

C2/3 Transfacetal fixation: An underutilized technique of C2 fixation in the management of atlantoaxial dislocation – A technical note with review of literature

ABSTRACT

Background: Atlantoaxial Dislocation (AAD) is a complex disorder of craniovertebral junction (CVJ). Many techniques are available to treat AAD but there are some specific conditions where some techniques have advantage over the other.

Technical Advantage: C2-3 transfacetal screw with standard C1 lateral mass fixation provides a stronger construct because of four cortices incorporation and divergent course of screws and is biomechanically comparable to other forms of C2 fixation techniques. It is a technically less demanding and time-consuming. It is also a good alternative in cases having significant osteopenia.

Conclusion: C2-3 transfacetal screw with standard C1 lateral mass fixation is an effective alternative to routine C1 lateral mass and C2 pedicle/pars screw fixation in cases of atlantoaxial dislocation complicated with high riding or posteriorly placed vertebral artery and thin pedicle of C2 vertebra.

Keywords: Atlantoaxial dislocation, C2 pedicle, C2/3 transfacetal screws, high riding vertebral artery

INTRODUCTION

Atlantoaxial Dislocation (AAD) is a complex disorder of craniovertebral junction (CVJ) with its deep-seated anatomic structures and their variations. The most important factor deciding its surgical course is its reducibility and the variation of its bony anatomy and the vertebral artery (VA) course. Thin C2 (Axis) vertebra pedicles and high riding VA pose a complex intraoperative scenario. To overcome these problems, many techniques have been described, like C2 subfacetal screws and C2 translamina screws. However, in the case of high degree of AAD with narrow corridors, subfacetal screw placement is difficult as the heads of the screws collide with each other. Furthermore, C2 translamina screws provide stability inferior to subfacetal screws or C2 pedicle/pars screws as it's not an inline facet fixation. To avoid these problems, C2-C3 transfacetal screws were first introduced by Goel in 2017.^[1] Here we will be discussing the technical details along with two cases of AAD where the anatomy of the

C2 pedicle and VA impelled the use of C2-C3 transfacetal screws for the C1-C2-C3 fusion.

SURGICAL TECHNIQUE OF C2-C3 TRANSFACETAL SCREWS

The patient was positioned prone on the operating table and the head was placed on a horseshoe headrest. Midline neck incision frominion to C4 spinous process was made with meticulous midline dissection to expose the lower

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occiput, C1 posterior arch, and C2 lamina. Subperiosteal dissection along the superior and medial border of the C2 pedicle was done to expose the C1/C2 joint as described by Goel *et al.*^[2] Bone graft was placed inside the joint after decortication using high-speed burr, then C1 lateral mass screw was inserted under C-arm guidance. The C2-C3 facet joint was exposed, decorticated and bone graft placed. The entry point for the C2-C3 transfacetal screw was made on the inferior facet of C2, 5 mm above the middle of the C2-C3 facet joint. The direction was straight in the coronal plane and perpendicular to the C2-C3 facet joints in the sagittal plane. All four cortices were breached with a high-speed drill using a 1 mm diameter matchstick drill bit, and then, a 2.8-mm handheld manual drill was used to expand the trajectory. Serial advancement of 2 mm of the drill was made until all four cortices were breached. A round tip bone sound was used to check for the integrity of the bony wall on all sides and an appropriate length of 3.5 mm self-tapping screw with the polyaxial head was inserted for C2-C3 transfacetal fixation. The same procedure was repeated on another side. 4 mm rod was used to connect C1 lateral mass/C2-3 transfacetal screws on both sides. Screw placement was followed by bony decompression if needed.

Transfacetal screw placement is a relatively easy technique without any risk to VA injury. Furthermore, its biomechanical strength is comparable to pedicle screws as it involves four cortical surfaces. The only disadvantage is that it incorporates an additional level in fixation, although its practical implication in range of motion (ROM) is minute.^[3]

CASE HISTORY

Case 1

A 34-year-old male patient presented with complaints of neck pain and left upper limb pain with left upper and lower limb weakness and numbness for the past 2 years. There was no history of trauma. On neurological examination, the patient had spastic quadriparesis (Medical Research Council's (MRC) grading, MRC Grade-4/5 in all four limbs). Deep-tendon reflexes across major joints were brisk. Bilateral plantar reflex were extensor. The Bilateral Hoffmann sign was positive. No involvement of bladder and bowel was seen. Sensory modalities were intact and breath-holding time was 42s. The Modified Japanese Orthopedic Association (mJOAS) score at admission was 16/18.

