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A Review of Techniques for Atlanto-Axial Fixation

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Abstract: Many techniques have been developed for the fixation of atlanto-axial junction in cases with significant instability. Currently, the techniques most commonly used for atlanto-axial fusion are posterior wiring techniques, posterior clamps, C1-C2 transarticular screws, C1 lateral mass screw with C2 pedicle screw fixation and rod and clamp fixation. This article aims to describe each of these methods in terms of their principle, advantages and disadvantages over each other.

Introduction

Atlantoaxial instability is a potentially life-threatening condition. Many methods have been developed for the fixation of unstable atlanto-axial joint due to trauma, infection, tumour, rheumatoid arthritis etc. Each of these methods has its own advantages and disadvantages. Never advances in these techniques have aimed to reduce the complications and at achieving improved fixation at the same time.

The first attempt at atlanto-axial fixation was done by Mixter and Osgood[1] in 1910. They achieved it by wiring spinous processes of C1 and C2 with heavy silk thread. In 1939, Gallie[2] advocated wiring laminae of C1 and C2 to achieve fusion. An alternative method of posterior laminar wiring was described in 1979 by Brooks and Jenkins[3].The inter-laminar clamps were introduced in the year 1980[4]. In 1991, Dickman and Sonntag[5] modified the technique of posterior cervical wiring.

Goel et al[6,7] developed the technique of C1 lateral mass screw with C2 pedicle screw supplemented with plate in 1980. This technique and its modifications are widely used in recent years.C1-C2 transarticular screw is the other most recent method for atlanto - axial fixation.

A transoral method is also described but is not preferred as much as the other methods. The most common indication for posterior C1-C2 stabilization is trauma. This includes Type II and Type III odontoid fractures. Most Type II odontoid fractures can be treated with immobilization or anterior odontoid screw fixation[8]. However, there are several types of this fracture pattern which are not amendable to these treatment methods. These include Type II odontoid fractures associated with fractures of the atlantoaxial joint, Type II odontoid fractures with oblique fractures in the frontal plane , Type II odontoid fractures with significant displacement which may not heal in immobilization (and are too displaced to place an odontoid screw), Type II odontoid fractures with an associated Jefferson fracture, and Type II odontoid fractures with a ruptured transverse ligament.Other indications are patients with large thoracic kyphosis, elderly patients with osteoporotic bone, non union of odontoid process after previous screw fixation and in patients who have failed immobilization.Type III odontoid fractures with atlantoaxial joint fracture combinations and Type III odontoid fractures with associated Jefferson fracture are also unstable and are often best treated with a posterior C1 and C2 stabilization procedure[8].

Congenital malformations of C2 (i.e. os odontoideum and odontoid agenesis), degenerative diseases, inflammatory diseases, tumors, and infections can also result in instability of the atlantoaxial complex. Specifically, rheumatoid arthritis can often result in atlantoaxial subluxation or superior migration of the odontoid into the foramen magnum (with compression of the brainstem and upper cervical spinal cord) necessitating a posterior occipitocervical decompression and fusion (with or without transoral resection of the odontoid).

Post-surgical instability relating to C1 and C2 laminectomies with or without removal of adjoining facets is another indication for posterior C1-C2 fixation. When the atlanto-dental exceeds 5 mm in non-rheumatoid patients and when it exceeds 8 mm in rheumatoid patients, there is instability of the C1-C2 complex and posterior C1/2 fixation is indicated[9,10,11,12].

Atlanto-axial rotatory dislocations are also an indication for C1 and C2 fixation. This problem can be treated via a posterior reduction and fusion approach or via an anterior transoral reduction and C1-C2 fixation.

Posterior C1/C2 Fusion With Inter Laminar Clamps

The interlaminar clamp technique was first described in 1984 and it was called the Halifax technique. It was followed later by the Apofix clamp technique[13].

In this method, the spine is approached posteriorly and clamps are used by placing hooks on the superior surface of the C1 lamina and hooks on the inferior surface of the C2 lamina. The hooks are tightened after placing a bone graft between the two lamina. The limitation of this method is that can be used only if the C1-C2 lamina are intact. It cannot be used in presence of significant degenerative changes or osteoporosis of the posterior elements of C1 and C2 . Also, this technique cannot be used in cases of Jefferson's fracture or a Hangman's fracture.

