Original Article

Management of traumatic atlanto-axial instability: A retrospective study of eight cases

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Abstract

Background: C1 lateral mass–C2 transpedicular fixation is an accepted surgical procedure of choice in a large number of cases with traumatic atlanto-axial instability. However, bony and vascular anomalies can predispose to unacceptably high risk with this procedure, And hence are the contraindications for this procedure. The purpose of this study is to analyze the clinical and radiological results in such cases for which only unilateral fixation has been performed in cases where bilateral fixation could not be performed due to various reasons.

Materials and Methods: Eight patients (7 males, 1 female) with a mean age of 41.12 years (range 12-68 years), who presented with traumatic atlanto-axial instability and in whom bilateral fixation could not be performed, were treated with unilateral C1 lateral mass–C2 transpedicular fixation. Of these cases, preoperative vertebral artery occlusion was noted in one case, iatrogenic vertebral artery injury in two cases and bony anomalies or fractures in the remaining of five cases. All patients were evaluated clinically with the American Spinal Injury Association (ASIA) scale and radiologically with computed tomography scans and serial X-ray using criteria to evaluate stability.

Results: All cases were evaluated at 6 months followup with mean followup of 2 years and one month (range 6 months to 4 years). All eight patients showed adequate stability and fusion at 6 months; clinically there was no significant restriction of neck movement in any of the patient. There was no neurological deterioration in any of the patient at their last follow-up.

Conclusion: Unilateral C1 lateral mass–C2 transpedicular fixation could be considered a viable option in cases of traumatic atlanto-axial instability where vascular and osseous anomalies contradict a bilateral fixation.

Key words: Atlanto-axial instability, C1 lateral mass–C2 transpedicular fixation, unilateral fixation

Introduction

C1 lateral mass–C2 pedicle screw fixation, first described by Goel *et al.*,[1,2] has gained acceptance as treatment option of choice in the management of atlantoaxial instability needing posterior fixation. This procedure provides excellent stability in 85–100% of cases.[3,4] The anomalies of the vertebral artery as well as bony anomalies are contraindication for this technique in a significant percentage of patients. In such situation, the operating surgeon is often forced to opt for an occipitocervical fusion which would restrict craniocervical mobility or choose alternative salvage procedures which would provide less rigid fixation, such as the use of translaminar screws or a lateral mass screw. The unilateral C1 lateral mass, C2 pedical screw fixation is indicated in unilateral vertebral artery and bony anomaly.

In this study, we retrospectively analyzed unilateral C1 lateral mass–C2 transpedicular fixation in eight patients in whom bilateral fixation could not be done for various reasons and evaluated their functional and radiological outcome for a minimum follow-up of 6 months.

Materials and Methods

A retrospective analysis of eight cases of traumatic atlanto-axial instability managed by unilateral C1 lateral mass–C2 transpedicle screw fixation was carried out from May 2005 to October 2010. All patients seen in casualty with suspected cervical spine injury, restricted neck movement and neurological deficit; as well as all cases with concussive

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head injury were subjected to X-rays of the cervical spine [Figure 1a]. All patients with neurological deficit and those with X-ray evidence of cervical spine injury without neurological deficit were subjected to magnetic resonance imaging (MRI) cervical spine.

A total of 34 cases with the atlanto-axial subluxation were treated using C1 lateral mass–C2 transpedicular screw. All 34 cases were subjected to preoperative computed tomography (CT) scan and CT/MR angiogram [Figures 1b and 2a]. A detailed preoperative neurological examination was done and patients were graded as per the American Spinal Injury Association (ASIA) scale. Twenty-six patients underwent bilateral C1 lateral mass–C2 transpedicular screw placement while eight cases (7 males and 1 female, mean age: 41.12 years) in whom preoperative evaluation or on table operative difficulties prevented bilateral fixation were subjected to unilateral fixation [Table 1].

No attempt at preoperative reduction with skeletal traction was done in any of the patients. On table reduction was achieved using articular joint release and on table manipulation.[5] Reduction was considered optimal if the anterior atlanto-axial distance was less than or equal to 3 mm and suboptimal if the anterior atlanto-dental distance was more than 3 mm (4 cases of bilateral fixation and 1 case of unilateral fixation). In these cases, excision of the C1 posterior arch was performed to achieve adequate decompression. In 19 cases, fusion was achieved with a Gallie fusion with iliac crest grafts, while in the remaining 15 cases intra articular fusion was performed. In all 8 cases where fixation was unilateral, fusion was achieved with unilateral intraarticular grafts reinforced with onlay grafts wedged between the rod and bony surface.

