

# C1 lateral mass reduction screws for treating atlantoaxial dislocations: Bringing ease by modification

## ABSTRACT

**Objective:** The C1-C2 fixation technique revolutionized the management of complex craniovertebral junction (CVJ) anomalies. Presently used polyaxial screw and rod systems have inadvertent technical difficulties in rod fitting and reduction of atlantoaxial dislocations (AAD) requiring forceful joint handling. The purpose of this study is to analyze the use of a specially designed “reduction screw” in C1 lateral mass in C1-C2 fixation for treating AAD with or without basilar invagination (BI).

**Study Design:** This is a retrospective cohort study in which long lateral mass reduction screws were used for C1-C2 fixation.

**Materials and Methods:** Eighteen patients diagnosed with congenital AAD with or without BI treated with C1-C2 fixations using C1 reduction lateral mass were included in the study. The outcome was measured clinically by the modified Japanese Orthopedic Association score and radiologically by conventional craniometric indices.

**Results:** Among all cases included in the study, 72% (13/18) are males and 18% (5/18) are females with average age at presentation of 33.5 years. Among 18 cases of AAD, 84% (15/18) of patients have BI, 22% (4/18) have Chiari Type 1 malformation, and one patient has Klippel–Feil syndrome. Symptomatic improvement is noted in all patients following surgery. Adequate reduction of AAD with normalization of radiological indices was also achieved in all 18 (100%) patients.

**Conclusion:** C1 lateral mass reduction screw in C1-C2 fixation helps in reduction of AAD and BI (Type A) even in difficult cases of CVJ anomalies with intraoperative technical ease, reduced operative time, no need for special instruments or complex maneuvers, and avoiding potential neurological injury.

**Keywords:** Atlantoaxial dislocation, breakable long head, C1-C2 fixation, craniovertebral junction, Goel's technique, reduction screw

## INTRODUCTION

The craniovertebral junction (CVJ) anomaly treatment underwent shift in the management in the past two decades from combined transoral decompression and posterior fixation to posterior only approaches with C1-C2 fixation with complete restoration of normal alignment at the joints.<sup>[1-5]</sup> Goel and Laheri pioneered and popularized the technique of C1-C2 fixation which was modified by Harms with the use of polyaxial screws and rod systems minimizing the need for transoral decompression.<sup>[3,4]</sup> Among different C1-C2 fixation techniques used in many recent studies, C1 lateral mass and C2 pedicle, pars, lamina, or subfacetal screw and rod fixation is most stable construct having high fusion rate, reduced neck

pain, and improved neurologic function.<sup>[1-5]</sup> Presently used implant system in C1 lateral mass and C2 pedicle or pars

**DEEPAK KUMAR SINGH, VIPUL PATHAK, NEHA SINGH<sup>1</sup>, RAKESH KUMAR SINGH, MOHAMMAD KAIF, KULDEEP YADAV**

Departments of Neurosurgery and <sup>1</sup>Radiodiagnosis and Imaging, Dr. Ram Manohar Lohia Institute of Medical Sciences, Lucknow, Uttar Pradesh, India

**Address for correspondence:** Dr. Deepak Kumar Singh, Department of Neurosurgery, Dr. Ram Manohar Lohia Institute of Medical Sciences, Lucknow, Uttar Pradesh, India.  
E-mail: gkp.deepak@gmail.com

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screw fixation includes simple polyaxial screws and rods. Even with advanced implants and instrumentation, presently used screw and rod systems have inadvertent technical difficulties in rod fitting and reduction of atlantoaxial dislocation (AAD) and basilar invagination (BI) requiring forceful joint handling in difficult cases associated with assimilated atlas, high riding vertebral arteries, thin C2 pedicles, and vertically slanting C1–2 joints (Sagittal inclination  $> 100^\circ$ ).<sup>[5,6]</sup>

We describe a modification of presently used lateral mass screw with the use of specially designed “reduction screw” in C1 lateral mass in C1-C2 fixation for treating AAD with or without BI. Reduction screws were designed and being used for spondylolisthesis reduction in lumbosacral spine with favorable outcomes for the past 10 years.<sup>[7,8]</sup> The use of reduction screw in C1 lateral mass in C1-C2 fixation for treating CVJ dislocations have advantage of technical ease in rod fitting and achieving reduction of AAD and BI in a gradual controlled manner on both sides without need for forceful (C1-C2) joint handling even in difficult cases. It also gives leverage so that C2 subfacetal screws can be easily put in cases of high-riding vertebral arteries.

