Treatment of Dens Fractures with Posterior Transarticular Fixation

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Introduction

Treatment of unstable dens fractures with posterior transarticular C1-C2 arthrodesis provides a biomechanically stable construct, even when poor bone quality is present, and a low rate of complications even in elderly patients; however, when this method of fixation is performed, cervical spine rotation is substantially reduced as compared with that associated with alternative fixation techniques¹⁻³.

The patient is placed in a prone position, and the head is fixed in a Mayfield clamp. Exact positioning of the patient and use of biplanar image intensification are mandatory for this procedure. A small posterior incision is performed from just below the external occipital protuberance to C3, and dissection is carried out down to the posterior arch of C1 and C2. The guiding Kirschner wires and the screws are passed through two separate stab incisions at the level of the spinous process of T1 or T2. With this technique^{4,5}, it is possible to achieve the appropriate entrance angle at the entry point at C2. After the exposure of C1 and C2 is completed, a wire loop is passed around the posterior arch of C1. The Kirschner wires are passed through the caudal incisions to the entry points of the screws at the lamina of C2. The guiding wires are aimed above the lower rim of the anterior arch of C1. The guiding wires are then replaced by screws. A rectangular corticocancellous graft is harvested from the ilium (about 3 cm) and shaped into an H configuration on the basis of the area that would allow it to fit between the spinous process of C2 and the posterior ring of C1. Finally, one wire end of the loop around C1 is guided underneath the spinous process of C2 and the free ends are tightened over the graft, providing a Gallie-type fusion⁶.

The procedure is performed with the following steps.

Step 1: Positioning

Exact positioning of the patient and use of image intensifiers are mandatory to obtain appropriate anteroposterior and lateral views of C1 and C2 (Figs. 1-C, 1-D, and 4-F and Videos 1, 2, and 3).

- Apply the Mayfield clamp with the patient in a supine position.
- Place the patient in a prone position on rolls or a positioning frame with the arms parallel to the body.
- Fix the clamp to the holder with the head and neck in a neutral position and perform slight distraction.
- Check the position of C1 and C2 on the lateral fluoroscopic view to exclude gross displacement.
- Check the head and neck position with the occipitocervical junction centered within the metallic bars that fix the Mayfield clamp to the table to obtain a free anteroposterior view of C1 and C2 and make sure that C1 through C7 are aligned without lateral deviation (Videos 2 and 3).
- Support the patient's feet and fix the thigh with a strap to the table.
- Tilt the table so that the neck is in a horizontal position.
- "Fine-tune" C1-C2 alignment to achieve a good reposition of C1 and C2 and avoid posterior displacement. Flexion of the head opens the space between C1 and the occiput and the corridor between the upper thorax and the entry at the T1-T2 level. Avoid overdistract. Check the corridor of the instruments from the stab incisions at the T1-T2 level to the entry point at C2 with a rod on the lateral view and make sure that the screws can be placed in the correct angle (Video 3).
- On the anteroposterior view, the pedicles of C2 should be identified, the dens should be centered between the lateral masses of the atlas,

and the C1-C2 joint should be visible bilaterally. Only the ventilation tube should be passed down the larynx to keep the anteroposterior view clear. On the lateral view, there should be no double contour of the C2 pedicle and the so-called Harrison ring⁷ (Video 3) should be visible and congruent.

- Make sure that the posterior iliac crest on one side is easy to access for harvesting of a bone graft. This usually causes no difficulties in the prone position.
- Do not start the operation if positioning of the patient, the position of C1-C2, or fluoroscopic views are not appropriate.

Step 2: Surgical Approach

Use the modified technique of Magerl and Seemann^{4,5}, as it allows a less extensive approach to C1 and C2, and the drill can enter through two incisions at the level of T1 (Fig. 1-F and Video 4).

- Perform a longitudinal midline incision from just below the external occipital protuberance down to the spinous process of C3.
- Incise the fascia.
- Identify the spinous process of C2.
- Perform a subperiosteal dissection of the muscles along the laminae of C2 from medial to lateral to reach the junction of the lamina with the articular mass.
- Identify the posterior arch of C1.
- Perform a subperiosteal dissection of the muscle from medial to lateral and expose approximately 2 to 3 cm of each side of the posterior arch of C1.
- Pass a cerclage wire (0.8 to 1.2 mm) around the posterior arch of C1 in the midline, forming a loop.
- Identify the entry point at C2, which is usually located in the axilla at the junction of the lamina and the articular mass. The anatomical configurations of the two sides usually are not identical.
- Check the entry point. The medial border of the C2 pedicle can be palpated with a small nerve hook.