Postoperatively, all eight patients treated unilaterally were subjected to flexion–extension X-rays and CT scans to assess reduction and stability as well as for evaluation of

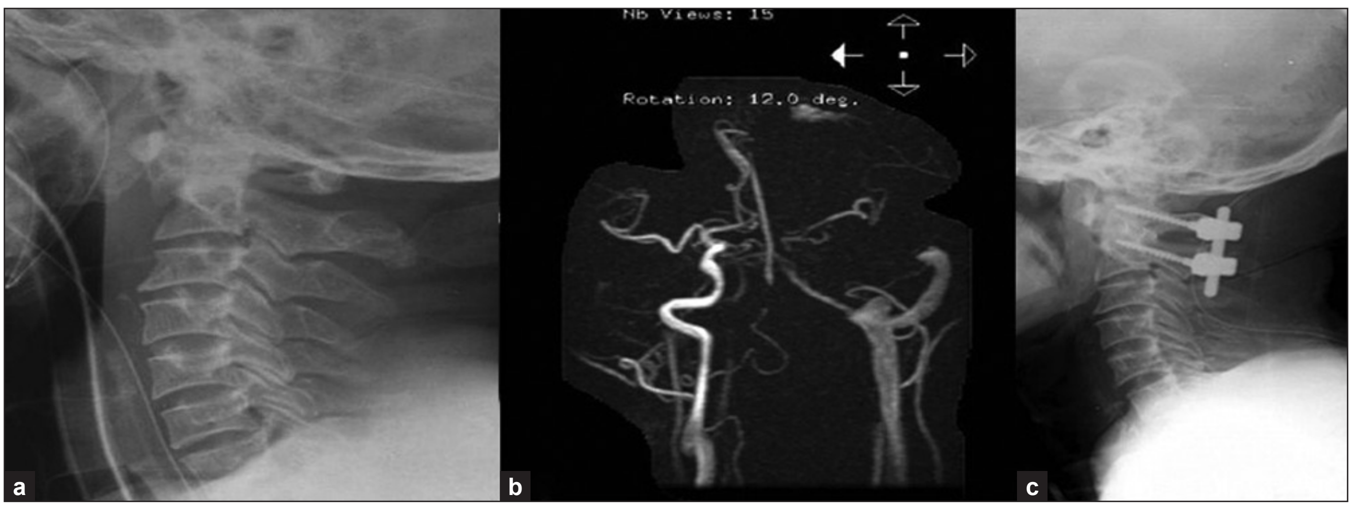

Figure 1: (a) X-ray cervical spine (lateral view) showing atlanto-axial subluxation; (b) MR angiogram showing vertebral artery occlusion on the left side; (c) 2-year follow-up X-ray showing good reduction with unilateral fixation and adequate fusion of C1 and C2

Table 1: Cases which underwent unilateral fixation

Case	Age (years)	Sex	Side of stabilization	Reason for unilateral fixation	ASIA scale (admission)	ASIA scale (6 months)
I	68	M	Left	Associated (R) vertebral artery occlusion with brain stem infarct	E	E
II	12	F	Left	Suspected (L) vertebral artery injury	E	E
III	36	M	Left	(L) Vertebral artery injury due to improper placement of C1 screw	B	D
IV	46	M	Right	Abnormally large (L) C2 foramen transversarium with small pedicle	D	D
V	48	M	Right	Abnormally large (L) C2 foramen transversarium with small pedicle	D	D
VI	31	M	Right	Associated fracture of the (L) C1 lateral mass	C	C
VII	27	M	Right	Fracture of C2 pedicle with breech of medial cortex during screw placement	B	E
VIII	61	M	Right	Large foramen transversarium (L) C1 with inadequate bone to allow screw placement	E	E

ASIA = American Spinal Injury Association screw placement. Dynamic imaging to check for stability was not done as this facility did not exist in our institute. All cases were reevaluated neurologically and ASIA grade was documented. Patients were followed up with X rays and neurological evaluation at 6 weeks, 3 months, 6 months, 1 year and thereafter yearly following surgery [Figures 1c, 2b].