### Study design

This is a retrospective observational study.

## MATERIALS AND METHODS

Eighteen patients diagnosed with congenital AAD with or without BI treated with C1-C2 fixations (C1 reduction lateral mass and C2 pedicle, pars, or subfacetal screw and rod) were included in the study. All patients were clinically examined on admission and functional grading of neurological status determined with the modified Japanese Orthopedic Association (mJOA) score.

### Preoperative evaluation

All patients underwent computed tomography (CT) CVJ in flexion and extension along with vertebral angiography to look for detailed regional anatomy and course of vertebral arteries around C1-C2 joint. Measurements of C1 lateral masses, C2 pedicles, and occiput-C1-C2 joint anatomy noted on CT scans. All patients have undergone postoperative CT CVJ before discharge.

Radiological indices such as atlantodental interval (ADI), distance of odontoid tip from Weckenheim’s clivus line (WCL) and from McRae’s line (ML) were used for radiological outcome analysis.

### Reduction screw

“Reduction screw” is similar to presently used polyaxial titanium screw with long head size with a hinge for cutting

extra head length after fitting of rod. Reduction screws were used successfully for the past 10 years in the lumbosacral spine for spondylolisthesis reduction with good outcomes. The screw has a cutting hinge for removal of extra head length after final tightening of rod after which it becomes a simple screw. Specially designed reduction screws for C1 lateral mass 2.8 mm–3.5 mm thickness and 22 mm–34 mm length were used in our study [Figure 1].

### Operative technique

All patients operated in general anesthesia from posterior-only approach and intraoperative traction was used wherever thought necessary. After proper exposure from the suboccipital region to C3, C1-C2 joint capsule opened bilaterally, and joint surfaces prepared with curette and drilling. We preferred to sacrifice C2 root ganglia in all cases. C1 lateral mass “reduction screws” and C2 pedicle, pars, or subfacetal screws (polyaxial titanium) put under anatomical and C-arm guidance by Goel’s and Laheri technique.<sup>[3]</sup> We prefer to push the C1 reduction screw head close to the posterior aspect of lateral mass to achieve good reduction. Reduction screw is a screw with double head length than the usual screw was used in C1 lateral mass [Figure 1]. Posterior decompression in the form of posterior C1 arch removal, foramen magnum decompression, or duraplasty was done wherever needed in cases associated with Chiari malformations. Autologous bone graft was used for fusion in all cases. Rod of appropriate length fitted in screw heads. Since the heads of both C1 and C2 screws lies at the same level in sagittal plane there is no difficulty in putting rods. Innis was tightened first at C2 screw head and then at C1 screw head. Slow tightening of innis on both sides C1 screw heads lead to gradual, controlled, and bilateral reduction of AAD. Reduction was confirmed under fluoroscopy, extra length of C1 screw head was cut and removed followed by drained closure of incision.



**Figure 1: Reduction lateral mass screw with hinged breakable polyaxial head (right) and old lateral mass screw (Left)**

Postoperatively all patients put on neck orthoses (Philadelphia/hard cervical collar/SOMI brace) and appropriate analgesics and antibiotics were given. Each patient has undergone CT CVJ before discharge from the hospital. Radiological analysis of successful reduction of AAD and or BI was done with comparing craniometrics before and after surgery. Clinical evaluation of functional status was done in follow-up outpatient department (OPD) visits from 15 days to 6 months from OPD cards and or telephonically with mJOA questionnaire.