Step 3: Insertion of Screws

Use smooth 2.0-mm Kirschner wires to prepare the canal for the screws, and subsequently replace them with 3.0-mm self-tapping screws (Videos 5, 6, and 7).

- Determine the length of the screws that will be needed on the preoperative CT scan; the screws usually will need to be 38 to 42 mm.

- Make two small skin incisions (1 cm) approximately 1.5 to 2 cm lateral to the midline at the T1-T2 level (Fig. 1-F).
- Introduce a Kirschner wire and slide it posteriorly to the rib cage to the entry point at C2.
- Check the direction on the anteroposterior and lateral fluoroscopic views. On the anteroposterior view, the tip of the wire should be in the center of the C2 pedicle and aim toward the middle of the C1-C2 joint. On the lateral view, the tip of the wire should aim toward the middle of the anterior arch of C1, penetrating the superior articular surface of C2 in the posterior third and just touching the so-called Harrison ring⁷ (Video 3).
- If necessary, a small-fragment wire guide can be introduced through the incision to achieve a steeper cranial angle of the wire. In addition, C2 can be flexed by applying a small-fragment reduction clamp onto the spinous process of C2 (Video 5).
- Advance the Kirschner wire under image-intensifier control in both planes up to the anterior border of the anterior arch of C1. One should “feel” the wire penetrating the two articular surfaces of the C1-C2 joint (Video 6).
- Repeat the procedure on the opposite side.
- If the Kirschner wires engage correctly in the lateral mass of C1, rotation between C1 and C2 is no longer possible. Before that, you can assess the rotation by surveying the spinous process of C2 and the posterior part of C1 and by intraoperative imaging. When you are drilling the Kirschner wire on the one side you have to apply a counterforce on the other side (Video 6) to prevent rotation to the side that is currently drilled.
- Replace the Kirschner wires with screws. Remove the Kirschner wire, introduce a long screwdriver through the same entry (the stab incision at the T1 level), introduce the screw separately through the incision over C2, engage the screw onto the screwdriver, and place the screw tip onto the entry point at C2 (Video 7). Use a 2-mm, and not thinner, Kirschner wire because it is easier to guide the stiffer wire to the desired end point in C1. Additionally, the thicker wire does not change its direction when it passes the cortices at the C1-C2 joint. The wire does not enter the joint surfaces in a 90° angle but in a steep inclined angle (differing from patient to patient) and thus tends to drift anteriorly.
- After the 2-mm Kirschner wire has been removed, we do not replace it with a thinner wire because we do not have a Kirschner wire that would be long enough for percutaneous in-

sertion of the screws. Additionally, a thinner Kirschner wire could easily break just after the screw enters the lamina of C2 as a result of bending of the wire in patients with severe upper thoracic kyphosis and at the level of the C1-C2 joint because of eccentric positioning of the wire in the joint space between C1 and C2 due to motions at the joint level during the insertion of the screws. The tip of the self-tapping screw is sharp enough to cut the wire if the screw is not inserted in the exact same angle as the wire.

- Check the angle of the screw on the anteroposterior and lateral fluoroscopic views.
- Advance the screw until the tip penetrates the anterior cortex of the arch of C1.

Step 4: Gallie Fusion

Perform a modified Gallie fusion⁶, in addition to the transarticular screw fixation, to increase stability and osseous fusion between C1 and C2 (Video 8).

- Measure the distance between the laminae of C2 and the posterior arch of C1.
- Harvest a rectangular corticocancellous graft of the measured dimensions and cancellous bone from the posterior iliac crest.
- Shape the graft to fit in between the spinous process of C2 and the posterior ring of C1.
- Use a high-speed burr to open the posterior cortex of the spinous process of C2 and the posterior ring of C1 at the contact area of the graft.
- Apply the graft.
- Guide one of the free ends of the loop around the spinous process of C2, posterior to the graft.
- Tighten the free ends over the graft, so that the graft is fixed.
- Add cancellous bone between the graft and the laminae of C1 and C2.

