Safety and Efficacy of Polyaxial Screw-rod System Fixation in Managing Upper Cervical Instability

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Abstract

Background Data: Upper cervical junction (UCJ) is a unique and complex structure because its discrete bony, ligamentous and vascular anatomy. Upper cervical instability (UCI) defined as loss of stability between the atlas and axis (C1–C2), resulting in loss of normal articulation that decrease the space for the lower brain stem and cervical cord and roots. It has different etiologies including; traumatic, inflammatory, idiopathic, or congenital abnormalities. Upon that UCJ have broad varieties of ultimate’s Clinical and radiological manifestations complex. In this study we consider the algorithm of safety and efficacy of polyaxial Screw-rod System Fixation in managing upper cervical instability by C1 Lateral mass (C1L) and C2 pedicle (C2P) screw fixation with or without occipital fixation either from congenital or acquired defect of the occipital bone, foramen magnum, or first two cervical vertebrae.

Purpose: To evaluate safety and efficacy of C1L-C2P with or without occipital polyaxial screw-rod system fixation in managing craniocervical instability of various etiologies.

Study Design: A retrospective descriptive clinical case study

Patients and Methods: Forty-two patients with UCI due to various etiologies were reported. The primary upper cervical pathology (UCP) reported in this series was; type II dens Fracture (N=8), type-II Hangman fracture (N=10), AARF (N=9), Down’s syndrome (N=4), Os Odentadium (N=3), plasma cell
cytoma (N=2), aneurysmal bone cyst (N=3), and atlanto-axial ligamentous instability (N=3). Those were treated surgically with reduction, decompression and internal fixation by poly axial screws and rods a within the atlanto-axial avenue. They were assessed pre- and postoperative radiographically by; full plain X-ray, MS 3D-Computed Tomography (MS 3D-CT), Magnetic Resonance Image (MRI), and clinically using Japanese Orthopedic Score (JOA).

**Results:** Forty two patients including 26 males and 16 females with mean age 31.6±12 (range 4-52) years. None of the patients developed a new postoperative neurological deficit. The follow-up was 47±9 (range 12 to 72) months. All patients improve at least 1 grade according to the JOA Scale which was at the last follow-up as follow: 30 normal (71.5%), 9 grade-I (Excellent), and 3 grade-II (good) (7%). None of the patients had neurological worsening during the follow-up period.

**Conclusion:** This prospective cohort suggested that Lateral mass C1 and transpedicular-C2 polyaxial screws fixation can be safely and effectively used in different entities of upper cervical instability, to achieve good purchase and fusion after decompression and reduction. Further prospective studies with longer follow-up are necessary to further establish its validity and safety. (2016ESJ109)

**Keywords:** upper cervical instability, polyaxial screws fixation, atlanto axial, fixation, fusion

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**Introduction**

Upper cervical spine instability (UCI) is a complex and had a wide range of radiological and clinical presentation.19 This great variability is due to the uniquely complex bony, ligamentous and vascular anatomy of the upper cervical spine region and the cranial base.17-19,21 Stability of the atlas and axis depends on strong ligamentous structures that still allow significant flexion, extension, and axial rotation.21

Different etiology for upper cervical instability including congenital, inflammatory, traumatic, and neoplastic lesions that lead to atlanto-axial subluxation (AAS). This condition also results in impairment in rotation of the neck. The anterior facet of C1 is fixed on the facet of C2.18 It may be associated with dislocation of the lateral mass of C1 on C2. The AAS subtypes are either anteroposterior subluxation or rotatory subluxation, known as atlantoaxial rotatory fixation (AARF), Vertical subluxation, and Lateral subluxation.17

Treatment of atlantoaxial dislocation aimed to neurological decompression, correction of sagittal alignment of the upper cervical spine, stabilization in near anatomical alignment, and adequate bony fusion.7 There is no uniformly accepted method for determining treatment strategies, with extremely varying opinion on indications of nonoperative versus operative treatment modalities and onwhich operative techniques are more appropriate.15,26,22,38

Many different surgical techniques either anterior and/or posterior methods had been developed to help surgeons with surgical treatment decisions for upper cervical spine instability (UCI).5,12-15 Gallie 1939,9 Brook 1978,3 described the sublaminar wiring technique, In the 1980’s interlaminar clamps introduced as an alternative method of posterior C1-C2 fixation with their disadvantage of direct cervical cord vulnerability and it poor stability in all plans.27 Laminar screws Transarticular screw introduced by Magerl1,14 anterior odontoid screws.28 C1 lateral mass /C2 pedicle screw10,12 are different surgical approaches were developed for achieve reduction and stability in UCI management but still under controversial results.

