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C1-C2 Goel-Harms Fixation, History of the Technique, Free Hand Technique Description

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Abstract

Objective: Short historical description of the evolution of C1-C2 fixation methods, anatomical tricks and free hand fixation technique description. Method: five patients were operated on using free hand technique, X-rays were only used after the positioning of the patient in the ventral position with Mayfield and at the end before locking the lateral rods. Results: no complications documented, in all the cases CT scans revealed good screw position. Conclusion: Using these landmarks and with a good preoperative planning, it is easy for experienced surgeons to perform the technique in a free hand manner, that avoids X-ray exposure for the whole team and the patient. This technique is not recommended for common use, especially for surgeons with few experiences in this field.

Keywords

C1 Lateral Mass, C2 Pedicle, Arthrodesis

1. Introduction

C1-C2 Goel-Harms fixation is a very efficient technique for surgical fixation of instability caused by inflammatory, tumoral, traumatic pathologies. It allows for a safe and reliable fixation with temporary or permanent effects, depending on the goals. This technique was first described by Goel using lateral mass screws linked with a radial plate in 1994 in his article on 30 patients with 19 months of follow up [1], later popularized by Harms using poliaxial screws and rods in 1997 on a series of 37 patients [2]. This technique usually needs the use of intra-operatory fluoroscopy and the use of navigation techniques that are not popular because of the high mobility of the cervical segments. This article describes the Goel-Harms technique in a hands-free manner, that avoids X-ray exposure for the whole team and the patient.

2. Historical Background

Atlantoaxial instability can be caused by trauma, infection, tumors, arthritis, congenital anomalies, iatrogenic, etc. The most common instability is at the C1-C2 complex and requires internal fixation not only for immediate stability but also to provide long-term immobility so as to attain a solid fusion. Wiring techniques such as the Gallie, Brooks and modified Brooks are known to provide less than optimal immobilization of the C1-C2 complex not only for axial rotation but also for lateral bending and flexion-extension [3] [4]. Newer internal fixation techniques have been developed, which include the trans articular C1-C2 fixation combined with posterior wiring [5] [6], the C1 lateral mass screw combined with C2 pedicle screws [1] [2], the C1-C2 trans articular screws plus a C1 claw and the C2 pedicle screws plus a C1 claw [4].

Surgical stabilization of the atlantoaxial complex has undergone a progressive evolution towards greater biomechanical stability. Sublaminar fixation techniques initially used had increased risk of spinal cord injury due to the inevitable need to pass the wires through the medullary canal [7] [8] [9] [10]. The bone fusion rate was around of 60% - 100%, while requiring the use of rigid orthosis in order to increase their efficacy [7] [8] [9] [10] [11]. Techniques with laminar hooks decreased the risk of spinal cord injury but were associated with considerable failure of the construction [7].

The Magerl, Wright and Goel-Harms techniques had the most impact on the modern concepts of upper cervical arthrodesis. In the present, the most used technique is Goel-Harms, as it has less vascular complications, is more robust and provides the best conditions for bone fusion.

In 1979, Magerl and Seemann first introduced the transarticular screw fixation of C1-C2, which they later published in 1987 [6]. This technique introduced the advantage of not requiring the integrity of the posterior elements of the spine and may be associated with effective decompression if spinal cord compression is present [6] [12] [13]. The technique significantly decreases mobility of the C1-C2 segment, ensuring an excellent stability and increasing the fusion rate between 87% and 100% [2] [7] [12] [14].

The principle of the method consists in the placement of two screws from the dorsal approach through atlantoaxial joints in the sagittal plane. The main indication for the Magerl's C1-C2 fixation is acute or chronic instability and painful osteoarthritis of atlantoaxial joints. This method is only contraindicated where massive destruction of the lateral mass of atlas and in an anomalous course of the vertebral artery is present.

C1 lateral mass and C2 pedicular fixation was first described by Atul Goel in 1994, and this concept of arthrodesis had a big impact on the treatment of upper cervical pathology. Atul Goel described 30 cases of atlanto-axial dislocation, over the period of 3 years and 9 months. He used a modified plate and screw method of fixation of the lateral masses of the atlas and axis. The technical aspects and merits of the method are as follows: a 100% bone union rate was achieved, with no morbidity, mortality, or instrument failure or fatigue. The average follow-up period is of 19 months. The technique described provided immediate rigid segmental internal fixation, permitting early mobilization with minimal external support. Onlay and interfacetal bone grafts subsequently produced bony fusion. Direct application of screws to the atlas and axis, thus utilizing the firm purchase in their thick and large cortico-cancellous lateral mass, provided a biomechanically strong fixation of the region [1]. They used screws and radio-ulna plates that can be molded and cut into various shapes and sizes. The authors described cutting the second cervical root ganglion which lies over the posterior aspect of the atlanto-axial joint in most of cases and was elevated out of the way in 2 patients.