Step 5: Wound Closure

Perform meticulous closure of the wound to avoid wound-healing complications.

- Thoroughly irrigate the wound.
- Insertion of a suction drain is optional; we usually do not use one.
- Close the fascia with single stitches, which should be tight.
- Close the subcutaneous layer by apposing the edges firmly.
- Close the skin with single stitches.

Results

In our original study⁸, we treated twenty-five patients with posterior transarticular fixation. All twenty-five patients were seventy-five years of age or older and had an unstable fracture of the dens. All showed union; even those who presented with broken screws in the follow-up period showed union. One patient had to undergo revision because of a malpositioned screw; he then had uneventful healing to union, and he did not have any neurologic impairments. The treated group of patients (seventy-five years of age or older) did not report that the fusion of C1 and C2 and the resulting lack of rotation at C1 and C2 impaired their functional abilities. Since younger patients have higher functional demands and a lower rate of complications after direct anterior fixation, they should be treated with that function-preserving technique when surgery is indicated.

What to Watch For

Indications

- An age of seventy-five years or older.
- Unstable fracture of the dens (Figs. 2 and 3) in patients seventy-five years of age or older.
- Unstable Anderson and D'Alonzo type-III fracture of the dens.
- Nonunion of the dens.

Contraindications

- High-riding vertebral artery in the lateral mass of C2.
- Severe thoracic kyphosis.
- Atypical fracture with extension into the posterior third of the lateral mass of C2 bilaterally.
- Severe osteolytic changes in the lateral mass of C2 and/or C1.

Pitfalls & Challenges

- Avoid overdistraction of the C1-C2 joints for reduction of the fracture.
- Check the preoperative computed tomography (CT) scan for the relationship between the anterior arch of C1 and the anterior border of the lateral mass of C1 in order to position the screws correctly in the lateral mass of C1. We often find a sagittal distance of 5 to 10 mm between the anterior cortex of the lateral mass and the anterior cortex of the anterior arch of C1 in elderly patients. In such a case, one should aim the screw tip toward the superior rim of the anterior arch of C1; otherwise the screws are inserted in too flat a position and do not gain sufficient purchase in the lateral mass of C1.

- In the majority of patients, the left and right sides of the posterior arch, including the inferior facet of C2, differ substantially with regard to their anatomic contour (Fig. 1-B).
- There may be two main problems interfering with correct screw placement in elderly patients: excessive thoracic kyphosis, which prevents adequate inclination of the screw during placement, and a high-riding vertebral artery.
 - » *Thoracic kyphosis:* Even though the head is fixed in a Mayfield clamp and the atlas is rigidly fixed to the head, C2 can be manipulated during the operation by applying a clamp onto the spinous process of C2. During insertion of the Kirschner wire, one can flex the axis body by manipulating the clamp, allowing a steeper placement of the Kirschner wire. Just before the Kirschner wire exits into the C1-C2 joint, the axis position is corrected by extension, so that the correct anatomical position of C1-C2 is achieved and the Kirschner wire enters the lateral mass of C1 in the middle third of the lower joint surface (Fig. 4). If necessary, we use drill guides for the Kirschner wires, which can be placed directly onto the entry point of the posterior lamina of C2. With these guides, the angulation of the Kirschner wire can be manipulated, and steeper cranial inclination is possible.
 - » *High-riding vertebral artery:* This problem is often seen, especially in elderly patients. However, usually there is still an osseous bridge medial to the vertebral artery, which allows placement of a screw. Therefore, we use 2.7 or 3.0-mm screws. Screws with a greater diameter occupy too much space. Additionally, in patients with a high-riding vertebral artery, we place the screws extremely close to the posterior edge of the cranial joint surface of the axis and even accept perforation of the lamina of C2 before entering the lateral mass of C1.
- With the described techniques, we were able to place two screws in all of the traumatic cases described in our paper⁸. However, we have since treated two patients with non-traumatic C1-C2 instability for whom different techniques had to be applied because of anatomic reasons.