In this study, we present the clinical and radiological results depends on safety and efficacy for poly axial screws fixation system
Patients and Methods

This is a retrospective descriptive clinical case study of the clinical and radiological outcomes of 42 consecutive patients with upper cervical spine instability for various etiologies the instability was due to traumatic, congenital, idiopathic, and neoplastic lesions. Patients were admitted and treated at our Suez Canal University Hospital through the period from 2006 to 2015. The mean age was 31.6±12 years with a range from 4 to 52 years. Twenty six were patients were males and 16 were females.

Various etiology were recorded in our study including; type-II dens Fracture in 8 patients, type-II Hangman on 10 patients, AARF in 9 patients, Down’s syndrome in 4 patients, Os Odentadium in 3 patients, plasma cell cytoma in 2 patients, aneurysmal bone cyst in 3 patients, and atlanto-axial ligamentous instability in 3 patients. (Table 1, Figure 2-5)

Ligamentous injuries were defined as abnormal spinal malalignment, outside of the normative ranges of alignment involving the following articulations: Occipital condyle-C1, C1-2 or C2-3 facet joints, seen with distraction or rotational injuries. Perched or locked cervical facet joints and an increase in the atlanto-dens interval of more than 3.5 mm are examples of ligamentous instabilities that may be detected with CT imaging, MRI or dynamic plain radiography. According to JOA Scale; twenty-two patients were normal (16-17), nine patients were grade-I (12-15), eight patients were grade-II (8-11), and three patients were grade-III (0-7) on JOA Scale. (Table 1)

In this series all patients were submitted to full study plain x-ray including dynamic study, Multi-slices Computed Tomography (MS-CT) with sagittal and coronal reformates, and Magnetic resonance image (MRI). The expected distance between anterior arch of C1 and the dens in the fully flexed position should be <3 mm in an adult (~5 mm in a child). In a vertical subluxation, the dens is often above the McGregor line by over 8 mm in men and 9.7 mm in women.

Surgical Procedure:
All patients were operated by posterior polyaxial C1 Lateral mass (C1L)-C2 transpedicular screw fixation (C2P) with decompression when needed. Bicortical C1 Lateral mass screws were inserted under fluoroscopy. The entry point for the C1 lateral mass screw is identified at the centre of the C1 lateral mass, precisely at the junction point of the midpoint of the C1 lateral mass and the inferior aspect of the C1 arch. Appropriate trajectory is 10-20° ascending direction, parallel to the plane of the C1 posterior arch in the lateral view and 10° towards the midline in axial plane. It should be noted that the vertebral artery often runs in a sulcus on the superolateral aspect of the C1 arch and care should be taken to avoid drilling in this area. The landmark for C2 pedicle screws is lateral to superior margins of C2 lamina about 2mm medial and 2mm cranial to pars interarticularis. The trajectory was 20-30° cranially and 20-25° in a convergent direction in axial plane. We did not sacrifice the C2 root ganglion. Then poly-axial smooth shank screws were inserted and top loading rods were placed that’s also helpnot irritate the C2 roots. Two cases with eroding tumor (one had aneurysmal bone cyst and one with plasma cell cytoma) due to weakness or destruction of unilateral C2 pedicle, fixation extended sub-axial to the
lateral mass of C3 and/or C4. Also the 7 cases with type-II Hangman fractures were treated with C2 pedicle screw fixation and C3 lateral mass fixation.

Postoperative all patients had clinical and plain radiological assessment at two weeks, one month, three months and then at six months interval. External orthosis was not prescribed after surgery. All the patients had CT-scan to check proper instrumentation placement after surgery one month after surgery.