Biomechanically, posterior laminar clamps have excellent stability with flexion and extension maneuvers. However, in rotational motion the clamps are not as effective as other techniques involving posterior screws or wires[14].Clamp fixation allows translational deformation along the sagittal plane, although it provides good anteroposterior stability. Thus, hardware failure and nonunion are common complications of the interlaminar clamps technique[15].Therefore, it is mandatory to immobilise the spine in a rigid collar or halo after fixation with clamps. If the posterior clamp construct loosens before bony fusion is achieved, then further surgical intervention will be required. Other complications of clam fixation are clamp slippage, pseudoarthrosis and late fractures of C1 posterior ring[15].

Hanimoglu et al[16] reported the use of C1 C2 claw system which is a modification of the interlaminar clamps system. In this technique, the C1 and C2 hooks are connected to each other with a transverse connector which significantly increases stability of the construct to rotational forces .

Posterior Wiring Techniques

The posterior wiring techniques also require an intact posterior arch of C1 and C2. They cannot be utilized if there are fractures of the C1 or C2 posterior elements (including Hangman's or Jefferson's fracture), or if posterior decompression of the C1-C2 complex is required, or if there is significant osteoporosis. The posterior wiring techniques require sublaminar passage of a cable and have the potential for injury to the dura or spinal cord during this maneuver. The double braided titanium wires are preferable for these techniques as they are flexible and have lesser chance of injury to dura or spinal cord during sublaminar passage .

Gallie Fusion

Gallie[2] first described posterior C1-C2 sublaminar wire fixation in 1939 in which an iliac crest bone graft is notched inferiorly and placed over the C2 spinous process and leaned against the posterior arch of C1. A sublaminar wire is passed beneath the arch of C1 and then wrapped around the spinous process of C2.This wire holds the graft in place. Passage of the sublaminar wire under the lamina of C2 is avoided and hence the risk of injury to the dura and spinal cord is decreased.

The Gallie fusion offers good stability in flexion and extension. However, like interlaminar clamping it offers very poor stabilization during rotational maneuvers. Consequently, the rate of nonunion with the Gallie fusion has been reported to be as high as 25%[17].

Brooks- Jenkins Fusion

In 1978, Brooks and Jenkins[3] proposed fusion with two separate iliac crest bone grafts for each side. The grafts are bevelled so as to fit in the C1 C2 interlaminar space on each side of the midline and are held in place with two separate sublaminar wires on each side passing around the arches of C1 and C2.

The Brooks- Jenkins technique provides greater stability in rotation[18] than that in the Gallie's fusion. Also, it provides similar stability in flexion and extension as seen with Gallie's technique[19]. As a result of these superior biomechanical advantages, the union rates after Brooks jenkins fusion is as high as 93 %[3]. The overall fusion rate is even greater with halo immobilisation following surgery.

However, as this technique involves passage of bilateral sublaminar wires beneath both C1 and C2, the risk of inury to dura or spinal cord is greater than in Gallie's fusion, since it involves passage of single sublaminar wire under C1 posterior arch.

Sonntag technique

In order to achieve the rotational stability as in Brooks Jenkins technique and at the same time prevent the disastrous complications of bilateral sublaminar wiring, Dickmann et al[5] put forth a modification of the Gallie's technique known as Sonntag technique. In this, a sublaminar wire is passed from inferioir to superior under the posterior C1 arch. After decorticating the superior aspect of C2 spinous process and the inferior arch of C1, an iliac crest bone graft is placed between the spinous process of C2 and wedged carefullly under the C1 posterior arch.The wire is then turned over the bone graft , tightened and crimped.

As per Sonntag, patients treated with this technique are to be immobilised with halo for three months after surgery, followed by use of rigid collar for two momths.With this immobilisation protocol, a fusion rate of 97 % with least complications has been reported by Sonntag.

