global hemiparesia with motor power of 4/5. The plain X-ray **(a)** and cervical MRI sections **(b)** revealed a type II odontoid fracture causing severe the spinal cord compression anteriorly. A halo vest was placed in the operating room and she underwent transoral resection of the odontoid and posterior occipitocervical fusion in the same session. A peroperative fluoroscopy view after transoral resection and intraoperative photo after occipitocervical fixation are shown in figures **(c)** and **(d)** respectively.

supported by capsuloligamentous attachments. All these bony and ligamentous structures allow for a variety of complex movements at the CCJ. However, the anatomical structures that allow this increased mobility also predispose the joints to OC instability. A number of factors detected in preoperative radiological investigations suggest upper cervical and CCJ instability (Table-2) [3,23,31] which require OC or atlantoaxial fixation.

Table - 2. Diagnostic clues suggesting upper cervical and CCJ instability

Diagnostic clues suggesting upper cervical and CCJ instability
Anterior/Posterior Arch and/or lateral mass fractures of C1
Basion-dental interval > 12mm on lateral plain X-ray or midsagittal CT
Avulsion fractures of occipital condyles
Subluxation of C1 over C2 > 6.9 mm on AP plain X-ray
Atlantodental distance > 3.5 mm on lateral plain X-ray or CT
Rupture or bony avulsion of the transverse ligament on MRI
Dislocation of type II odontoid fracture > 6 mm
Flextion / Extansion between C1 - C3 > 11°

Modified from (3, 23, 31)

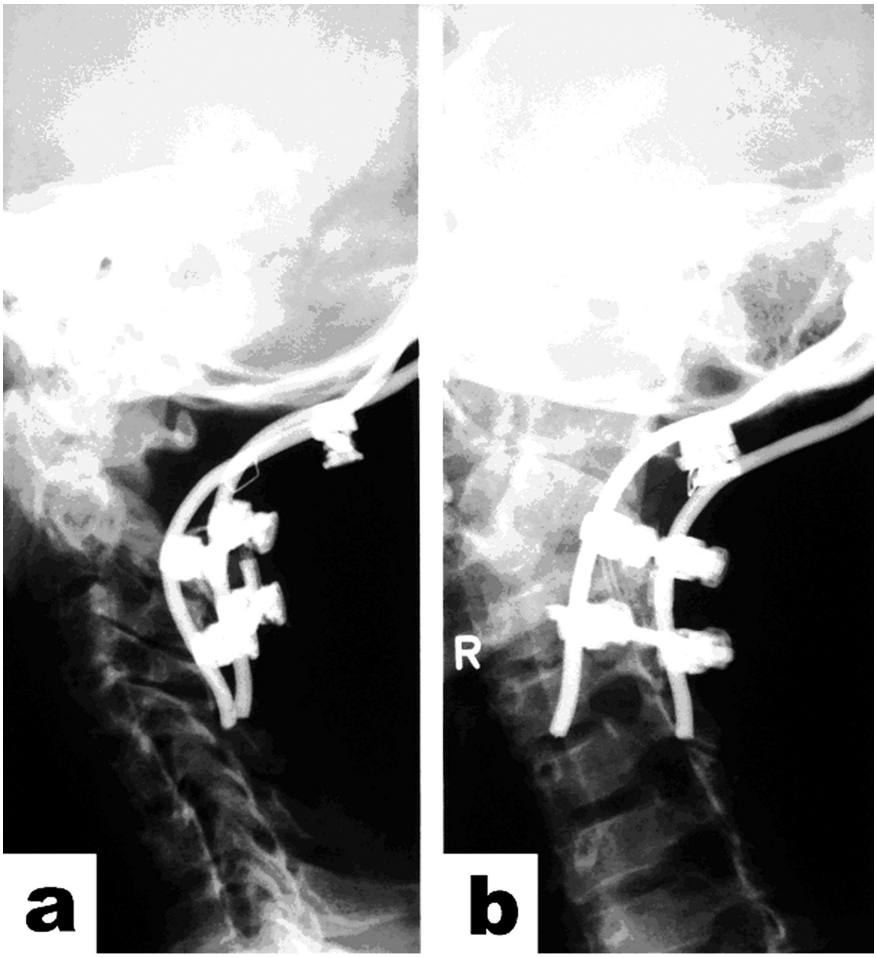

Figure-2. Postoperative lateral **(a)** and oblique **(b)** plain X-ray views one week after occipitocervical fixation.