The operative and postoperative course and complications were fully reported. Institutional ethical committee approval was obtained for the study.

Results

There were Forty two patients treated consecutively in the study period from 2006-2016. Twenty six patients (62%) were males and sixteen (38%) females. The mean age was 31.6±12 (range 4-52) years. All patients were treated by C1 lateral mass and C2 transpedicular poly axial screws fixation and fusion with iliac bone graft.

Reported congenital etiology in this study included three patients (7.2%) with Os odentadum and four patients (9.5%) with Down’s syndrome. Neoplasia were reported in 5 patients (11.8%) (2 aneurysmal bone cyst, 3 plasma cell cytoma). Trauma were reported in 32 patients as follow; ten patients (23.8%) were involved in car accident; six patients had a motorcycle accident (14.2%), five patients fallen from a height (11.9%), four patients sports injury (9.5%), one patient (2.4%) had diving injury onto shallow water, and six patients (14.2%) trivial trauma.

The mean operative time reported was 150±20 minutes. The mean intraoperative blood loss was 650±250 ml. The mean hospital stay was 6±3.4 days and ranged from 3 to 13 days. All patients were followed at the outpatient clinic according to our previously mentioned protocol and the follow-up period ranged from 12 to 72 with a mean of 47±9 months.

By clinical follow up all patients were pain free with no torticollis, any apparent deformity in head and neck or significant neck motion limitations. None of the patients developed de novo neurological deficit either immediate or at the postoperative follow up period.

During the follow up period all patients have shown improvement at least one grade on the JOS Scale and at the last follow-up, the JOA Scale functional outcome by was as follow; 30 patients (71.5%) were normal, 9 patients (21.5%) on grade-I, 3 patients on grade-II (7%) and none were grade-III. None of the patients had neurological worsening during the follow-up. (Figure 1)

Plain radiographic follow up showed that all patients in this series (N=42, 100%) had good stability of the hardware construct system consisted of poly-axial screws and rods. Only one patient had slipped rod due to problem with the anti-torque locking system of the construct system intraoperatively. This patient was revised in next elective list and the rod was re-applied and his follow up period was uneventful thereafter. Postoperative CT-scan showed perfect screws alignment through the C1 lateral mass and C2 pedicles with adequate purchase in the bi-cortical atlantal lateral mass screws in all but one patient who had a low purchase C2 pedicle screw. Intraoperative and postoperative reduction of the deformity was restored in all patients and was maintained through the follow up period. At final radiological follow up sound fusion were reported in 38 patients (90%) out of our 42 patients. (Table2)
We had an intraoperative vertebral artery injury with the bone drill during C2P screw purchase. This patient was 49-year-old female with a Levine type-II Hangman’s fracture, here screw purchase was low and here vertebral artery was high riding. Post-operative CT-angio was done and confirmed the diagnosis, patient was set on antiplatelet life time and she did well thereafter. One of our patients had a local infection at the iliac crest harvest graft site that responded well to conservative treatment. Fortunately we did not have any greater occipital nerve neuralgia in any of our patients.

**Table 1.** Reported Pathological Lesion in this Study

<table>
<thead>
<tr>
<th>Group</th>
<th>Pathology</th>
<th>No. (%)</th>
</tr>
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<tbody>
<tr>
<td>Congenital</td>
<td>Os Odentadium</td>
<td>3 (7)</td>
</tr>
<tr>
<td></td>
<td>Down’s syndrome</td>
<td>4 (9.5)</td>
</tr>
<tr>
<td>Traumatic</td>
<td>Type-II dens fracture</td>
<td>8 (19)</td>
</tr>
<tr>
<td></td>
<td>Type-II Hangman fracture</td>
<td>10 (23.8)</td>
</tr>
<tr>
<td></td>
<td>Atlanto-axial rotatory fixation</td>
<td>9 (21.4)</td>
</tr>
<tr>
<td></td>
<td>Ligamentous injury</td>
<td>3 (7)</td>
</tr>
<tr>
<td>Neoplastic</td>
<td>Aneurysmal bone cyst</td>
<td>3 (7)</td>
</tr>
<tr>
<td></td>
<td>Plasma cell cytoma</td>
<td>2 (4.8)</td>
</tr>
</tbody>
</table>