The C1–C2 complex was considered stable if there was no movement between C1 posterior arch and C2 spinous process on lateral flexion–extension films. Fusion was considered to be achieved if bony trabeculae continuity existed between the posterior arches of C1 and C2 in cases with Gallie fusion and in between the inter-articular spaces in cases with the intraarticular graft.[6]

Screw placement was recorded to be good if purchase into the lateral mass or C2 pedicle was achieved without vertical and horizontal breech of cortex. Grade I violation was defined as screw threads coming in contact and minimally perforating the cortex, grade II violation was defined as screw penetrating the cortex and coming in contact with dural space or foramen transversarium, and grade III violation was defined as penetration of the cortex with significant violation of the dural space or foramen transversarium.[7]

All patients were mobilized to sitting position in a Philadelphia collar on the 3rd postoperative day. Patients with no neurological deficit or with minimal neurological deficits who could be ambulated were mobilized after 1 week on a halo brace. The halo brace was continued for a period of 6 weeks. Patients whose neurological deficits prevented early mobilization were managed with a Philadelphia collar for 6 weeks. Similar protocol is also used by us for mobilization for bilateral fixation patients.

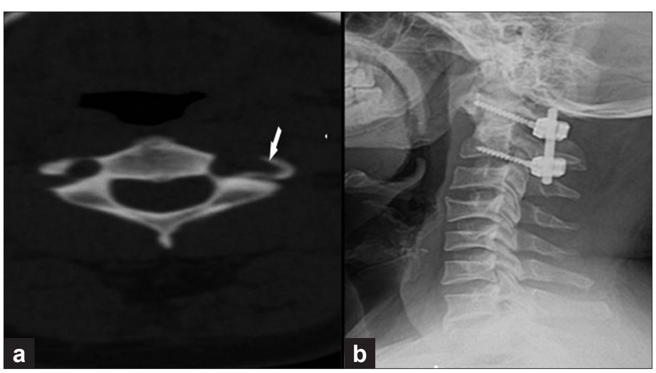

Figure 2: (a) Preoperative CT scan (axial cut) evaluation of patient (case IV) with abnormally large foramen transversarium at C2 with inadequate bone for screw placement; (b) cervical X-ray showing 1-year follow-up with adequate fusion in a well-reduced fixation achieved with unilateral fixation

Results

Postoperatively, neurological and radiological follow-up for a minimum period of 6 months was possible in all the eight cases (range: 6 months to 4 years, mean follow-up = 2 years 1 month) Optimal reduction was achieved in seven cases (87.5%) operated unilaterally while one patient was fixed unilaterally in suboptimal position with more than 3 mm atlanto-dental distance at fixation. Of the 26 patients in whom bilateral fixation was performed, intraoperative reduction was optimal in 22 (84.6%) cases and suboptimal in four cases despite on table reduction maneuver.

All eight cases (100%) operated unilaterally were noted to have adequate stability and fusion on evaluation at 6 months. Of the 26 cases fused bilaterally, 2 were noted to have recurrent subluxation. Of these, one patient underwent reexploration and augmentation of transarticular fixation with intralaminar wires and Gallie fusion. The second patient refused reexploration. One patient treated bilaterally expired postoperatively, and the remaining 23 cases (88.4%) showed good stability and fusion at 6 months.

Evaluation of the screw placement in the cases with unilateral fixation revealed two grade I violation and one grade III violation in the C1 screw and one grade I and one grade II violation in the C2 screw placement. Of the 26 patients treated with bilateral fixation, evaluation of the C1 screws revealed 16 violation with grade I violation (n=11), grade II violation (n=3) and grade III violation (n=2). Evaluation of the C2 screws revealed 7 grade I violation, 5 grade II violation and 1 grade III violation [Table 2].

An improvement of ASIA score was seen in two patients; one patient improved to ASIA grade E from ASIA grade B and another improved to ASIA grade D from ASIA grade B. There was no neurological deterioration in any of the remaining five patients in whom unilateral fixation was performed [Table 1].

There was no obvious injury to the vertebral artery in any of the cases treated by bilateral fixation. Of those treated by unilateral fixation, there were two cases that had severe arterial bleeding following the tapping of the C1 lateral mass screw, which was probably due to vertebral artery injury. In both the cases, hemostasis was achieved using bone wax and there were no neurological sequelae following the surgery.