Magnetic resonance imaging (MRI) CVJ showed AAD with compression and myelomalacia changes in the cervicomedullary junction area which correlates with the clinical complaints and examination of the patient [Figure 1a]. Computed tomography (CT) scan of the mid-sagittal section

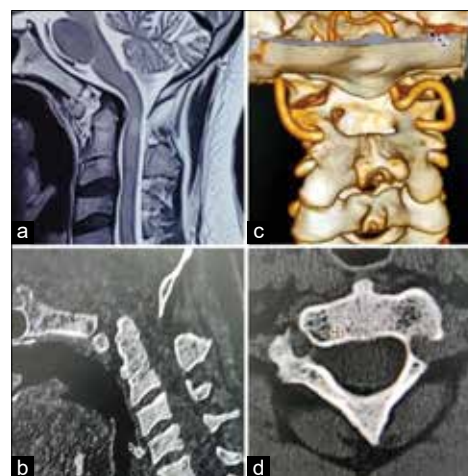


Figure 1: Preoperative images of case 1, a 34-year-old male. (a) Magnetic resonance imaging of Craniovertebral junction showing cord compression with myelomalacic changes. (b) Computed tomography scan of mid-sagittal section of craniovertebral junction showing basilar invagination with atlantoaxial dislocation. (c) 3-Dimensional reconstruction of computed tomography craniovertebral junction with vertebral angiogram showing assimilation of Atlas with bilateral high riding vertebral arteries with right vertebral artery coursing just posterior to right C1-C2 joint. (d) Axial Computed tomography section through C2 vertebra shows bilateral thin C2 pedicles

of CVJ showing basilar invagination with AAD [Figure 1b]. CT angiography of the neck vessels with 3D reconstruction shows the bilateral high riding VA [Figure 1c]. Furthermore, the right AV courses just posterior to right C1-C2 joint. Axial CT images of the C2 vertebra shows bilateral thin C2 pedicles [Figure 1d]. CT scan also shows poor bone quality of the cervical spine. T score of -3.5 on the DEXA scan confirmed the diagnosis of severe osteopenia.

Because of thin C2 pedicles and right side high riding VA, bilateral C1 lateral mass and C2-C3 transfacetal screws fixation was planned and achieved during surgery. Postoperative images show reduction of AAD and basilar invagination with placement of screws and rod construct [Figure 2a-c]. After surgery, there was an immediate improvement in the postoperative period, and the patient was discharged on postoperative day 5. On follow-up at 3, 6, and 12 months, the patient had no complaints and was taking treatment for osteoporosis.

Case 2

A 37-year-old male patient presented with weakness in all four limbs for the past 3 months. There was no history of trauma. On neurological examination, the patient had spastic quadriparesis (MRC grading, Grade-4/5 in all four limbs). Deep-tendon reflexes across major joints were brisk. Bilateral plantar reflex were extensor. Bilateral Hoffmann signs were positive. Involvement of the bladder and bowel was seen. There was a reduced sensation to touch and pain below the



Figure 2: Postoperative images of case 1. (a) Postoperative computed tomography scan through sagittal sections showing reduction of atlantoaxial dislocation and basilar invagination. (b) Intra-op radiograph showing the bilateral C1 lateral mass screws and bilateral C2-3 transfacetel screw insertion. (c) Sagittal section of postoperative computed tomography scan through C1 lateral mass and C2-C3 facet joint showing the C1 lateral mass screw and the C2-C3 transfacetel screw

neck. The breath-holding time was 18 s. The mJOAS score at admission was 14/18.

MRI CVJ showed AAD with severe compression and myelomalacic changes in the cervico-medullary junction area [Figure 3a]. CT CVJ confirmed the diagnosis of AAD [Figure 3b]. CT angiography of the neck vessels with 3D reconstruction showed normal VA course with hypoplastic left VA and dominant right VA [Figure 3c]. Axial CT images showed a narrow C2 pedicle on the right side [Figure 3d].

Transfacetel C2/C3 screw insertion was planned on the right for thin right C2 pedicle and pars and dominant right VA. The patient was taken for surgery and left C1 lateral mass/C2 pedicle and right C1 lateral mass and C2/C3 transfacetel fixation and fusion were achieved. Postoperative images show reduction of AAD with placement of screws and rod construct [Figure 4a-d]. After surgery patient showed significant improvement and was discharged on postoperative day 7. On follow-up at 3, 6, and 12 months, the patient had no new complaints and was showing constant improvement.

