10.5005/jp-journals-10039-1087

REFLECTION

Atlantoaxial Fixation—Anterior or Posterior Approach: Critical Review

Vinu V Gopal

ABSTRACT

Atlantoaxial facet joints have been proposed as the center of mobility and also center for instability of the atlantoaxial region. Because of the high mobility of the atlantoaxial (C1-C2) motion segment, fusion rates at this level have been substantially lower than those at the subaxial spine. The success of craniovertebral junction surgery depends on adequate reduction, decompression of craniovertebral (CV) junction followed by immediate fixation of atlantoaxial joint followed by bone grafting with compression for solid bony fusion. Current options for atlantoaxial fixation include anterior or posterior approaches. The biomechanical stability and fusion rates of posterior fixation surgery had been proved beyond doubt. The main disadvantages of posterior surgery involve disruption of posterior ligamentous complex which are essential for stability. C2 root denervation also aggravates the paraspinal muscle atrophy leading to instability So now advances in spinal surgery made neurosurgeons to think of an anterior technique which can establish fusion and fixation at the same time avoiding the above mentioned complications. The advantages are that there are no anatomical constraints like posterior approach in reaching C1-C2 joint. The risk of neuralgia, bleeding from venous plexus is avoided along with practically no damage to vertebral artery. Newer techniques of anterior transarticular screw and bilateral atlantoaxial fixation and fusion through unilateral right sided retropharyngeal approach had been described in literature. Anterior approach still needs further randomized controlled trials for level 1 evidence, Further research on along with biomechanical feasibility using anatomical *ex vivo* and *in vivo* constructs need to be done to further validate the appropriateness and safety of anterior approach for C1-C2 fixation and fusion.

Keywords: Anterior, Atlantoaxial, Posterior.

How to cite this article: Gopal VV. Atlantoaxial Fixation—Anterior or Posterior Approach: Critical Review. J Spinal Surg 2016;3(2):51-54.

Source of support: Nil

Conflict of interest: None

INTRODUCTION

The atlantoaxial joint complex, bearing the weight of the head, generates most of the rotation of the head and neck. Atlantoaxial facet joints have been proposed as the center of mobility and also the center for instability of the atlantoaxial region.[1,2] It is one of the most mobile joints of the body. The atlantoaxial joints of two sides along with the occipitoaxial joints form the rostral two limbs of the Y-shaped configuration of the human spinal support pillar.[1,2] Because of the high mobility of the atlantoaxial (C1-C2) motion segment, fusion rates at this level have been substantially lower than those at the subaxial spine. The concept that the seat of atlantoaxial instability rests in the facetal malalignment and arthrodesis with stable bony fusion along with fixation as the treatment of atlantoaxial instability has revolutionized the treatment of atlantoaxial instability.[1,2]

The aim of treatment of atlantoaxial instability is to achieve a solid fusion between C1 and C2, virtually eliminating any motion between them. The success of craniovertebral (CV) junction surgery depends on adequate reduction and decompression of CV junction followed by immediate fixation of atlantoaxial joint followed by bone grafting with compression for solid bony fusion. This will relieve the neck pain and avoid the risk of further neurological deficit. Over the past years, advances have been made on techniques of fixation of unstable atlantoaxial joint.

Current options for atlantoaxial fixation include anterior and posterior approaches.

POSTERIOR APPROACHES

Atlantoaxial fusion was first described by Mixter and Osgood in 1910 using braided sutures. The use of posterior cervical wiring of the lamina of C1 and C2 dates to 1939 in a report by Gallie.[3] Unfortunately, failure rates using this technique are unpredictable, ranging from 2% to as high as 80%.[3-7] The Gallie technique, although rather simple to perform, does not provide sufficient stability of the fixation site.[3,8] Brooks and Jenkins further offered an alternative method of posterior C1 to C2 laminar wiring in 1978.[8] Brooks posterior fixation yields a more stable repair compared to the Gallie technique. Another technique by Halifax using clamps with a claw-type construct has resulted in a 20% failure rate.[4,9] All these posterior wiring techniques had fallen into disrepute due to high failure rates and lack of stability.