**Figure 1.** Neurological outcomes: Pre and Postoperative JOA Scale showed N.39 (93 %) patients were improved to normal or on G 1 (excellent) and no patients in G3 postop.
Table 2. Radiographic outcome parameters in our 42 patients

<table>
<thead>
<tr>
<th>Parameter</th>
<th>No.</th>
<th>%</th>
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<tbody>
<tr>
<td>Construct Integrity</td>
<td>42</td>
<td>100</td>
</tr>
<tr>
<td>Screw Purchase</td>
<td>41</td>
<td>98</td>
</tr>
<tr>
<td>Sound Fusion</td>
<td>42</td>
<td>100</td>
</tr>
</tbody>
</table>

Figure 2. Seven years old boy with down’s syndrome, neck pain, no clear history of trauma, and grade-II JOA Scale. (A,B) dynamic Preoperative plain X-ray showing reducible atlantoaxial subluxation. (C) Axial cut CT-scan showing narrowed space available for the spinal cord. (D) Preoperative sagittal T1 MRI showing severe cord compression. (E) Operative fluoroscopy control image showing adequate spinal alignment (F) postoperative lateral X-ray showing C1 C2P screw fixation with adequate screw purchase.

Figure 3. A male patient 21 years old with neck pain and no history of trauma. (A,B) Pre-operative dynamic plain X-ray showing severe reducible atlanto-axial subluxation diagnosed as Os Odentedium after complete radiographic workup. His JOA Score was grade-I and had C1L-C2P fixation. (C) Postoperative plain X-rays showing adequate reduction and good screws alignment. (D) Postoperative axial CT-scan showing adequate C2P screw purchase.
Figure 4.
A female 11 years old adolescent patient with neck pain, torticollis, and grade-I JOA Scale.
(A) MS CT-scan showing osteolytic expanding lesion of C2 body and pedicle.
(B) T1 axial MRI showing same lesion expanding the C2 posterior arch, left pedicle, and body.
(C) Operative image showing complete excision of the mass with good neural decompression and bilateral C1L, right unilateral C2P, bilateral C3 lateral mass fixation. Biopsy proved aneurysmal bone cyst.
(D) Plain X-ray lateral view showing adequate screw purchase.
Discussion

In this study, we reported 42 consecutive patients with upper cervical instability through the period from 2006 to 2015. Twenty-six patients were males and sixteen females with mean age of 31.6±12 years. All patients were treated by C1 lateral mass and C2 transpedicular poly axial screws fixation and fusion with iliac bone graft with or without C3 or C4 lateral mass fixation. Different pathology and clinical status were reported in our method section.

The complex and unique anatomy and strong stability related to the ligamentous status of this region result in some peculiarities that distinguish this region from the subaxial cervical

Figure 5. Male 48 years old patient with neck pain and grade-II JOA Scale. (A) MS CT-scan showing expanding lesion of C2-3 body. (B) Sagittal T1 MRI showing the same pathology. (C) Preoperative plain X-ray with C2-3 body expansion. (D) Intraoperative image showing screw insertion. (E) Postoperative lateral X-ray showing C1L, C2P, C3, C4 lateral mass screw fixation with good screw purchase and alignment.
Biomechanically it’s responsible for the majority of axial rotation at the atlantoaxial complex and the greatest range of flexion and extension at the occiput–C1 joint.\textsuperscript{21}

Craniocervical instability represent a small number of cervical spine pathology, affecting the skull base, the atlas, and the axis.\textsuperscript{25,37} The traumatic instability due to bony or ligamentous injury are generally associated with high-energy trauma, but they also can be secondary to low-energy injuries in older individuals with bone fragility.\textsuperscript{37,19,21}