## Case illustration

### Case 1

A 24-year-old male patient presented with gradually progressive spastic quadriparesis. Magnetic resonance imaging (MRI) and CT CVJ confirmed the diagnosis of AAD with BI. Axial CT cuts revealed thin C2 pedicles on both sides. C1/C2 joint on the left side is vertical with very narrow corridor and pseudo-occipital-C2 joint. C1 lateral mass and C2 subfacetal screw fixation were planned. The patient was put in prone position under general anesthesia and routine C1-C2 joint exposure and preparation obtained. C1 lateral mass reduction screw was put in bicortical manner on the right side and its head was pushed close to the posterior surface of lateral mass. Using the long head of the screw as a lever lateral mass of C1 was tilted up and C2 subfacetal screw entry point was made anterior to the exit of vertebral artery (VA) from C2 foramina. After probing and tapping, appropriate length subfacetal screw was put in C2. Procedure was repeated on the left side, and similarly, C1 reduction lateral mass and C2 subfacetal screw were put. Rods were put on both sides. Because of extra length of C1 screw head, rods were easily put on both sides simultaneously. C2 inni was tightened on both sides than C1 inni was put and tightened on both sides together. This causes gradual reduction of AAD and BI as C1 lateral mass was gradually pulled back and upward over C2 superior facet. After complete tightening, extra length of C1 screw head was cut at hinge and removed. Autologous bone graft was placed in and around joint space and wound closure done in layers over drain. Postoperative CT scan confirms the reduction of AAD and BI [Figure 2a-c].

## RESULTS

Among all cases included in this study, 72% (13/18) are males and 18% (5/18) are females with average age at presentation 33.5 years. Among 18 cases of AAD, 84% (15/18) of patients having BI, 22% (4/18) having Chiari Type 1 malformation, and one patient has Klippel–Feil syndrome. AAD was irreducible in 78% (14/18) cases and reducible in 22% (4/18) cases. All cases in our study had Type A dislocation, i.e., C1 displaced anteriorly over C2 which is the most common type observed in almost

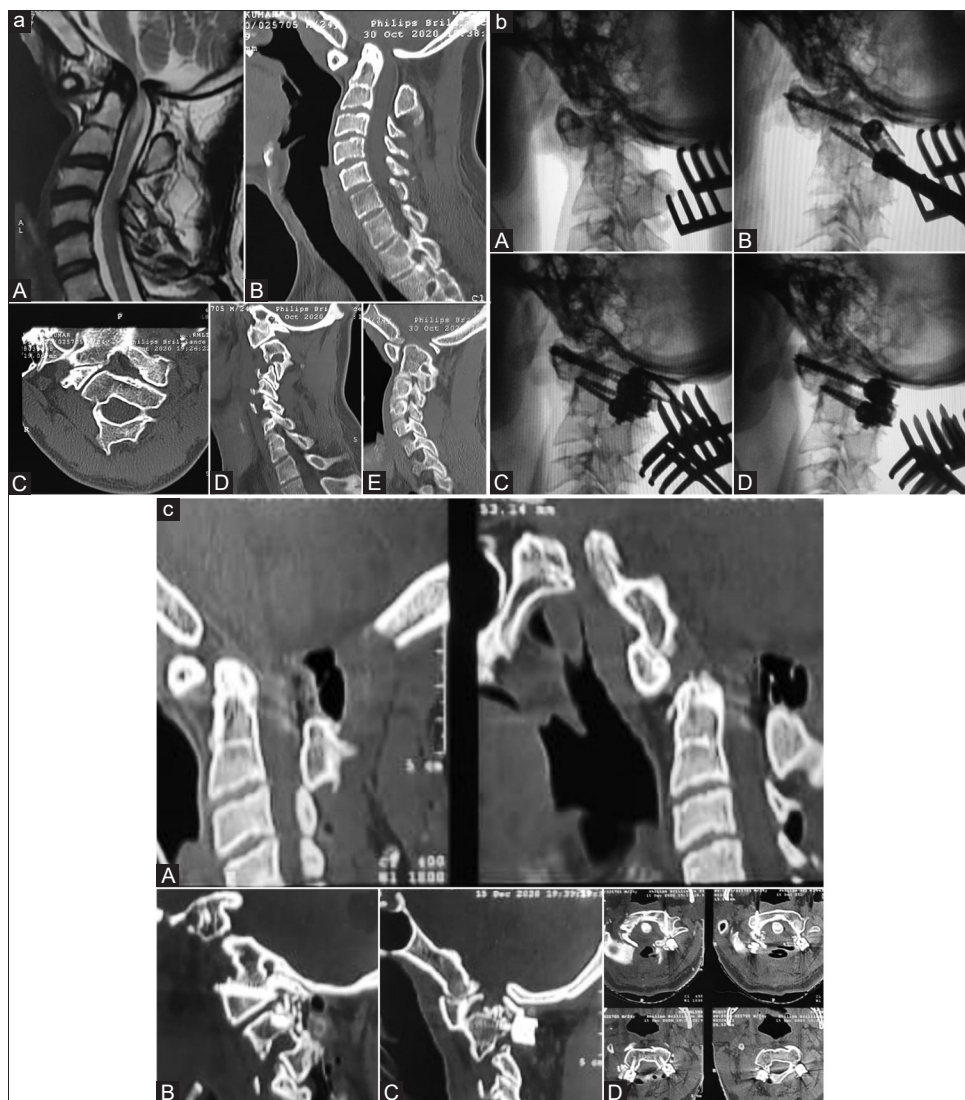
90% of cases. The most common anatomical deformity present was assimilation of the atlas in 78% (14/18) of cases and OS odontoideum in one case.