In 1986, Magerl proposed a technique for C1 to C2 fusion using transarticular screws (TASs). The screws

Associate Professor

Department of Neurosurgery, Government Medical College Kottayam, Kerala, India

Corresponding Author: Vinu V Gopal, Associate Professor Department of Neurosurgery, Government Medical College Kottayam, Kerala, India, Phone: +919656769340, e-mail: vinoogopa@gmail.com

were inserted through a posterior approach combined with a Brooks type of fixation. Several series have reported 95 to 100% fusion rates with his method.[4,5,8,10] Central screw positioning provides better control of stability than the previous techniques, which rely only on peripheral fixation. Posterior transarticular screws (PTSs) using the Magerl technique offer several advantages. They do not require immobilization in a Halo vest postoperatively. Biomechanical studies have shown this construct to be superior to Halifax, Gallie, and Brooks fixation.[9] Excellent results have also been obtained with the use of Magerl screws without posterior wiring.[10] The use of TASs avoids complications associated with the passage of sublaminar wires. This is especially important in situations where pannus has resulted in compromise of the spinal canal. It allows for adequate decompression when necessary and makes fusion possible even in the presence of deficient posterior arch of the atlas.

Despite its success, there are complications associated with the Magerl technique.[5,8] It is a technically demanding procedure and poses risks of injury to the spinal cord and vertebral artery.[11,12] It has been associated with a complication rate as high as 10% in the form of superficial infections and occipital nerve injury.[8,10] A narrow pars intraarticularis or a high-riding foramen transversarium places the vertebral artery at an unacceptably high risk of injury. Another disadvantage is that it requires perfect alignment of joint for proper fixation. Image guidance can reduce the complications.[11]

Posterior transarticular screw fixation with or without posterior laminar wiring and bone grafting gained wide acceptance. It showed high fusion rates up to 100%.[7,8] Biomechanically, it is superior to previous wire-based techniques.[8] Complications, such as misplacement of the screws (15%), injury to the vertebral arteries in about 2 to 5% cases,[7] injury to the hypoglossus nerve or even the spinal cord, screw breakages,[8] and revision surgeries in up to 17%[3,5] cases demanded further research on the feasibility of PTS. About 20% of axis vertebra are not suitable for bilateral PTS due to thin diameter of the pars interarticularis C2.[9]

The technique of atlantoaxial fixation and fusion using C1 lateral mass screw and C2 pedicle screw and plates was pioneered by Prof. Goel et al.[2] The C1 lateral mass screw with C2 pedicle screw construct was initially created with plates and screws by Goel et al[2] in the 1980s and then subsequently popularized by Harms and Melcher in 2001.[13] The authors achieved 100% fusion with minimal rate of complications. The authors advocated bilateral sacrifice of C2 ganglia in order to prepare the atlantoaxial facet joints for arthrodesis.

The C1 to C2 joint distraction, jamming the joint with bone graft with C1 lateral mass and C2 pedicle screw fixation, was described by Atul Goel and Vinod Laheri for atlantoaxial instability.[1,2,14] This technique of atlantoaxial fixation involves blocking or "jamming" of movements of the atlantoaxial joint by forcible impaction of spiked titanium metal spacers and bone grafts within the distracted atlantoaxial facet joints. The new technique was based on the concept that the seat of atlantoaxial instability rests in the facetal malalignment. Goel et al also introduced the concept that atlantoaxial dislocation is never or only extremely rarely fixed or irreducible.[1,2,14] The concept stated that the dislocation could be manually reducible.[1,2]

Even though fusion rate was more in the Magerl technique,[7] the risk of vertebral artery injury was also more. The concept of opening up the joint, curettage, and grafting with spacers has made fusion and fixation almost similar to a TAS technique. Biomechanical testing has shown that C1 lateral mass screw with C2 pars screw construct allows more motion than does a C1 to C2 TAS. The main advantage is that anatomic alignment of the C1 to C2 complex is not necessary prior to instrumentation. In addition, this technique can be utilized where there is an aberrant vertebral artery. Goel et al[14] had reported that sacrifice of the C2 ganglion provides a wide exposure and does not lead to any significant neurological symptom.