Surgical main goals for atlanto-axial instability are: 1) avoidance of further neurological injury, 2) reduce and stabilize injured segments and 3) provide long-term stability for healing and avoiding deformity. To define the best indications for surgical treatment, many surgical modalities have been developed to help surgeons with surgical treatment decisions for upper cervical spine instability (UCI).\textsuperscript{21,18,8,15} Sub-laminar wiring (Gallie 1939, Brook 1978, Soontag 1991), Laminar clamps (Halifax 1975), Transarticular screw (Magerl 1987), C1 lateral mass /C2 pedicle screw (Goel 1994, Harms 2001), and C2 laminar screw are te procedures that represent the timeline development of atlanto-axial fixation surgery.\textsuperscript{9,3,16,27,14,10,12}

In our study we recruited 42 patients with upper cervical instability (UCI) with different etiologies, and we were enrolled for surgery after failure of conservative management. Seven patients (16.7 %) had congenital etiology (os odentadium, and Down’s syndrome), and five patients (11.9%) had neoplasia, and thirty patients (71.4%). That’s was corresponding with Hedequist et al,\textsuperscript{15} and Song and Maher\textsuperscript{30} who postulated that these congenital conditions are associated with craniocervical region abnormalities that predispose these populations to developing atlantoaxial dislocation. One particularly Down’s syndrome (trisomy 21) is the most common inherited chromosomal disorder. Predisposing sequela include hypermobility and instability caused by ligamentous laxity and osseous abnormalities resulting in an increased incidence of atlantoaxial dislocation (15 to 20%). Traditionally believed to be a congenital anomaly, os odontoideum may in fact be caused by an early traumatic injury in which the odontoid is separated completely from the axis and then heals to resemble a separate ossicle. The resulting condition predisposes patients to dislocation.

Traumatic atlantoaxial dislocation is due to forced displacement of the neck resulting in disruption of the transverse ligament uncommon simultaneously involved of the alar and apical ligaments. A literature review by Ni et al,\textsuperscript{23} and Salunke et al,\textsuperscript{29} reported that traumatic atlantoaxial instability ranged from 45-78%, while Venkatesan et al,\textsuperscript{34} found only 12 adult cases (26%), so described a purely traumatic atlantoaxial dislocation in the absence of another predisposing risk factor is rare may due to usually associated with severe head injury.

Epidemiological data in this paper has shown that 26 were males and 16 females and age ranged from 4-52 years and correspond to most of reported literatures.\textsuperscript{2,29,35} All patients in this series had diagnosed by plain x-ray (static and dynamic), multislices CT scan, and MRI in non traumatic UCI. Padua et al,\textsuperscript{24} and Subach et al,\textsuperscript{28} reported the importance of functional /dynamic CT-scan in the diagnosis of UCI.

Preoperative all patients clinically suffered from with neck pain and/or torticollis, and neurologically as follow; 22 were normal (Grade 1 JOA), 17 patients between (Grade-I,-II JOA), and 3 patients were (grade-III JOA). Joaquim et al,\textsuperscript{18} reported that; In contrast to the subaxial cervical spine and the thoracolumbar...
spine, neurological deficit is uncommon in upper cervical spine injuries and surgery is more commonly indicated for ligamentous disruption. The presence of a neurologic injury, when present, does however portend a highly unstable injury, requiring surgical stabilization.

Radiological outcome has shown that all patients but one (98%) had very good screws purchase, and all patients (100%) had stable upper cervical vertebrae and sound fusion at follow-up period. Harms and mecher\textsuperscript{12} in their study reported satisfactory screws placement and solid fusion in all patients (N=39). This figures in our results matches with literatures as Yang et al,\textsuperscript{36} who reported that C1 lateral mass C2 pedicles screws fixation had best overall stability; more stable than intact spine on axial rotation, lateral, and AP translation; less stable on flexion/extension. Also C1L-C2P fixation is a structurally superior construct because it is stiffer in lateral bending and axial rotation when compared with C1 Lateral mass screw and C2 laminar screw fixation. C2P fixation permits individual placement of screws in C1 and C2 to allow direct intraoperative manipulation for corrective alignment of the head and reduction of the dislocation.\textsuperscript{4,5}

In this series one patient had early postoperative rod slippage that re-operated and fixed on next elective operative list. Another patient had operative vertebral artery injury with screw drill with no serious illness. Otherwise we had no serious complications or mortality in this series. Harms J,\textsuperscript{12} reported no serious complications in his series and stated that most neural complications associated with posterior wiring of the Gallie and Magerl techniques are mostly eliminated because sublaminar wiring is not required for C1L-C2P fixation.