In the eight cases treated unilaterally, there was no mortality. Case no. I developed a right-sided aspiration pneumonia secondary to lower cranial nerve dysfunction and needed a tracheostomy, ventilatory care and prolonged antibiotic therapy. Of the 26 cases treated with bilateral fixation, one

Table 2: Evaluation of screw placement

Bilateral fixation	Total	Adequate	Grade I violation		Grade II violation		Grade III violation	
	n=26		Med	Lat	Med	Lat	Med	Lat
C1 screws	52	36 (69.2%)	2 (L), 2 (R)	4 (L), 3 (R)	1 (R)	1 (L), 1 (R)	0	1 (L), 1 (R)
C2 screws	52	39 (75%)	1 (L), 1 (R)	3 (L), 2 (R)	1 (L), 1 (R)	1 (L), 2 (R)	0	1 (R)
Unilateral fixation	8 cases							
C1 screws	8	5 (62.5%)	1 (L)	1 (R)	-	-	-	1 (L)
C2 screws	8	6 (75%)	-	1 (L)	-	1 (R)	-	-

Med: Medial; Lat: Lateral; (L): Left; (R): Right

patient with associated polytrauma including thoracic injury expired on the 3rd postoperative day, one patient developed an occipital bed sore, iliac graft site infection was noted in three cases, and deep vein thrombosis and chest infection was seen in two cases each.

Discussion

Of the various treatment options available for posterior stabilization in cases with traumatic atlanto-axial instability, C1–2 transarticular fixation and C1 lateral mass–C2 transpedicular fixation provide a degree of rigidity superior to the other presently available stabilization procedures.[3,4,8,9] The transarticular C1–2 fixation can be performed percutaneously using specialized equipment; alternately, it can be performed as an open procedure in thin individuals in whom reduction can be achieved in military truck position.

Approximately 20% of patients will have anatomical anomalies which precludes the safe placement of transarticular screw on one side.[6,10,11] In patients with vertebral anomalies of the foramen transversarium and a high riding vertebral artery, this procedure is contraindicated.[12]

In cases that have already undergone odontoid excision, the lack of the odontoid as a radiological landmark makes correct angulations of the screw difficult. In addition, it is difficult to assess the amount of reduction achieved. This is particularly important as the risk of vertebral artery injury is higher in cases where reduction is suboptimal; in addition, no further reduction can be achieved once the transarticular screws are passed through the articular point.

C1 lateral mass–C2 transpedicular fixation using a plate / rod screw construct provides equally rigid stability. One significant advantage with this procedure is the ability to achieve optimal and near-optimal reduction in so-called irreducible cases by using the retraction effect of the screw–rod construct. This retraction can further be augmented by using spacers, etc., as proposed by Abumi *et al.*[13,14]

At present, we do not subject patients to prolonged traction or odontoid excision and are able to achieve optimal and near optimal reduction in most cases using a combination of articular joint release, on table manipulation as described by Shetty *et al.*,[5] and the retraction effect provided by the C1 lateral mass–C2 transpedicular screw and rod construct. In a few cases where reduction was felt to be inadequate, we have relied on excision of the posterior C1 arch to provide adequate decompression. The risk of vertebral artery injury is said to be less with C1 lateral mass–C2 transpedicular fixation than with transarticular fixation.[15] However, a significant risk of vertebral injury does exist. Injury during passage of C2 screw is higher in patient with a high riding vertebral artery and in cases where the screw trajectory is lower than normal and also in cases where the reduction is suboptimal as in the cases with transarticular screw fixation.[4,8,12]

The vertebral artery is most prone to injury during placement of the C2 screws. This is because the superior facet of the C2 vertebra is in close proximity to the body itself unlike in other subaxial cervical vertebrae where the superior facet lies closer to the laminae. Additionally, the vertebral artery lies closely related to the inferior aspect of the superior facet of the C2 vertebra unlike in its relation to other cervical vertebrae where it is primarily related to the transverse process.[16] However, the artery does not intrude onto the body or pars intra articularis itself. Hence, an entry point away from the inferior margin of superior facet of C2 and a medially projected trajectory are advisable.[17]

The relationship of the vertebral artery to its groove on the inferior surface of the superior articular facet of C2 is variable.[16,18] The occupancy of the groove by the artery varies from 34 to 100%, hence CT imaging of the groove alone as a guide to the vertebral artery is unreliable and angiographic preoperative evaluation should be done.