The concept of decompressive bone surgery, both from the anterior transoral route and from the posterior route, had fallen into disrepute. Reducible subluxations by preoperative skeletal traction was managed previously by posterior fixation and in case of irreducible subluxations transoral odontoid excision followed by posterior fixation. Transoral odontoid excision is associated with significant morbidity since posterior fixation is often done in the suboptimal position. This can result in significant restriction of neck movement. The excision of the odontoid process reduces the ability to visualize the odontoid on fluoroscopy, which makes accurate passage of transarticular C1 to C2 screws difficult. The risk of vertebral artery injury is also higher in cases where transarticular screws are placed in inadequately reduced subluxations following transoral odontoid excision. The length of C1 lateral mass screw is difficult to assess, and anterior transgression of screws can result in carotid artery injury. Transoral decompression still may be required in cases where exuberant callus prevented reduction by posterior manipulation.

A new technique of distraction, compression, and extension reduction of basilar invagination and atlanto-axial dislocation was proposed by Sarat Chandra, from AIIMS, New Delhi.[15]

The main disadvantages of posterior surgery involve disruption of posterior ligamentous complex, which are essential for stability. C2 root denervation also aggravates the paraspinal muscle atrophy leading to instability. This also increases morbidity in terms of neuralgic pain. Posterior approaches to C1 to C2 fusion may not be suitable in the setting of revision posterior surgery, anomalous vascular anatomy, hypoplastic bone morphology, or deficit.

So now advances in spinal surgery made neurosurgeons to think of an anterior technique that can establish fusion and fixation at the same time avoiding the abovementioned complications. The advantages are that there are no anatomical constraints like the posterior approach in reaching C1 to C2 joint. The risk of neuralgia, bleeding from venous plexus, is avoided along with practically no damage to vertebral artery.

ANTERIOR APPROACHES

Whitesides[16] described anterior C1 to C2 joint arthrodesis using separate exposure of C1 to C2 joint in 1971.

Transoral instrumentation for unstable CV junction was described by Goel et al in 1994.[2] The technique was performed with the use of a "T-plate" (Depuy Spine, Raynham, MA). The horizontal portion of the plate is placed over the C1 lateral masses anteriorly. The vertical portion of the plate rests on the body of C2 inferior to the base of the dens. Two vertebral body screws are then placed superior and parallel to the C2 to 3 disk space. This procedure required an extensive posterior pharyngeal C-shaped flap. The transoral approach has not gained popularity since it was associated with excessively high infection rates of up to 50%, since the spine is contaminated with oropharyngeal bacteria.

In light of shortcomings of PTS and posterior screw and rod fixation for atlantoaxial instability, certain centers have tried anterior transarticular screw (ATS) fixation. The ATS fixation of the atlantoaxial joint was first described by Lesoin et al[17] in 1987. Apostolides et al[18] reported a triple anterior screw fixation technique.

Anterior transarticular screw fixation was done for chronically displaced non-united type II odontoid fracture by Vaccaro et al.[19] An anterior retropharyngeal approach was used to perform an anterior C1 to C2 fusion.

Reindl et al[20] have described a large series of ATS technique of fusion of C1 to C2 joint.

Minimally invasive ATS fixation and microendoscopic bone graft for atlantoaxial instability was described by Jian Wang.[21] ElSaghir et al[22] experimented with posterior C1 to C2 fusion with percutaneous transarticular fixation. This reduced the exposure and the surgical trauma to the cervical segments, but had a high rate of fusion (98%). They found that the percutaneous technique reduced the operating time and blood loss even though the learning curve was steep. Some physical characteristics, such as a short neck, considerable cervical kyphosis, or concomitant thoracic kyphosis may interfere with the fixation. This technique is not appropriate for a patient with an irreducible atlantoaxial dislocation. Potential complications of the percutaneous technique included accidental puncture injury to the carotid artery. Another potential complication is injury to the esophagus. Careful monitoring with image intensification may help to prevent these complications.

Sen et al[23] reported a biomechanical study on atlantoaxial fusion using ATS fixation, which supported clinical case experience of ATS introduced by Reindl et al.[20] The strength of the construct, the ease of the surgical approach, and the decreased risk associated with screw insertion make ATS fixation comparable to the Magerl screw technique.