We noticed symptomatic improvement in the form of pain relief, reduced spasticity, and decreased paresthesia in all 18 patients after surgery. Eighty-nine percent (16/18) of patients showed good neurological recovery in the form of improvement in their mJOA scores during the follow-up period. Radiologically evident reduction of AAD with normalization of ADI and restoration of normal C1-C2 joint alignment was achieved in all 18 (100%) patients. Odontoid tip distance from WCL (normal 0 mm or more) was normalized after surgery in 14 patients of 15 cases of BI. Odontoid tip distance from ML (normal 3 mm–5 mm or more) was normalized postoperatively in 13 of 15 patients. Postoperative course of all patients was uneventful with no any major neurological or vascular complications. All patients had postoperative C2 dermatome numbness which gradually improved over the period. Follow-up CT of CV junction at 6 months showed fusion in (100%) all 18 patients.

## DISCUSSION

The CVJ anomaly treatment has undergone phenomenal change with pioneering work by Goel *et al.* and others.<sup>[9-12]</sup> The entire focus is now on atlantoaxial screw placement with C1-C2 joint manipulation.<sup>[5,6,11-17]</sup> Presently used poly axial C1-C2 screws and rod systems have inadvertent disadvantage of difficulty in fitting rod and require forceful handling of joint. Presently employed methods for rod fixation and reduction of AAD in those cases are forceful handling of joint manually, extension of the head, and pushing C2 screw head anteriorly or with instruments such as rod reducer, rocker, or distractor. Abovementioned methods are associated with increased operative time and risk of potential neurological injury. Our technique with reduction screws in C1 lateral mass enables not only easy fitting of rod without forceful joint handling or without any need for special instruments but also achieves reduction of AAD in a gradual and controlled manner, thereby avoiding any potential neurological injury. “Reduction screw” as used in many studies in lumbosacral spine instrumentation corrects spondylolisthesis.<sup>[7,8]</sup> With the same principle of action, it causes reduction of AAD which is actually nothing but anterior listhesis of C1 over C2.

With our technique of reduction screw in C1 lateral mass, extra head length of screw alleviates discrepancy in C1-C2 screw head heights, thereby making rod fixation technically easy and no or decreased need for forceful joint handling. Another problem is insertion of C2 subfacetal screws in cases of thin C2 pedicles or high-riding VA because of narrow space and crowding of screw heads. Extra head length of C1 screw



**Figure 2:** (a) Preoperative magnetic resonance imaging and computed tomography images showing atlantoaxial dislocations and basilar invagination (A and B) with thin C2 pedicles on both sides (C). Right side C1- C2 joint inclination is normal in sagittal plane (SI-60°) (D). The left side C1-C2 joint is vertical in the sagittal plane (SI > 160°) (E). (b) Intraoperative fluoroscopy images showing mechanism of reduction achieved using reduction screw in C1 lateral mass. Per-operative fluoroscopic image before reduction (A) The screw heads of C1 and C2 are almost at the same level in the sagittal plane (B), that permits easy insertion of rods and gradual reduction simultaneously on both sides (C). After complete reduction and breakage of hinged extra head length of C1 lateral mass screws (D). (c) Postoperative computed tomography scan showing adequate reduction of atlantoaxial dislocations and basilar invagination (A) with optimum screws positions in C1 and C2 (D). The Right (B) and left side joints are also properly aligned now (C)

allows manual upward tilting of C1 lateral mass that opens up the space and C2 subfacetal screw can be easily put anterior to exit of VA from C2 foramina. Tightening of rod causes posterior and upward sliding of C1 over C2 and reduction of AAD and BI in a gradual and controlled manner. No special instruments such as rod reducer or rocker are needed for rod fixation. We were able to achieve good reduction in cases associated with high riding with vertically oriented C1/2 joints also (SI > 100°) [Figures 3a and b and 4a and b].