All wiring techniques require intact atlas posterior arch and axis lamina. These wiring techniques also risk injury to spinal cord. As these techniques are not sufficiently stable by themselves, they have to be supplemented with a particular period of post- operative immobilsation which may hamper quality of life of the patient[2,5]. Hence, nowadays never methods of fixation are preferred over these techniques.

Atlantoaxial Transarticular Screw Technique

Transarticular screw was first described by Jeanneret and Magerl[19] in 1992. In this , two transarticular screws are inserted bilaterally through atlantoaxial joints.The entry point for the screw is 3 mm lateral and 2 mm cephalad from the medial C2-C3 joint line. After confirming entry , the screw is directed toward the anterior arch of the atlas in sagital plane and 0 to 10 degrees medially in the horizontal plane.This technique can be combined with a Gallie fusion if the posterior arch of atlas is intact. It can be followed with a C1 hook to enhance fixation. Some authors suggest that isolated transarticular screw without Gallie fusion or other additional fixation avoids risk of neurological damage.

The advantages of transarticular screws are its high fusion rate, excellent stability and no requirement of postoperative halo vest immobilisation[20,21]. Hence , it offers better quality of life to patients. Further, this technique can be used successfully in patients without intact C1 and C2 posterior elements. Due to all these reasons, transarticular screw fixation is regarded by many as the gold standard method of posterior atlantoaxial fusion[22,23].Transarticular screws have excellent stability during rotational motion.

The transarticular screw cannot be used if the atlantoaxial joint is not reduced prior to screw insertion.It is contraindicated in patients with with thoracic kyphosis due to difficult placement of screws in these patients[19]. The technique is asssociated with long and steep learning curve inspite of being a very effective method of C1-C2 fusion.

The potential complications of transarticular screws are injury to the vertebral artery, the spinal cord and hypoglossal nerve(one case of bilateral hypoglossal nerve palsy was reported by Jeanneret and Magerl in their original study[19]). Hence, preoperative CT angiography of bilateral vertebral arteries is essential before the procedure to confirm the anatomic relations of vertebral arteries and to identify anatomic variations of the vertebral arteries or foramen transversarium, destuction of bone at site of screw insertion or an abnormally small pars.

As per meta analysis studies, Atlantoaxial transarticular screw technique provides a fusion rate of 94.6 %. The incidence of neurologic injury is 0.2 % whereas incidence of vertebral artery injury is found to be 3.1 %. Also, the incidence of clinically significant malpositioned screws is 7.1 %[24].

Screw-Plate System

Goel's screw -plate system

Goel and Laheri[25] first devised the use of screws and plate for effective atlantoaxial fixation in 1994. It was in this original study that the popular C1 lateral mass screw technique was first describes.The technique requires sarcrificing the C2 ganglion in order to prepare the facet joints for arthrodesis. Two screws are inserted in C1 lateral mass on both sides and two screws into the C2 pars on both sides. The C1 and C2 screws of each side are connected with a plate to give rigid fixation which is stable to flexion - extension as well as rotational forces.Goel et al reported 100 % fusion rate with their technique[25].The excision of C2 ganglion may lead to postoperative loss of scalp sensation in some patients[26].The screw insertion is technically demanding and requires precise knowledge of the anatomical relations of vertebral arteries.

In 2008, Kelly[27] reported a novel screw plate system in which C1 posterior locking plate is combined with C2 translaminar screws.This technique has less chances of surgical risk.

Screw-Rod System

Harms and Melcher[28] in 2001 first introduced the concept of Screw - rod system as a modification of the screw-plate technique.Since this technique provides excellent fixation with fever complications than the previous methods, it is widely used currently for atlantoaxial fixation.Since then , many modifications of the original technique have been developed, but the basic construct in all these systems is the use of C1 screws, C2 screws and connecting rods between C1 and C2 screws.

C1 lateral mass screw technique

Initially proposed by Goel and Laheri[25], C1 lateral mass technique was modified in 2001 by Harms and Melcher[28].The entry point is the centre of junction of the C1 posterior arch and midpoint of of the posteroinferior part of C1 lateral mass. The screw is then directed in a slightly convergent path in anteroposterior direction and parallel to plane of posterior arch of C1 in sagittal direction[25].The advantage of Harm's technique is that it preserves the C2 ganglion.However, the surgeon has to deal with the massive bleeding from venous plexus and prevent injury to C2 nerve while inserting screw into C1 lateral mass[29,30,31,32,33].