In this series, rigid OC fixation with sublaminar hooks and occipital screws provided immediate stability of the CCJ with favorable postoperative fusion rates and clinical outcome. The laminar hooks are attached directly to the rod which facilities the setup of the implant and the stability of the fixation while avoiding the usual complications of screwing or wiring. The procedure is easy handling and safer than the other fixation systems, allowing immediate removal of external fixation devices such as halo vests. The disadvantages are similar and comparable to the general disadvantages of the OC fixation systems [26].

A variety of surgical techniques have been described for OC instability which included both anterior and posterior approaches [2,4-5,8-9,12-13,19,25-30,33-34]. Anterior approaches with bone graft without internal fixation required prolonged halo immobilization and reported with poor clinical results [2,33]. Posterior approaches involving simple posterior onlay bone grafts and halo immobilization, on the other hand, have resulted in high pseudoarthrosis rates [19] and have gradually been replaced by rigid posterior fusion involving instrumentation and bone grafts. For providing immediate stability and enhancing the rate of arthrodesis several internal fixation

methods have been proposed. In summary, the internal fixation techniques include occipital and sublaminar wiring and the use of a rectangular rod, occipital screws and C2 lamina claw hooks and rod, occipital screws and C1-C2 transarticular screws and rod, occipital screws and C1-C2 transarticular screws and Y-plate, as well as occipital screws and C2 pedicle screws and rod [26,32]. One of the simplest techniques of achieving rigid internal fixation during OC fusion was reported by Clark et al which involves the use of methylmethacrylate supplemented by wire [5]. However this technique requires large amount of methylmethacrylate, which increase the deep infection rate and does not allow for correcting kyphotic deformity [4,34]. Several authors have described the use of plates that are fixed to the occiput and cervical spine by screws [12,17,25,29,30]. Rigid screw fixation of the OC junction has been shown to be biomechanically superior to wiring and combined wire–rod techniques. Grob et al. have investigated the advantages of screw fixation compared with wiring techniques in RA patients who underwent OC fusion [12]. The neurological improvement in the wiring group was 40 % whereas in the Y-plate fixation group, 86 % neurological improvement was observed. Moreover the pseudoarthrosis higher in the wiring group than the plate and screw fixation technique group (27 % compared to 6 %) [12]. However, early screw-based constructs, while providing increased stability and better outcomes when compared with prior instrumentations, also had limitations. The plates were constructed with slots or holes for screw placement, limiting screw entry points and trajectories, which could be frustrating when trying to plan transarticular screw trajectories parallel to the predetermined slots. Although the latest generation of fixation devices with polyaxial screw heads and malleable rods has eliminated most of the shortcomings of the previous generation of OC plates, the potential complications regarding the use of wires and particularly the screws in this systems require caution [9,25].

The complications of cervical screw dependant systems can be devastating and lateral mass screw implantation is shown to be associated with risks of nerve root injury and vertebral artery damage [1,16]. In 78 patients operated with posterior cervical plating and lateral mass screwing, immediate radicular symptoms were encountered in 7 (9 %), cerebellar infarction in one patient and anterior horn infarction in another [14]. The use of sublaminar hooks in OC fixation have been reported with good outcomes [13,27]. In our series, although the number of patients is limited, the fusion rates were consistently good, and no obvious pseudoarthrosis was noted on plain X-ray graphies or on CT. The integrity of the construct was maintained in all of the patients for the duration of the follow-up period and there were no instrumentation failure. When the potential problems of screw placement in elder population are considered, laminar hook based system is also particularly beneficial in the osteoporotic spine. For instance 4 of our 6 patients in this series were over the age of 50 and no complications related with the hook implantation during the procedure or in the follow-up period were encountered.

There is still controversy about the decision to include the occiput or the third cervical vertebra in surgical stabilization of the upper cervical vertebrae and the atlanto-axial joint pathologies. However it is obvious that when

the pathology involves the atlas, inclusion of the occiput in the fusion is necessary. We have decided to perform OC fixation in all cases for mainly 4 reasons: 1) in chordoma cases the tumor extension involved most of the anterior part of atlas and was removed. 2) In RA cases the anteriorly situated pannus was widely resected along with most of the C1. 3) To facilitate the positioning of the lower occipital hooks. 4) Either the pathology itself or the transoral approach caused body destruction or disruption of the capsuloligamentous attachments such as the alar ligaments, tectorial membrane, and/or transverse atlantal ligament, which demanded a more rigid fixation.