The vertebral artery can be injured while exposing the C1 vertebra. Ebrahim *et al.*[19] advocated restriction of dissection to 12 mm from the midline over the posterior surface of C1 lamina and to 8 mm over the superior surface. The relationship of the vertebral artery to its groove on the posterior arch of C1 vertebra is also variable. The average distance of the vertebral artery from the C2 ganglion is about 7.2 mm and its distance from the dural tube is approximately 15 mm, which would provide adequate space for safe screw placement in most cases where preoperative evaluation has ruled out an aberrant vertebral artery course or an excessively large, medially placed foramen transversarium. However, an erroneous lateral entry point and failure to direct the screw medially can lead to vertebral artery injury (case III). Injury while placing the C1 screws may occur as the artery loops over the superior surface of C1 posterior arch. Hence, careful evaluation of the CT angiogram is essential. In cases where the CT shows abnormally large or medially placed C1–C2 foramen transversarium, the risk of safe placement of screw would be unacceptably high.

In the two cases where vertebral artery injury was suspected on table, the preoperative CT angiogram did not reveal any anomaly of the vertebral artery. However, postoperative CT scan revealed a grade III violation in one patient . The risk of the vertebral artery injury due to inaccurately placed screws could be reduced with the use of intraoperative navigation in centers where this facility exists.

Evaluation of the bone on preoperative CT scan should ensure adequate bone to allow safe passage of screws and to rule out associated fractures in the bone which would prevent screw placement. In a significant number of cases, abnormal vertebral artery anatomy or bony anomalies and fractures preclude the placement of bilateral screws. In cases where vertebral artery injury is suspected at the time of surgery or where a pre-existing vertebral artery occlusion or atresia exists, it is best to avoid placement of screws on the other side as the risks of bilateral vertebral injury are extremely high.

In these cases, the surgeon is often forced to perform alternative salvage fixation procedures which provide less than favorable outcome. In cases where osseous / vertebral artery anomalies or injury prevent the placement of C1 lateral mass screws, salvage operations are restricted to wiring procedures which provide inferior stability or occipitocervical fusion, which restricts mobility significantly. In cases where anomalies preclude placement of C2 pedicle screws, alternative methods of fixation include the use of translaminar and C2 lateral mass screws. Of these options, the lateral mass screws provide the least stability and have the poorest pullout strength. Translaminar screws provide good restriction of flexion–extension, but are inferior to transpedicular screws or C1–C2 transarticular screws in restricting lateral bending or torsional movement.[20-22] In addition, studies done in Asian patients, especially adolescents, have shown that 38–50% of lamina are inadequate to safely perform translaminar screw fixation,[23,24] though this has been disputed by other studies.[25]

In these eight cases we found the stability provided by unilateral C1 lateral mass and C2 transpedicular fixation to be as effective as in cases where bilateral fixation was performed and it could be considered an option in patients in whom preoperative evaluation or on-table complication prevents bilateral fixation being performed.

It must be mentioned that the number of cases studied (8) is small, and to draw definitive guidelines for unilateral C1 lateral mass and C2 transpedicular fixation, a larger multicentric study would be required. In addition, all these cases were of post-traumatic atlanto-axial dislocation. The role for unilateral fixation in non-traumatic atlanto-axial dislocation in whom anomalies which preclude bilateral fixation tend to be higher has not been evaluated by us.

Conclusion

Unilateral C1 lateral mass–C2 transpedicular fixation could be considered a viable option in cases of traumatic atlanto-axial instability where vascular and osseous anomalies contradict a bilateral fixation.