DISCUSSION

AAD is a complex disorder of CVJ because of its complex anatomic structures and their variations. The atlantoaxial screw fixation technique has the advantage of insertion of the screw in the strongest component of the vertebra and at the site of the fulcrum of spinal movements.^[2] The most important factor which needs consideration during surgery is its reducibility, anatomy of C1 and C2, and the course of VA and its variations.

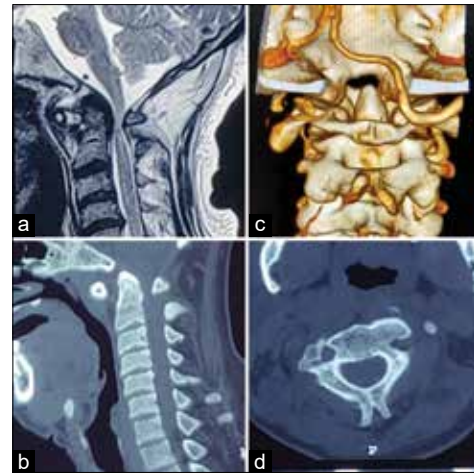


Figure 3: Preoperative images of case 2, a 37-year-old male. (a) Magnetic resonance imaging of craniovertebral junction showing severe cord compression with myelomalacic changes. (b) Computed tomography scan of mid-sagittal section of craniovertebral junction showing atlantoaxial dislocation. (c) 3-dimensional reconstruction of Computed tomography craniovertebral junction with vertebral angiogram showing right high riding vertebral arteries. (d) Axial Computed tomography section through C2 vertebra shows right thin C2 pedicle

Thin C2 pedicles and high riding vertebral arteries pose an increased risk for VA injury, especially if pedicle and pars screws are used. There was a 2%–8% incidence of VA injury during C2 transpedicular screws placement in cases of high riding VA.^[4] Placement of C2 pedicle screws is also not possible in 18% of the patients due to the atypical course of the VA.^[3]

The VA is also at risk, if the C2 pedicle is thin or if VA foramen is located in the C2 pedicle. Yoshida *et al.* concluded that all pedicle screw trajectories were limited by the width of the pedicle.^[5] Sairyo *et al.* found that the minimum pedicle diameter for safe implantation of pedicle screws should be 3.5 mm.^[6] Meng and Xu's radiographic study of C2 anatomy in patients with Os odontoideum recommended at least 5.5 mm diameter. He also found that 50% of patients with Os odontoideum have C2 pedicle width <3.5 mm.^[7] Case 1 of our study has bilateral thin C2 pedicles.

Poor bone quality like in osteoporosis and spondylosis also demands a stronger construct. Horn *et al.* concluded that in the case of osteoporosis, the construct has to be extended to C4 to provide strong fusion and stability.^[8] Transfacetel screws incorporate a C2/3 facet joint and purchase four cortices, hence may have better pullout strength than Pars or laminar screws. Several other methods have been used to fix the C2 in cases of thin pedicles and avoid the complications of VA injury like subfacetel screws, vertebral and translaminar screws.

Subfacetel screws also called vertebral screws was first named by SV Patkar in 2016, as an improvement over transpedicular

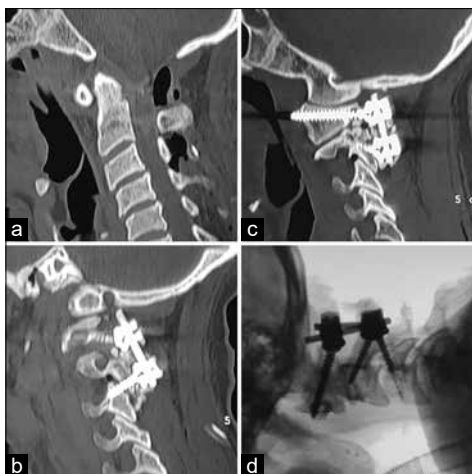


Figure 4: Postoperative images of case 2. (a) Postoperative computed tomography scan through sagittal sections showing reduction of atlantoaxial dislocation. (b) Right para-sagittal section of postoperative computed tomography scan through right C1 lateral mass and C2-C3 facet joint showing the C1 lateral mass screws and the C2-C3 transfacet screw. (c) Left para-sagittal section of postoperative computed tomography scan through left C1 lateral mass and C2 pedicle showing the C1 lateral mass screws and C2 pedicle screw. (d) Intra-operative radiograph showing the bilateral C1 lateral mass screws and right C2-3 transfacet and left C2 pedicle screw and rod fixation