Rheumatoid arthritis is the most commonly seen inflammatory arthropathy affecting the high cervical spine, and although atlantoaxial and subaxial instability is its more common component, occipitoaxial instability can also occur with gross instability [24]. Conservative treatment usually has poor results with reported mortality results of 100 % at 8 years [20, 22]. In these patients surgical stabilization has been shown to be effective in both relieving the symptoms of pain and myelopathy in the long term and increasing the survival and functional outcome [21]. Both of the RA patients in this series have benefited from surgical treatment with relive of preoperative symptoms although preoperative quadriparesis in Case #1 persisted in the follow-up period. However this did not affected her daily functions and she can live independently and self- sufficiently. Considering the life expectancy of both patients surgical treatment is proved to be a wise decision with favorable postoperative outcomes. In this series, one patient with RA had superficial wound infection postoperatively and none developed an infection in the bone graft harvest site, which was comparable to the 5 % rate reported by others [6]. Moreover no injuries to the vertebral artery or spinal cord were encountered.

In conclusion, transoral decompression of upper cervical spine pathologies necessitates safe and effective stabilization of the CCJ. Rigid OC fixation with sublaminar hooks and occipital screws provided immediate stability of the CCJ with favorable postoperative fusion rates and clinical outcomes. Occipital screws at the cephalic end of the fusion may limit problems associated with occipital fixation. Before the procedure the patients must be informed about the potential disadvantages of this procedure such as the limitation of cervical motion or neck stiffness.

REFERENCES:

1- An HS, Gordin R, Renner K. Anatomic considerations for plate-screw fixation of the cervical spine. *Spine* 1991; 10: 548-551.

2- Bonney G. Stabilization of the upper cervical spine by the transpharyngeal route. *Proc R Soc Med* 1970; 63: 40-41.

3- Bono CM, Vaccaro AR, Fehlings M, Fisher C, Dvorak M, Ludwig S, Harrop J; Spine Trauma Study Group. Measurement techniques for upper cervical spine injuries: consensus statement of the Spine Trauma Study Group. **Spine** 2007; 32(5): 593-600.

4- Bryan WJ, Inglis AE, Sculpo TP, Ranawat CS. Methylmethacrylate stabilization for enhancement of posterior cervical arthrodesis in rheumatoid arthritis. J Bone Joint Surg 1982; 64A: 1045-1050.

5- Clark CR, Goetz DD, Menezes AH. Arthrodesis of the cervical spine in rheumatoid arthritis. *J Bone Joint Surg A* 1989; 71: 381-392.

6- Deutsch H, Haid RW Jr, Rodts GE Jr, Mummaneni PV. Occipitocervical fixation: long-term results. *Spine* 2005; 30: 530-535.

7- Dickman CA, Neil RC, Brantley AGU, Sonntag VKH. Biomechanical effects of transoral odontoidectomy. *Neurosurgery* 1995; 36: 1146–1152.

8- Fehlings MG, Errico T, Cooper P, Benjamin V, DiBartolo T. Occipitocervical fusion with a five-millimeter malleable rod and segmental fixation. *Neurosurgery* 1993; 32(2): 198-207.

9- Finn MA, Bishop FS, Dailey AT. Surgical treatment of occipitocervical instability. Neurosurgery 2008; 63(5): 961-968.

10-Gluf WM, Schmidt MH, Apfelbaum RI. Atlantoaxial transarticular screw fixation: a review of surgical indications, fusion rate, complications, and lessons learned in 191 adult patients. *J Neurosurg Spine* 2005; 2: 155-163.

11-Grob D, Dvorak J, Gschwend N, FroehlichM. Posterior occipito-cervical fusion in rheumatoid arthritis. *Arch Orthop Trauma Surg* 1990; 110(1): 38-44.

12-Grob D, Dvorak J, Panjabi M, Antinnes J. The role of plate and screw fixation in occipitocervical fusion in rheumatoid arthritis. *Spine* 1994; 19: 2545-2551.

13-Heidecke V, Rainov NG, Burkert W. Occipito-cervical fusion with the cervical Cotrel-Dubousset rod system. *Acta Neurochir (Wien)* 1998; 140(9): 969-976.

14-Heller JG, Silcox DH 3rd, Sutterlin CE 3rd. Complications of posterior cervical plating. *Spine* 1995; 22: 2442–2448.