References

1. Goel A, Laheri V. Plate and screw fixation for atlanto-axial subluxation. Acta Neurochir (Wien). 1994;129:47-53.
2. Goel A, Desai KI, Muzumdar DP. Atlantoaxial fixation using plate and screw method: A report of 160 treated patients. Neurosurgery 2002;51:1351-7.
3. Harms J, Meicher RP. Posterior C1-C2 fusion with poly axial screw and rod fixation. Spine (Phila Pa 1976)2001:26;2467-71.
4. Farey ID, Nadkarai S, Smith N. Modified gallie technique vs trans articular screw fixation in C1-C2 fusion. Clin Orthop Relat Res 1999;359:126-38.
5. Shetty A, Kini A, Prabhu J. Odontoid fractures – a retrospective analysis of 53 cases. Indian J Orthop 2009;43:352-60.
6. Madawi AA, Casey AT, Solanki GA, Tuite G, Veres R, Crockard AH. Radiological and anatomical evaluation of the atlanto axial trans articular screw fixation technique. J Neurosurgery 1997:86:961-8.
7. Miller RM, Ebrahim NA, Xu R, Yeasting RA. Anatomic consideration of transpedicular screw placement in the cervical spine – an analysis of two approaches. Spine (Phila pa 1976) 1996;21:2317-22.
8. Goel A, Gupta S. Vertebral artery injury with trans articular screw. J Neurosurgery 1999:90;376-7.
9. Goel A, Kulkarni AG, Sharma P. Reduction of fixed atlanto axial dislocation in 24 cases technical note. J Neurosur Spine 2005;2:505-9.
10. Paramore CG, Dickman CA, Sontaq VK. The anatomic suitability of C1-2 complex for transarticular screw fixation. J. Neurosurg 1996:85:221-4.
11. Cought NH, Lanryssen C. Vertebral artery injury in C1-2 trans articualr screw fixation results of a survey of AAMS/CNS sector on disorders of spine anal peripheral nerves. J Neurosurg 1998:86:634-40.

12. Resnick DK, Lapsiwala S, Trost GR. Anantomic suitability of C1-C2 complex for pedicle screw fixation. Spine (Phila Pa 1976) 2002;27:1494-8.
13. Abumi K, Itoh H, Taneichi H, Kaneda K. Transpedicular screw fixation for tramatic lesion of middle and lower cervical spine description of techniques and priliminary report. J Spinal Disord 1994;7:19-28.
14. Mummareni PV, Haid RW. Atlanto axial fixation: overview of all techniques. Neurol India 2005;53:408-15.
15. Hott JS, Lynch JJ, Chamberlain RH, Sonntag VK, Crawford NR. Biomechanical comparision of C1-2 posterior fixation techniques. J Neurourg Spine 2005;2:175-81.
16. Cacciola F, Phalke U, Goel A. Vertebral artery in relationship to C1-C2 vertebrae: An anatomical study. Neurol India 2004;52:178-84.
17. Gupta S, Goel A. Quantitative anatomy of the lateral masses of the atlas and axis vertebrae. Neurology India. 2000;48:120-5.
18. Paramore G, Dickman CA, Sonntag VK. The anatomical suitability of the C1–2 complex for transarticular screw fixation. J Neurosurg 1996;85:221-4.
19. Ebraheim NA, Xu R, Ahmad M, Heck B. The quantitative anatomy of the vertebral artery groove of the atlas and its relation to the posterior atlantoaxial approach. Spine (Phila Pa 1976) 1998;23:320-3.
20. Gorek J, Acaroglu E, Berven S, Yousef A, Puttlitz CM. Constructs incorporating intralaminar C2 screws provide rigid stability for atlantoaxial fixation. Spine (Phila Pa 1976) 2005;30:1513-8.
21. 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.
22. Dmitriev AE, Lehman RA Jr, Helgeson MD, Sasso RC, Kuhns C, Riew DK. Acute and long-term stability of atlantoaxial fixation methods: A biomechanical comparison of pars, pedicle, and intralaminar fixation in an intact and odontoid fracture model. Spine (Phila Pa 1976) 2009;34:365-70.
23. Wang MY. C2 crossing laminar screws: cadaveric morphometric analysis. Neurosurgery 2006;59:ONS-84-8.
24. Chern JJ, Chamoun RB, Whitehead WE, Curry DJ, Luerssen TG, Jea A. Computed tomography morphometric analysis for axial and subaxial translaminar screw placement in the pediatric cervical spine: Clinical article. J Neurosurg Pediatr 2009; 3:121-8.
25. Dorward IG, Wright NM. Seven years of experience with C2 translaminar screw fixation: Clinical series and review of the literature. Neurosurgery 2011;68:1491-9.

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