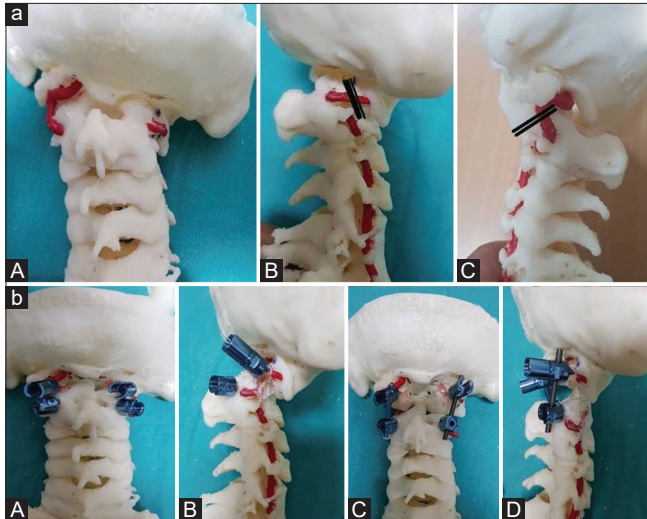
Most recent studies such as Menezes<sup>[1]</sup> and Chandra *et al.*<sup>[5,6]</sup> advocate occipitocervical fusion in cases of CVJ anomalies with assimilated atlas. In our study, even with the assimilation

of atlas in 15 (83.3%) patients, C1-C2 fixation was easily performed in all of them.

The presence of VA course variation at the CVJ may influence treatment options for CVJ anomalies. In our study, the VA course was abnormal in 50% (9/18) patients causing technical difficulties in C1-C2 joint exploration. Even though we were able to dissect VA in all cases and with the ease of leverage provided by long reduction screws in C1, C1-C2 reduction, and fixation were easily achieved.

The study by Chandra *et al.*<sup>[6]</sup> described the correlation of sagittal and coronal inclination of the odontoid process and

craniocervical tilt with the severity of BI in which complex lines from fixed bony points are described. Chandra *et al.* universally promote occipitocervical fusion in all cases with capitalized C1. They proposed a treatment algorithm based on sagittal inclination of C1/2 joints, where distraction, compression, extension, and reduction (DCER) alone is advocated for cases having SI < 100° (Group 1), joint remodeling, and DCER for SI 100°–160° (Group 2) and extra-articular distraction using spacers in pseudo-O-C2 joints with DCER in cases (Group 3)