Kim[24] showed that ATS and PTS are comparable. Kim et al in their cadaver-based study demonstrated that biomechanical results for ATS were comparable to those of PTS and lateral mass–pedicle/pars screw. It was recommended as a safe and effective method. As dominant movement of C1 to C2 articulations is rotation; the authors judged ATS as a sufficient technique.

Koller et al[25] reported a morphometric study on the anatomical feasibility of ATS. Their modifications of previous ATS with a transcorporal pathway of the screws inside the vertebral body of the C2 vertebra increased the screw purchase and enhanced the stability of the ATS.[17,19,20,26]

Anatomic considerations of ATS fixation for atlantoaxial instability was also extensively studied by Lu J et al.[26]

Dr Sushil Patkar came forward with a large series of 62 cases of bilateral atlantoaxial fixation and fusion through unilateral right-sided retropharyngeal approach. This new concept provides the opportunity of opening up the C1 to C2 joint followed by fixation by C1 lateral mass and C2 body screw plate or using multiple transarticular screws. Bilateral ATS was done in 39/62 cases and bilateral C1 to C2 fixation with C1 lateral mass and C2 body screw plate was done in 23/62 cases. The advantage is that odontoid decompression can be done if needed along with fixation technique. The advantage of this procedure is that it can avoid problems of muscle denervation, cervical plexus injury, and C2 ganglion injury. Patkar et al demonstrated that the joint reduces in supine position and extension spontaneously, making fixation easy. The feasibility in chronic atlantoaxial instability needs further clinical data. Results showed that there was 100% fixation with 0% mortality and 0% vertebral artery injury. The technical difficulty of the approach, steep learning curve along with the possibility of carotid artery, marginal mandibular nerve, hypoglossal nerve, vagal nerve and recurrent laryngeal nerve injury need to be validated with the help of large sample prospective case studies. Moreover, data regarding technical difficulty of distraction and compression with plates, problems with screw loosening implant failure, risk of overdistraction, and long-term follow-up regarding fusion need to be addressed. Recently the author has published a technical note of C1 to C2 joint distraction with titanium spacer, which will augment fusion. Further follow-up clinical data and level 1 evidence are needed for precise information.

Biomechanical feasibility with polyaxial screws with rodes will be a future area of research so that distraction and compression just like mentioned for the posterior approach can be applied for anterior procedures also.

To conclude, the anterior approach still needs further randomized controlled trials for level 1 evidence. Further research along with biomechanical feasibility using anatomical *ex vivo* and *in vivo* constructs needs to be done to further validate the appropriateness and safety of the anterior approach for C1 to C2 fixation and fusion.