Clinical Comments

- Although transarticular fixation of C1-C2 can be performed from an anterior or posterior approach, we regard the posterior technique as the standard for elderly patients. The posterior technique is associated with a very low incidence of complications and a high likelihood of successful fusion. For patients who cannot tolerate the prone position (very rarely, patients show severe circulatory instability in the prone position that cannot be handled by the anesthesiologists), the anterior technique may be an option. Do you think that an anterior approach to transarticular fusion is of equal safety and efficacy?
- We have sometimes seen dens nonunion following transarticular fixation; however, fractures managed with a Gallie procedure have united. Do you think the nonunion of the dens has any clinical relevance in this situation?
- Harvesting of the corticocancellous graft for the Gallie fusion is a safe procedure that is routinely performed. Although we have not noted any donor site complications, patients routinely have postoperative pain at the donor site and there is a risk of wound infection or other complications. Do you think that biomaterials might replace the autologous graft in the near future?

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Figures

Fig. 1

A seventy-six-year-old patient who sustained an unstable fracture (Anderson and D'Alonzo type II⁹) and was treated with transarticular fixation. **Fig. 1-A** Initial CT scan in the sagittal plane shows an unstable fracture. **Fig. 1-B** Initial CT scan in the axial plane shows the difference between the left and right lateral masses (arrows). **Fig. 1-C** Preoperative positioning of the patient and of the two c-arms. **Fig. 1-D** Preoperative control of correct angulation and the entry point of the Kirschner wires. **Fig. 1-E** Percutaneous insertion of the Kirschner wires and screws. **Fig. 1-F** Skin incision. **Fig. 1-G** Intraoperative fluoroscopic sagittal view for control of the position of the screws and Gallie fusion. **Fig. 1-H** Postoperative CT scan in the sagittal plane showing the Gallie fusion (thin arrow) and good reduction of the dens (thick arrow). **Fig. 1-I** Postoperative CT in the sagittal plane. The arrow points at the canal of the vertebral artery; the screw runs directly cranial to the canal. Perfect angulation of the screw and of the Kirschner wires is essential to avoid perforation of the artery.

Fig. 2
Stability testing. **Fig. 2-A** Initial displacement of $\geq 5\text{ mm}$ indicates instability. **Fig. 2-B** Initial displacement of $< 5\text{ mm}$ indicates stability. **Fig. 2-C** Initial angulation of $\geq 11^\circ$ indicates instability. **Fig. 2-D** Initial angulation of $< 11^\circ$ indicates stability. **Fig. 2-E** An initial fracture gap of $\geq 2\text{ mm}$ (arrow) indicates instability. **Fig. 2-F** An initial fracture gap of $< 2\text{ mm}$ (arrow) indicates stability.

Fig. 3
Sagittal flexion-extension cervical spine radiographs of two patients. The black lines indicate the center of the cranial and caudal fragments. Flexion (**Fig. 3-A**) and extension (**Fig. 3-B**) radiographs of a patient who sustained an unstable fracture: the center lines are separated by ≥ 2 mm. Flexion (**Fig. 3-C**) and extension (**Fig. 3-D**) radiographs of a patient who sustained a stable fracture: the center lines are separated by < 2 mm.

Fig. 4

An eighty-two-year-old patient with an unstable fracture type (Anderson and D'Alonzo type II⁹) and excessive thoracic kyphosis (**Fig. 4-F**). Transarticular fixation was performed. Adequate inclination of the Kirschner wire (and later of the screws) during placement was achieved. **Fig. 4-A** Intraoperative sagittal fluoroscopic view showing how C2 is flexed by a clamp (arrow shows direction of flexion) and the Kirschner wire is placed. **Fig. 4-B** Intraoperative sagittal fluoroscopic view showing how C2 is extended by a clamp (arrow shows direction of extension) after the Kirschner wire has been placed in the correct angle to restore the reposition of the dens. **Fig. 4-C** Intraoperative sagittal fluoroscopic view showing both Kirschner wires in the correct position. **Fig. 4-D** Both screws have been inserted. The arrow points to the Gallie fusion. **Fig. 4-E** Intraoperative photograph. **Fig. 4-F** Intraoperative photograph of the excessive thoracic kyphosis. The thin arrow points at a tape that pulls the patient's shoulder down to make the cervical spine visible in the intraoperative fluoroscopic sagittal plane. The thick arrow points at a pillow that supports the kyphotic thorax of the patient.