C1 pedicle screw technique

This technique, also called C1 via posterior arch lateral mass screw fixation or C1 posterior arch screw fixation, is a modifiation of C1 lateral mass screw in which the screw is inserted via the posterior arch.It was first reported by Resnick and Benzel in 2002[34,35,36].This technique has been show to be superior to the C1 lateral mass technique. It guarantees stronger pullout strength, avoids the problems of excessive bleeding from venous plexus as well as irritation of the C2 nerve root[35,37,38,39].Therefore, this technique has become the most widely used C1 screw technique[39,40,41,42].The limitation of this technique is the 4 mm height of the C1 pedicle[43,44] (defined as the C1 vertebral artery groove). However, it has been shown that if there is a medullary canal in the C1 pedicle, a 3.5-mm diameter pedicle screw can be safely placed into the atlas, even if the pedicle height is less than 4 mm[45].

C1 notching technique

In this modification of the C1 pedicle screw technique, a high entry point is taken at the junction of the midpoint of the C1 lateral mass and the inferior aspect of the posterior arch[46] . Following this, a notch is made at the entry point, which allows screw placement away from C2 ganglion.Hence, the notching technique prevents post operative C2 dysfunction[47].

C2 pars screw technique

The entry point for this technique is 3 mm rostral and 3 mm lateral to the inferomedial aspect of the inferior articular surface. The screw is directed parallel to the C2 pars.The potential complication with this technique is injury to vertebral artery[48].

C2 pedicle screw technique

It was first described by Goel and Laheri and later modified by Harms and Melcher.The entry point is midway between the superior and inferior articular processes. The screw is directed 15–30 medial and 20–25cephalad. It has been proven that C2 pedicle screw has twice the pullout strength of C2 pars screw[49,50].

C2 translaminar screw technique

In this technique,which was described by Wright[51] in 2004, screws are inserted into the lamina of C2 in a crossed trajectory and then connected with rods to C1 lateral mass screws, C1 pedicle screws, or even the C1 locking plate . The translaminar screw is superior to the pars screw in both pullout strength and insertional torque[52]. It is technically simple and eliminates the risk of vertebral artery injury. Thus, the C2 translaminar screw technique is a salvage option in failed C2 pedicle insertion and in cases of high-riding anomalous vertebral arteries[53].

Anterior C1-C2 Fixation

This technique was first desribed by Goel in 1994[51]. Through a transoral approach, a large C shaped posterior pharyngeal flap is raised and a T shaped plate is fixed such that the horizontal portion of the plate is placed over the C1 lateral masses anteriorly and the vertical portion of the plate rests on the body of C2 inferior to the base of the dens.Screws are placed through the horizontal part of the plate into the anterior C1 lateral mass to achieve a bicortical purchase .Through the vertical part of the plate vertebral body screws are inserted superior and parallel to the C2-3 disc space.

Conclusion

A variety of techniques have been developed for atlanto-axial fusion. The posterior wiring techniques like Gallie's Brook's etc are technically easier but have less rigid fixation and require postoperative immobilization in halo immobilizer to achieve satisfactory fusion. These techniques are also associated with high risk of complications like injury to dura and spinal cord. The C1-C2 trans-articular screw gives much effective method to achieve fusion and has advantages of less risk of injury to dura, coed and vertebral artery. The screw and rod or screw and clamp techniques result in less rigid fixation than the transarticular screw but higher rates of union than posterior wiring techniques used alone.Howeve, these techniques can be very difficult to perform in case of abnormality of posterior elements. Similarly,the posterior wiring techniques cannot be done in case of deficient posterior elements of atlas and/or axis. In our practice, we consider the C1-C2 transarticular screw as the gold standard for atlanto- axial fixation. Other method of choice include Goel's technique combined with posterior wiring technique of Sonntag.

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