REFERENCES

1. Goel A. Craniovertebral anomalies: role for craniovertebral realignment. Neurol India 2004 Dec;52(4):427-429.
2. Goel A, Laheri V. Plate and screw fixation for atlantoaxial subluxation. Acta Neurochir (Wien) 1994;129(1-2):47-53.
3. Clark CR, Goetz DD, Menezes AH. Arthrodesis of the cervical spine in rheumatoid arthritis. J Bone Joint Surg Am 1989 Mar;71(3):381-392.
4. Coyne TJ, Fehlings MG, Wallace MC, Bernstein M, Tator CH. C1-C2 posterior cervical fusion: Long-term evaluation of results and efficacy. Neurosurgery 1995 Oct;37(4):688-692; discussion 692-693.
5. Farey ID, Nadkarni S, Smith N. Modified Gallie technique versus transarticular screw fixation in C1-C2 fusion. Clin Orthop Relat Res 1999 Feb;(359):126-135.
6. Fielding JW, Hawkins RJ, Ratzan SA. Spine fusion for atlantoaxial instability. J Bone Joint Surg Am 1976 Apr;58(3):400-407.
7. Fried LC. Atlantoaxial fracture-dislocations. Failure of posterior C.1 to C.2 fusion. J Bone Joint Surg Br 1973 Aug;55(3):490-496.
8. Grob D, Jeanneret B, Aebi M, Markwalder TM. Atlanto-axial fusion with transarticular screw fixation. J Bone Joint Surg Br 1991 Nov;73(6):972-976.
9. Statham P, O'Sullivan M, Russell T. The Halifax Interlaminar Clamp for posterior cervical fusion: Initial experience in the United Kingdom. Neurosurgery 1993 Mar;32(3):396-398; discussion 398-399.
10. Stillerman CB, Wilson JA. Atlanto-axial stabilization with posterior transarticular screw fixation: Technical description and report of 22 cases. Neurosurgery 1993 Jun;32(6):948-954; discussion 954-955.
11. Yamazaki M, Okawa A, Furuya T, Sakuma T, Takahashi H, Kato K, Fujiyoshi T, Mannoji C, Takahashi K, Koda M. 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 Oct 15;37(22):E1389-E1397.
12. Wright NM, Lauryssen C. Vertebral artery injury in C1-2 transarticular screw fixation: Results of a survey of the AANS/CNS section on disorders of the spine and peripheral nerves. American Association of Neurological Surgeons/Congress of Neurological Surgeons. J Neurosurg 1998 Apr;88(4):634-640.
13. Harms J, Melcher RP. Posterior C1-C2 fusion with polyaxial screw and rod fixation. Spine (Phila Pa 1976) 2001 Nov 15;26(22):2467-2471.
14. Goel A. Atlantoaxial joint jamming as a treatment for atlantoaxial dislocation: a preliminary report. Technical note. J Neurosurg Spine 2007 Jul;7(1):90-94.
15. 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 Jun;72(6):1040-1053; discussion 1053.
16. Whitesides TE Jr, Kelly RP. Lateral approach to the upper cervical spine for anterior fusion. South Med J 1966 Aug;59(8):879-883.
17. Lesoin F, Autricque A, Franz K, Villette L, Jomin M. Transcervical approach and screw fixation for upper cervical spine pathology. Surg Neurol 1987 May;27(5):459-465.
18. Apostolides PJ, Theodore N, Karahalios DG, Sonntag VK. Triple anterior screw fixation of an acute combination atlas-axis fracture. Case report. J Neurosurg 1997 Jul;87(1):96-99.
19. Vaccaro AR, Lehman AP, Ahlgren BD, Garfin SR. Anterior C1-C2 screw fixation and bony fusion through an anterior retropharyngeal approach. Orthopedics 1999 Dec;22(12):1165-1170.
20. Reindl R, Sen M, Aebi M. Anterior instrumentation for traumatic C1-C2 instability. Spine (Phila Pa 1976) 2003 Sep 1;28(17):E329-E333.
21. Wang J, Zhou Y, Zhang Z, Li C, Zheng W, Zhang Y. Minimally invasive anterior transarticular screw fixation and microendoscopic bone graft for atlantoaxial instability. Eur Spine J 2012 Aug;21(8):1568-1574.
22. ElSaghir H, Bohm H. Anderson type II fracture of the odontoid process: results of anterior screw fixation. J Spinal Disord 2000;13(6):527-530.
23. Sen MK, Steffen T, Beckman L, Tsantrizos A, Reindl R, Aebi M. Atlantoaxial fusion using anterior transarticular screw fixation of C1-C2: Technical innovation and biomechanical study. Eur Spine J 2005 Jun;14(5):512-518.
24. Kim SM, Lim TJ, Paterno J, Hwang TJ, Lee KW, Balabhadra RS, Kim DH. Biomechanical comparison of anterior and posterior stabilization methods in atlantoaxial instability. J Neurosurg 2004 Mar;100(Suppl 3 Spine):277-283.
25. Koller H, Kammermeier V, Ulbricht D, Assuncao A, Karolus S, van den Berg B, Holz U. Anterior retropharyngeal fixation C1-2 for stabilization of atlantoaxial instabilities: Study of feasibility, technical description and preliminary results. Eur Spine J 2006 Sep;15(9):1326-1338.
26. Lu J, Ebraheim NA, Yang H, Heck BE, Yeasting RA. Anatomic considerations of anterior transarticular screw fixation for atlantoaxial instability. Spine (Phila Pa 1976) 1998 Jun 1;23(11):1229-1235; discussion 1236.