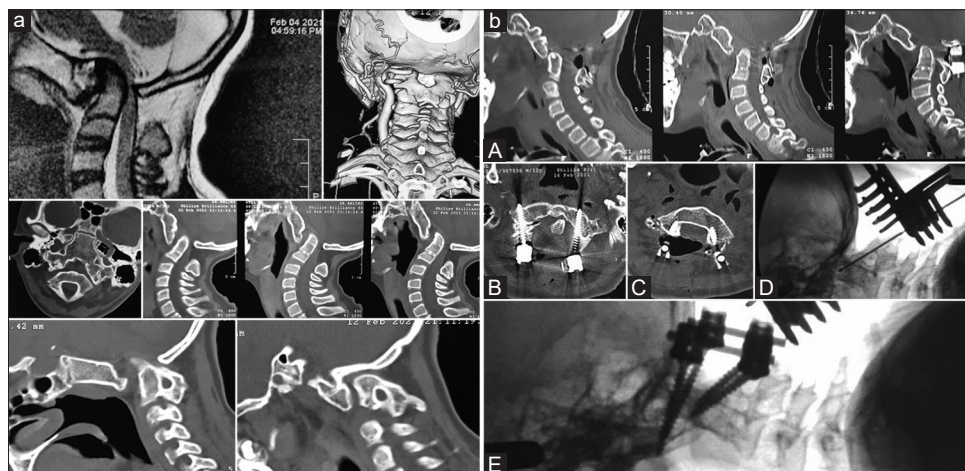


**Figure 3:** (a) Three dimensions model of a case of atlantoaxial dislocations and basilar invagination having vertical sagittal inclination of both C1-C2 joints (B and C-double black lines). The left side vertebral artery is coursing against the joint (A). (b) Representation of reduction by putting reduction lateral mass screws in both C1 lateral masses. Both side C1 lateral mass screws and C2 pedicle screws are at the same level in coronal (A) and sagittal plane (B). Both side rods can be easily put simultaneously and bilateral gradual reduction of atlantoaxial dislocations and basilar invagination can be achieved by simply tightening the innis in C1 reduction lateral mass screws and C2 pedicle screws. (C and D) After final reduction, note how C1 is pulled back and up and the canal is wide open (C and D)

having vertical joints (SI > 160°). Although this algorithm is impressive, it does not circumvent the problems of proposed occipital fixation in all cases. Hwang *et al.*<sup>[18]</sup> in their series of occipital fixation has reported intraoperative complication in range of 15%–18%. We were able to avoid occipital fixation in all cases. Joint remodeling is also not possible in all (Group 2) cases as sagittal inclination is almost always associated with coronal inclination and exit foramina of VA limits joint drilling below and lateral to it. The study is limited in describing the joint remodeling techniques in coronal plane. Yamazaki *et al.*<sup>[19]</sup> have reported 11%–15% prevalence of VA course anomalies, that further limits the joint modification suitable enough for spacer insertion and DCER. Pseudo O-C2 joints, although present in almost all cases with vertical joints (Group 3, SI > 160°), are not sturdy enough and anatomically suitable to hold spacers and allow manipulations in every case. Anomalous VA course against the pars of C2 again limits the use of pseudo-O-C2 joint for instrumentation.

In our study, we found that reduction screw in C1 gradually pulls the C1 lateral mass up and back over C2 superior facet and adequate reduction is achieved in all cases independent of C1-2 joint sagittal inclination. By keeping the head of the reduction screw close to the posterior surface of C1 lateral mass, adequate amount of reduction can be achieved even in difficult cases.

All patients in our study showed symptomatic improvement with 89% (16/18) patients showing improvement in mJOA score on follow-up up to 6 months and remaining have the same score as preoperative status. On radiological analysis, ADI was normalized in 100% patients with restoration of normal C1-C2 joint alignment in all of them with 100% fusion



**Figure 4:** Preoperative magnetic resonance imaging and computed tomography scan (4a) of the case shown in Figures 3a and b. Vertical inclination of both C1-C2 joints is evident (4a-bottom row). Postoperative computed tomography scan (4b) (A,B,C) and intraoperative fluoroscopy (D and E) showing adequate reduction of atlantoaxial dislocations and basilar invagination (A) with optimum placement of screws in C1 (B) and C2 (C)

rate. We observed no any screw-related complications in our study. We noticed good functional and radiological outcomes in our study which was similar to other studies in the past such as Melcher *et al.*<sup>[20]</sup> and Wang *et al.*<sup>[21]</sup>

## CONCLUSION

The use of C1 reduction screw in C1-C2 fixations is safe and effective method for treating ADD with or without BI, having advantage of technical ease in rod fixation, C2 screw insertion in high riding VA, and achieving reduction of AAD and BI in gradual controlled manner.

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Nil.

## Conflicts of interest

There are no conflicts of interest.