### Conclusion

C1L-C2P poly-axial screw-rod system fixation is safe and effective in managing for upper cervical instability regardless of the etiology cervical instability. None of our patients deteriorated in neurological, deformity, or instability status. Meticulous technique and anatomical knowledge are mandatory. Multi-slice CT-scan-/CT angiogram is essential tool to exclude C2 anomalous vertebral artery. Further prospective long term studies with standardized patient reported outcome are necessary to further establish the clinical validity and safety of this technique.

### References

between the irreducible and reducible varieties. Neurosurg 104(2, Suppl):115–122, 2006

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أمان وفاعلية استخدام مسامير متعددة المحاور وققبان في أصلح عدم ثبات الفقرات العنقية العلوية

البيانات اللفغية: أنعدم ثبات الفقرات العنقية هو حالة شائعة جدا وتعد الآسياج لها من آسياج خلقية إلى أصابات مختلفة الطرق و بعض أنواع الأمراض التي تسبب هذه المنطقة في الفقرات إلى مجهولة السبب وبالرغم من تعدد طرق علاجها جراحياً سواء من الأمام أو الخلف فليس هناك توافق على الطرقية المثلى من ناحية الفاعليات الآمان.

الغرض: أجريت هذه الدراسة لتحقيق فاعلية وأمان استخدام مسامير خلفية متعددة على في أصلح تثبيت الفقرات الأولى والثانية العنقية وتحديد النتائج الأكليينيكية والفحوصات أتتشاعرية.

تصميم الدراسة: دراسة تفصيلية باثر بعد للمرضى الذين حضروا للمستشفى الجامعي لجامعة قناة السويس يعانون من عدم ثبات الفقرات العنقية العلوية لأسباب متعددة في الفترة من 2001 الي 2010. المرضى والطرق: تم مراجعة سجلات المستشفيات الجامعية لدينا في الفترة من 2001-2010 وأستطلعت متابعة 42 مريض يعانون من عدم ثبات الفقرات العنقية العلوية لأسباب متعددة من أسباب خلقية 27 مريض و 0 مريض يعانون من أورام مختلفة في هذه المنطقة و40 مريض يعانون من عدم ثبات الفقرات العنقية العلوية لاصطبابات مختلفة منها حادث سير أو سيارة أو السقوط من أعلى أو الغوص في ماء ضحل، كما يوجد 3 مرضى أشتكوا بأنهم بدون أسباب ظاهرة. وتنوعت أعراضهم العصبية من لا اعراض على درجة الثالثة على المقياس جمعية العظام الياباني وخصوصاً جمعياً للإضاعة العلوي والمقاعية متعددة القطاعات التشخيصية. وتم عمل جراحة لجميع المرضى عن طريق التثبيت الخلفي للفقرات باستخدام مسامير متعددة المحاور عبر اعونتين للفقرتين الأولى والثانية العنقية مع استخدام وصلة عمودية ورزع رقعة عظمية مناسبة. تمت التابعة على مدى 24 شهر على الأقل.

النتائج: أظهرت النتائج تحسن كل المرضى من حيث أختفاء الألم و التحسن درجة على الـ2 إلى النطاق على مقياس (ج.ع.ى) كما أظهرت ألمعالات بعد الجراحة وجود أستراجع في وضعية الفقرات و ثبات ملموسة لها ووضعية جيدة للمسامير داخل الفقرات والتحام جيد بينهما في المتابعة.

الاستنتاج: أثبت أن طريقة لاستخدام المسامير متعددة المحاور عبر العنقتين في الفقرات العنقية العلوية هي طريقة ناجحة من حيث تحسين ثبات الفقرات في جميع المحاور وفقدانها وعدم وجود علاقة للآسياج المختلفة لفقدان هذا الثبات ووضع المسامير داخل الفقرات مع قابلية أتحامها ووجود مضغوطات محتملة قليلا ولكن نحتاج لاستكمال الدراسات لتحسين النتائج.