15-Hultquist R, Zygmunt S, Saveland H, Birchlensen M, Wollheim FA. Characterization and functional assessment of patients subjected to occipito-cervical fusion for rheumatoid atlanto-axial dislocation. *Scand J Rheumatol* 1993; 22(1): 20-24.

16-Jonsson H Jr, Rausching W. Anatomical and morphometric studies in posterior cervical spinal screw-plate systems. *J Spinal Disord* 1994; 5:429–438.

17-Kerschbaumer F, Kandziora F, Klein C, Mittlmeier T, Starker M. Transoral decompression, anterior plate fixation, and posterior wire fusion for irreducible atlantoaxial kyphosis in rheumatoid arthritis. *Spine* 2000; 25(20): 2708-2715.

18-Laborde G, Gilsbach J, Bertalanffy H, Harders A, Hardenack M. Limits of the transoral approach in craniospinal malformations. *Skull Base Surg* 1992; 2(1): 6-10.

19-Lee P, Chun S, Leong J. Experience of posterior surgery in atlantoaxial instability. *Spine* 1984; 9: 231-239.

20-Marks JS, Sharp J. Rheumatoid cervical myelopathy. *Q J Med* 1981; 50: 307–319.

21-Matsunaga S, Ijiri K, Koga H. Results of a longer than 10-year follow-up of patients with rheumatoid arthritis treated by occipitocervical fusion. *Spine* 2000; 25: 1749-1753.

22-Matsunaga S, Sakou T, Onishi T, Hayashi K, Taketomi E, Sunahara N, Komiya S. Prognosis of patients with upper cervical lesions caused by rheumatoid arthritis: Comparison of occipitocervical fusion between C1 laminectomy and nonsurgical management. *Spine* 2003; 28: 1581-1587.

23-Menezes AH, Traynelis VC. Anatomy and biomechanics of normal craniovertebral junction (a) and biomechanics of stabilization (b). *Childs Nerv Syst* 2008; 24(10): 1091-1100.

24-Mori T, Matsunaga S, Sunahara N, Sakou T. 3- to 11-year follow-up of occipitocervical fusion for rheumatoid arthritis. *Clin Orthop Rel Res* 1998; 351: 169-179.

25-Nockels RP, Shaffrey CI, Kanter AS, Azeem S, York JE. Occipitocervical fusion with rigid internal fixation: long-term follow-up data in 69 patients. *J Neurosurg Spine* 2007; 7(2): 117-123.

26-Oda I, Abumi K, Sell LC, Haggerty CJ, Cunningham BW, McAfee PC. Biomechanical evaluation of five different occipitoatlanto-axial fixation techniques. *Spine* 1999; 24: 2377–2382.

27-Paquis P, Breuil V, Lonjon M, Euller-Ziegler L, Grellier P. Occipitocervical fixation using hooks and screws for upper cervical instability. *Neurosurgery* 1999; 44(2): 324-330.

28-Sandhu FA, Pait TG, Benzel E, Henderson FC. Occipitocervical fusion for rheumatoid arthritis using the inside-outside stabilization technique. *Spine* 2003; 28: 414-419.

29-Sasso RC, Jeanneret B, Fischer K, Magerl F. Occipitocervical fusion with posterior plate and screw instrumentation. A long-term follow-up study. *Spine* 1994; 19: 2364-2368.

30-Smith MD, Anderson P, Grady MS. Occipitocervical arthrodesis using contoured plate fixation. An early report on a versatile fixation technique. *Spine* 1993; 18: 1984-1990.

31- Sonntag VKH, Hadley MN. Management of upper cervical spine instability. In: Neurosurgery. Eds : Wilkins RH, Rengachary SS, McGraw-Hill, Inc., New York, 1996, pp 2915-2926.

32-Tan KJ, Hee HT. Neurological recovery after occipitocervical fixation. *J Orthop Surg (Hong Kong)* 2007; 15(3): 323-326.

33-Thompson H. Transpharyngeal fusion of the upper cervical spine. *Proc R Soc Med* 1970; 63(9): 893-896.

34-Zygmunt SC, Ljunggren B, Alund M, Brattstrom H, Saveland HG, Holtas S, Larsson EM, Redlund-Johnell I. Realignment and surgical fixation of atlanto-axial and subaxial dislocations in rheumatoid arthritis (RA) patients. *Acta Neurochir* 1988; 79-84.