With the introduction of interarticular fixation with screws to the lateral masses of C1 and to the pedicles of C2 united with a plate (Goel technique and Laheri), a new concept of atlantoaxial stabilization has emerged, maintaining excellent rates of bone fusion and lower risk of vertebral artery injury [1] [13].

Later in 2001, Harms and Melcher popularized the same technique with use of poliaxial srews, described as a novel technique of atlantoaxial stabilization using individual fixation of the C1 lateral mass and the C2 pedicle, with minipolyaxial screws and rods and the initial results of this technique on 37 patients were published [13]. In 1994, much before 2001, Goel had already published his series of 30 patients operated with 19 months of follow up [1].

Wright implemented translaminar C2 screws. According to Wright, anatomic variability of the foramen transversarium in the body of the axis can preclude safe transarticular C1-C2 screw placement in up to 20% of patients. Although more recent methods of C2 screw fixation with pedicle screws allow for safer fixation in a higher number of patients, there remains a significant risk to the vertebral artery with the C2 pedicle screw placement. The author described a novel technique of C2 rigid screw fixation with crossing, bilateral C2 laminar screws, which does not place the vertebral artery at risk during C2 fixation. This technique has been successfully used by the author in cases of craniocervical and atlantoaxial fixation as well as for incorporation of C2 into subaxial fixations. The author's initial experience was in treating 10 patients with crossing, bilateral C2 laminar screws for indications of trauma, neoplasm, pseudarthrosis, and degenerative pathologies [15].

The Wright technique of translaminar screws in C2 achieved high rates of bone consolidation (90% - 100%), further reducing the risk of injury to vertebral arteries [7] [15] [16]. Both techniques can be performed without an anatomical reduction of the complex C1-C2, enabling stabilization in patients with fixed joint dislocation, a condition that contraindicates transarticular fixation techniques [2] [7] [15] [16] [17] [18]. In patients with aberrant artery vertebral pathways (anatomical variants that occur in up to 20% of cases), this technique is safer than the transarticular screw and the risk is minimized with the use of translaminar screws in the fixation of C2 [2] [7] [15] [16] [17] [18]. Several studies have been conducted in order to understand the biomechanics of the C1-C2 segment after fixation surgery [7]. In the studies, it was not possible to determine a clear difference in stability and mobility of the cervical spine between the Magerl technique and the technique by Goel-Harms [7].

3. Anatomical Considerations

The atlantoaxial joint is a highly mobile joint with four synovial interfaces: between the posterior surface of the C1 anterior arch and the odontoid process, the odontoid process and the transverse ligament, and the C1–C2 facet joints bilaterally. The atlantoaxial joint allows a large degree of axial rotation, but has a limited amount of flexion/extension, and very little amount of lateral bending. Badhiwala *et al.* [19] found that the range of motion at C1-C2 for axial rotation of either side, flexion, extension, and lateral bending to be 38.9˚, 11.5˚, 10.9˚, and 6.7˚, respectively.

Lateral mass fusion is ideal and is sometimes the only available option in situations where the posterior arch of atlas is either congenitally absent, hypoplastic [20] [21], cartilaginous or broken following trauma or sublaminar wire tightening. Large extradural veins frequently caused troublesome bleeding [1]. The bleeding in this region during the cutting of the second root ganglia is from the venous plexus around the second root and the radicular artery. This bleeding can be minimized to 100 - 300 ml, using small tricks:

1) Good knowledge of anatomy;

2) Procleave position of the surgical table;

3) Careful coagulation with bipolar cauterization of upper and lower parts of the second rood ganglia after blunt and subperiosteal dissection from C1 and C2 pedicles. This technique shrinks the venous plexus and the bleeding is minimal;

4) Subsequent cutting of ganglia with monopolar coagulation (small potency, usually at 10);

5) Hemostatic foam is very efficient at stopping venous bleeding. Sometimes it is useful to put foam with cotton under pressure on the bleeding side and proceed with root cutting of the opposite side, while the bleeding stops;

6) Coagulation of radicular artery by bipolar cauterization, usually situated inside the root.