## REFERENCES

- Menezes AH. Craniovertebral junction anomalies: Diagnosis and management. *Semin Pediatr Neurol* 1997;4:209-23.
- Goel A, Bhatjiwale M, Desai K. Basilar invagination: A study based on 190 surgically treated patients. *J Neurosurg* 1998;88:962-8.
- Goel A, Laheri V. Plate and screw fixation for atlanto-axial subluxation. *Acta Neurochir (Wien)* 1994;129:47-53.
- Goel A, Desai KI, Muzumdar DP. Atlantoaxial fixation using plate and screw method: A report of 160 treated patients. *Neurosurgery* 2002;51:1351-6.
- Chandra PS, Kumar A, Chauhan A, Ansari A, Mishra NK, Sharma BS. Distraction, compression, and extension reduction of basilar invagination and atlantoaxial dislocation: A novel pilot technique. *Neurosurgery* 2013;72:1040-53.
- Chandra PS, Prabhu M, Goyal N, Garg A, Chauhan A, Sharma BS. Distraction, compression, extension, and reduction combined with joint remodeling and extra-articular distraction: Description of 2 new modifications for its application in basilar invagination and atlantoaxial dislocation: Prospective study in 79 cases. *Neurosurgery* 2015;77:67-80.
- Floman Y, Millgram MA, Ashkenazi E, Smorgick Y, Rand N. Instrumented slip reduction and fusion for painful unstable isthmic spondylolisthesis in adults. *J Spinal Disord Tech* 2008;21:477-83.
- Pan J, Li L, Qian L, Zhou W, Tan J, Zou L, *et al.* Spontaneous slip reduction of low-grade isthmic spondylolisthesis following circumferential release via bilateral minimally invasive transforaminal lumbar interbody fusion: Technical note and short-term outcome. *Spine (Phila Pa 1976)* 2011;36:283-9.
- Goel A, Kulkarni AG, Sharma P. Reduction of fixed atlantoaxial dislocation in 24 cases: Technical note. *J Neurosurg Spine* 2005;2:505-9.
- Goel A. Treatment of basilar invagination by atlantoaxial joint distraction and direct lateral mass fixation. *J Neurosurg Spine* 2004;1:281-6.
- Salunke P, Sharma M, Sodhi HB, Mukherjee KK, Khandelwal NK. Congenital atlantoaxial dislocation: A dynamic process and role of facets in irreducibility. *J Neurosurg Spine* 2011;15:678-85.
- Jian FZ, Chen Z, Wrede KH, Samii M, Ling F. Direct posterior reduction and fixation for the treatment of basilar invagination with atlantoaxial dislocation. *Neurosurgery* 2010;66:678-87.
- Suh BG, Padua MR, Riew KD, Kim HJ, Chang BS, Lee CK, *et al.* A new technique for reduction of atlantoaxial subluxation using a simple tool during posterior segmental screw fixation: Clinical article. *J Neurosurg Spine* 2013;19:160-6.
- Yin YH, Qiao GY, Yu XG, Tong HY, Zhang YZ. Posterior realignment of irreducible atlantoaxial dislocation with C1-C2 screw and rod system: A technique of direct reduction and fixation. *Spine J* 2013;13:1864-71.
- Chandra PS. In reply. *Neurosurgery* 2014;74:E148-50.
- Deepak AN, Salunke P, Sahoo SK, Prasad PK, Khandelwal NK. Revisiting the differences between irreducible and reducible atlantoaxial dislocation in the era of direct posterior approach and C1-2 joint manipulation. *J Neurosurg Spine* 2017;26:331-40.
- Lapsiwala SB, Anderson PA, Oza A, Resnick DK. Biomechanical comparison of four C1 to C2 rigid fixative techniques: Anterior transarticular, posterior transarticular, C1 to C2 pedicle, and C1 to C2 intralaminar screws. *Neurosurgery* 2006;58:516-21.
- Hwang SW, Gressot LV, Rangel-Castilla L, Whitehead WE, Curry DJ, Bollo RJ, *et al.* Outcomes of instrumented fusion in the pediatric cervical spine. *J Neurosurg Spine* 2012;17:397-409.
- Yamazaki M, Okawa A, Furuya T, Sakuma T, Takahashi H, Kato K, *et al.* Anomalous vertebral arteries in the extra- and intraosseous regions of the craniovertebral junction visualized by 3-dimensional computed tomographic angiography: Analysis of 100 consecutive surgical cases and review of the literature. *Spine (Phila Pa 1976)* 2012;37:E1389-97.
- Melcher RP, Puttlitz CM, Kleinstueck FS, Lotz JC, Harms J, Bradford DS. Biomechanical testing of posterior atlantoaxial fixation techniques. *Spine (Phila Pa 1976)* 2002;27:2435-40.
- Wang C, Yan M, Zhou H, Wang S, Dang G. Atlantoaxial transarticular screw fixation with morselized autograft and without additional internal fixation: Technical description and report of 57 cases. *Spine (Phila Pa 1976)* 2007;32:643-6.