C2 screws for avoiding VA injury, especially in high riding vertebral arteries (HRVA) cases. Bloch *et al.* defined an HRVA when the height of the C2 pedicle isthmus was <5 mm and/or the internal height was <2 mm on the sagittal image that is 3 mm lateral to the cortical margin of the spinal canal wall at C2. Furthermore, divergent screws of the subfacet technique were claimed to offer greater resistance to pull out forces as compared to C2 pars/pedicle screws. However, the placement of subfacet screws was not possible in every case as the heads of the screws used to collide in the narrow corridor of high degree AAD and putting it does not completely exclude the possibility of VA injury in high-risk cases.

The translaminar screw of C2 was firstly described by Wright in 2004.^[9] It was considered to reduce the risk to the VA. Although a computerized tomography angiogram-based morphometric analysis conducted by Riesenburger *et al.* showed that C2 translaminar screws could jeopardize the vertebral arteries in the foramen transversarium or the C1-2 interval. Clinical studies also reported a lower probability of ventral cortical breaches or instrumentation failures with C2 translaminar screw fixation and a higher fusion rate of 97% without neural or vascular complications. Translaminar screws are not as affected by variations in a patient's anatomy unlike other C2 screw fixation options like C1-C2 transarticular screws, C2 pedicle screws, etc.

Several studies showed C2 translaminar screw was similar to the C2 pedicle screw and C2 pars screw-in biomechanical

performance. Although bi-cortical purchase afforded by C2 transpedicular screws may account for the increased C2 transpedicular screw stiffness in axial rotation and lateral bending when compared with C2 translaminar screws. C2 translaminar screws are difficult to incorporate into a rod construct owing to the medial position of the screw head and can't be used as leverage to reduce dislocation. Furthermore, the fixation is away and not inline of the C1/C2 joint hence considered an inferior method of fixation.

To avoid these complications and limitations of subfacet and translaminar C2 screw fixation, C2-C3 transfacet screws were first introduced by Goel in 2017.^[11] Transfacet screws provide stronger fixation and increased pull out strength as it incorporates four cortical surfaces. Its trajectory practically excludes the chances of VA injury and provides an inline fixation; hence, the C1 lateral mass screw can be used as leverage to reduce the dislocation.

One disadvantage of C2-C3 transfacet screws is that they incorporate an intact motion segment (C2-3) in fixation construct level reducing the ROM. Hartl *et al.*^[10] compared biomechanics of C1-C2 fixation with C1-C2-C3 fixation and found that later had reduced ROM when compared with the former. Though there was no difference in one study conducted by Paramore *et al.*^[3] The author also concludes that there are no practical implications of additional C2/C3 fixation in these cases.

Goel *et al.* summarized indications that can utilize transfacet screws. They include high riding VA, course of VA posterior to C1-C2 joint, absent pedicle of C2 vertebra, degenerative conditions affecting C2 pedicle or tuberculosis of C2 vertebra, Hangman's fracture, disruption of C2 pedicle during surgery, etc., Transfacet screw fixation is technically less demanding and time-consuming and provides a stronger construct that may be comparable to other methods of C2 fixation.

CONCLUSION

C2-3 transfacet screw with standard C1 lateral mass fixation is a satisfactory alternative to routine C1 lateral mass and C2 pedicle/pars screw fixation in cases of AAD complicated with high riding or posteriorly placed VA and thin pedicle of C2 vertebra. It is also a good alternative in cases having significant osteopenia. It has a lesser risk of VA injury and pedicle breach during surgery. It is a technically less demanding and time-consuming method with practically no risk of VA injury and can be used as a rescue technique during surgery after iatrogenic C2 pedicle or pars fracture. It provides a stronger construct because of four cortices incorporation and divergent course of screws and is

biomechanically comparable to other forms of C2 fixation techniques, although large-scale, long-term studies are needed to confirm these findings.

Declaration of patient consent

The authors declare that they have obtained consent from patients. Patients have given their consent for their images and other clinical information to be reported in the journal. Patients understand that their names will not be published and due efforts will be made to conceal their identity but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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