4. Free Hand Technique Descriptions

The patients are positioned in prone position with the head fixed in Mayfield. We use it to fixate the head in a slight traction and flexion position to amplify the space between C1 and C2 arches. The classic midline approach is performed, exposing C1 and C2 as there is no need to expose C0 and C3 to spear muscle insertions. The C2 nerve groove is easily recognized, always surrounded by venous plexus. The groove from C1 pedicle and C2 isthmus is dissected first. After that, the upper and lower part of groove is coagulated with a bipolar pincet with continuous irrigation. The venous plexus shrinks and then the groove is cut with monopolar slight coagulation at 10. We cut the groove on the line parallel to midline from the middle part of the C1 pedicle. It is important not to cut too medial because of the risk of LCR leak, or too lateral due to abundant venous bleeding and risk of VA injury. The hemostatic foam is very efficient to stop venous bleeding. Sometimes it is useful to put foam with cotton under pressure on the bleeding side and proceed with the cutting of the opposite side root while the bleeding stops. The cauterization of the radicular artery using bipolar pincet is needed, usually situated inside of the root.

After cutting the groove, the lateral mass of C1 and C1-C2 articulation are exposed. The articulation is drilled and packed with bone from spinous process of C2 or a small cage can be inserted. The C1 lateral mass screw insertion point is in the middle of the junction of the C1 pedicle to the mass, facilitated by palpation with a small dissector on the lateral and medial border of the mass. The screw direction is slightly upward about 20˚ and slightly convergent about 10˚. The length is previously studied on CT scan slices, but also confirmed during the surgery. We create the screw pathway using the manual drill tool and when we feel a resistance it means that it touches the anterior cortical bone of C1. It is safe to stop there and measure the pathway depth with the palpator and add 1cm, and this is the length of the shaft of the screw. As the shaft length is 1cm, when the thread disappears into the bone of lateral mass, the screw touches the anterior cortical bone of C1. We continue with half a rotation and the screw becomes bicortical and the risk of CA or hypoglossal nerve is nil.

C2 isthmus is easily palpated until the beginning of the pedicle, the entry point is in the middle of the isthmus and the screw direction is the same as C1-C2 articulation, about 30˚ upwards and 20˚ convergent. In case of pedicular fractures, we use also shaft screws due to the compressive effect of the screw. To enhance the interarticular C1-C2 fusion after drilling the interarticular space and packing with bone graft from the spinous process of C2 vertebra, we put a screw from the anterior cervical plate system with 12 - 14 mm length into the articular space, as the manufactured C1-C2 cage is not always available. The screw that goes into the interarticular space serves as an interarticular cage and has more impact on the bone graft.

As an alternative, the C2 isthmic screw can be inserted in a free hand manner. Usually a 16 - 18 mm long screw is placed with a trajectory similar to the C1-C2 transarticular screw. The entry point for the C2 pars screw is about 3 mm cranial and 3 mm lateral from the medial border of the C2-C3 facet joint. The screw should be parallel to the C2 pars in the sagittal plane, and parallel to the medial border of the pars in the axial plane, easily seen during the surgery. Another alternative technique is intralaminar C2 screw, inserted with no need of X-Rays.

Using these landmarks and with a good preoperative planning, it is easy for the experienced surgeons to perform this technique in free hand manner, avoiding X-ray exposure for the whole team. Cutting the C2 root is a safe procedure associated with occipital hypesthesia, very well tolerated by patients. After one year of follow up, the hypoesthesia diminishes and the patients do not mention it. They only acknowledge of it if asked. The advantages of C2 root cutting are better recognition of landmarks, less or no bad positioned screws, less bleeding during the surgery and no radicular irritation pain after the surgery.

Key points for free hand technique:

1) Good preoperative planning using CT scan slices, studying all the parameters of the C1 lateral mass and C2 pedicles, good vertebral artery anatomy;

2) Positioning in prone position with slight traction and flexion;

3) Cutting the C2 root groove;

4) Recognizing the lateral and medial border of C1 lateral mass;

5) Making the pathway of C1 lateral mass screw until anterior cortical bone of C1, respecting the directions upward of about 20˚ and slightly convergent of about 10˚;

6) Inserting the screw until the shaft screw thread disappears into the lateral mass and continue with about half a rotation;

7) Drilling of the interarticular C1-C2 space to remove the cartilage and recognize the direction of the articular space with subsequent packing of the bone graft and 12-14mm length screw (optional);

8) Palpating the isthmus and the beginning of the C2 pedicle and inserting the screw respecting the directions of about 30˚ upwards and of 20˚ convergent;

9) Important: this technique is not recommended for common use, especially for the surgeons with few experiences in this field.

Next are some examples of free hand C1-C2 arthrodesis.

First case is a 76 years old woman with a type II C2 fracture with pseudoarthrosis, treated with C1-C2 Goel-Harms arthrodesis in free hand manner (**Figure 1**, **Figure 2**).

Second case is an 88 years old male with the same diagnosis, type II C2 fracture (**Figure 3**, **Figure 4**).

I started to practice the free hand technique after being performed more than a hundred surgeries in my service and, at this moment, 5 cases were done using the free hand technique, no complications registered, with CT scans confirming good screw positioning.

Last case is a free hand fixation with a C1-C2 interarticular cage. As industrial cages are not always available, I usually use a screw for anterior cervical plating (12 × 3.5 mm) (**Figure 5**).

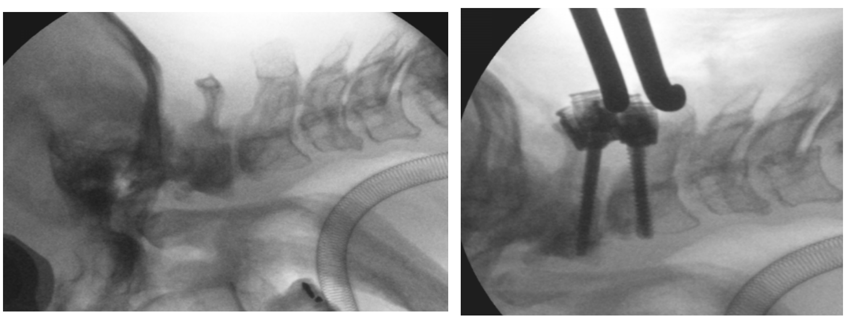

Figure 1. X-ray performed before and after fixation.

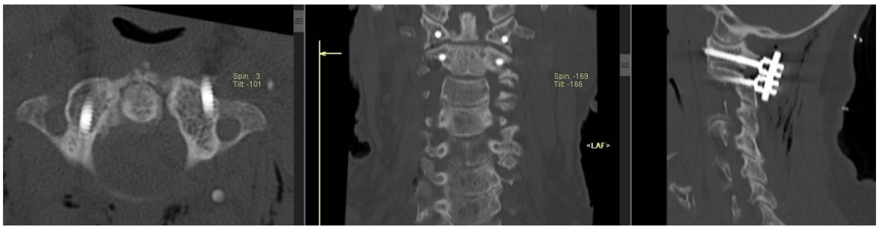

Figure 2. CT scan after surgery also confirms good positioning of screws.

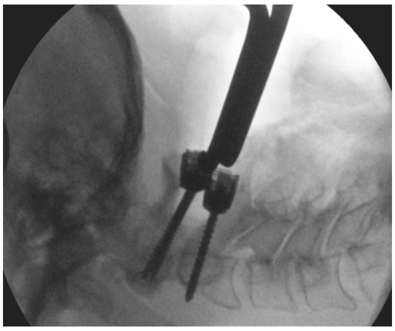

Figure 3. X-Ray confirms good position of the screws before putting rods and wound closure.

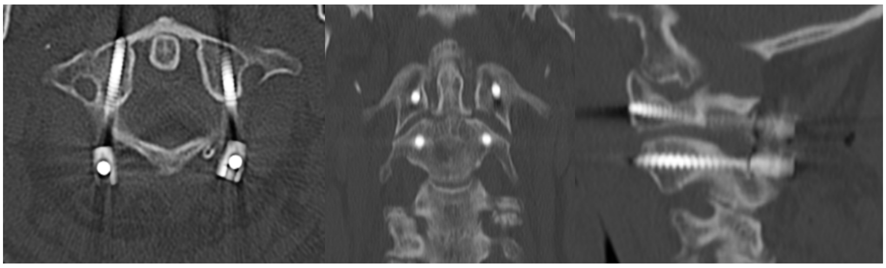

Figure 4. CT scan after surgery also confirms good positioning of screws.

Figure 5. CT scan: Goel-Harms free hand fixation with interarticular C1-C2 screws.

5. Discussion

When discussing the instable fractures of C2 there is no question about surgical fixation. When C1-C2 fixation is necessary, the most important point to be considered is the specific anatomic patterns of this region, described in many articles in detail. The Goel-Harms technique has always been the most popular, with a very small nonunion rate. This technique was described in a good amount of literature with X-Ray references that always works. The freehand technique is an alternative way to fix this kind of fracture that requires good preoperative planning and the analysis of the anatomy from CT scan. Overall, this is a method that I believe should be implemented in the skillset of many neurosurgeon/orthopedic surgeons when attempting a C1-C2 fusion.

6. Conclusion

Using these landmarks and with a good preoperative planning, it is easy for the experienced surgeons to perform the technique in a free hand manner, avoiding X-ray exposure for the whole team. This technique is not recommended for common use, especially more for the surgeons with little experience in this field.

Disclosure

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Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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