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HOW I DO IT

How I do it: cervical lateral mass screw fixation

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Abstract
Background Cervical lateral mass screw fixation is indicated for the treatment of cervical subaxial C3-C7 lesions associated with instability.
Method The authors first describe the surgical anatomy of the subaxial cervical posterior approach. Then the Magerl technique is detailed. In particular, tricks to avoid complications are presented. The ideal screw entry point, direction, size and exit point are mentioned. A surgical video, artist's drawings and a radiological case report are included.
Conclusion The Magerl technique is a safe and effective lateral mass fixation technique. Respecting anatomical landmarks is crucial to avoid nerve root, vertebral artery and facet joint injury.

Keywords Cervical instability · Lateral mass · Screw placement · Magerl technique

Relevant surgical anatomy

A standard posterior cervical approach is performed to expose lateral masses. Three different muscular layers are crossed. The first one is the trapezius muscle, which originates from the external occipital protuberance, the medial nuchal line and the C7 to D12 spinous processes; the trapezius muscle also inserts onto the upper body of the scapula, acromion and the lateral aspect of the clavicle. The intermediate layer includes the splenius capitis and splenius cervicis. The sacrospinalis muscle group (semispinalis cervicis, semispinalis capitis, semispinalis medially, longissimus cervicis and longissimus capitis centrally, then the ciliocostalis laterally) and the transversospinalis muscle group (semispinalis muscle, multifidus muscle and rotator muscle) represent the third deepest layer [2, 13, 14, 16].

The facet joint is composed of articular processes, the facet capsular ligament and intervening fibro-cartilage. The lateral mass area is the part lateral to the lamina and between the inferior borders of the adjacent inferior facets. The mean superoinferior length of the lateral mass ranges between 11 mm at C3 and 15 mm at C7, and the mean mediolateral distance ranges from 12 to 13 mm at C3 through C7. The isthmus is the part of the bone between the superior and inferior facet joint, the equivalent of the more evident region in the lumbar region [3, 4, 10, 14].

The spinal nerve exits the spinal canal through the interpedicular foramen. Laterally, it divides into a larger ventral ramus and a smaller dorsal ramus. The ventral ramus of the cervical spinal nerve courses on the transverse process in the anterolateral direction to form the cervical and the brachial plexus [4]. The mean distance from the posterior center of the lateral mass and the projections of the spinal nerves is about 5.6 mm [5]. On the axial plane, the spinal nerve is situated anteromedially to the anterior aspect of the superior facet.

The V2 segment of the vertebral artery goes from the sixth to the second cervical transverse foramen. On the

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axial plane, the vertebral artery lies in front of the lateral mass, but is separated by the spinal nerve. The vertebral artery is not at risk of injury as long as the screw is directed laterally to the sagittal plane [4].

Description of the technique

Posterior placement of lateral mass screws is a well-established and routine technique used in the fusion and stabilization of the subaxial cervical spine. The patient is placed in prone position with the chest elevated 15° to reduce venous bleeding and the neck in a neutral position to avoid fusion in rotation. The head is fixed into a three-pin Mayfield head-holder allowing strong immobilization during screw placement. The arc of Mayfield head holder should be perpendicular to the floor. The shoulders are stitched off with a tap in order to improve the visualization of the lower subaxial spine. Lateral fluoroscopy is performed to confirm the level.

After disinfection, a median skin incision is made. Muscular subperiosteal dissection is performed and self-retaining spreaders installed. The spinous processes, the laminae and the lateral masses are prepared. The lateral dissection is stopped as soon as the external border of the lateral mass is identified to avoid annoying bleeding [11, 12].

The lateral mass is considered to be split in four quadrants. A cross is marked with a monopolar coagulation, and the lateral mass center point is identified.

According to the Magerl technique [8], the entry point is 1 mm above and 1 mm medial to the center point (Fig. 1).

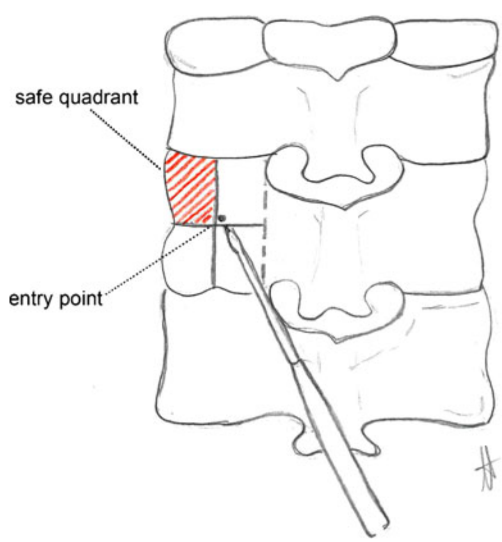

Fig. 1 Artist's drawing: the left lateral mass is identified; "the safe quadrant," the entry point and the drill direction are detailed. The drill is touching the spinous process of the vertebra below

A 2-mm high-speed drill is used to decorticate the bone at the entry point. Under fluoroscopic control, a manual 2.9-mm drill with an adjustable drill guide is then directed toward the so-called "safe quadrant," which is the supero-lateral one (Fig. 1). The direction is 20 to 30 degrees divergent from the midline (Fig. 2) and upwardly parallel to the superior facet joint (Fig. 3). A useful trick is to operate from the controlateral side and to touch the tip of the spinous process of the vertebra below with the drill (Fig. 1). The technical challenge is not to be too high, thus avoiding the facet joint, and also not to be too low, thus avoiding root injury. In this way, the tip of the screw at the exit point will be far enough from both the vertebral artery, which is more medial and anterior, and the exiting nerve root, which is more downward and anterior (Fig. 4). Normally both cortical bones of the lateral mass should be drilled in order to have better purchase. As demonstrated previously by Heller et al., bicortical purchase provides a greater pullout resistance for lateral mass screws with a gain of approximately 30% [6]. The breaching of the deep cortical bone can only be felt as a loss of resistance.

The surgeon can imagine the ventral perforation of the lateral mass on lateral fluoroscopy. The tip of the screw should never overpass the posterior fourth of the vertebral body [5].

Afterwards, a 3.5-mm tap is used, and a 4-mm-diameter polyaxial screw is inserted. The usual length is between 12 to 18 mm. The screws are then connected with rods. A head nut is then inserted and closed with a dynamometric tool.

Wound closure is accomplished by suturing the muscle layers in a multiple plan using resorbable stitches, and the skin is finally sutured.

Minimally invasive procedures through tubular retractors have also been described to achieve lateral mass fixation. In this way, muscular damage and postoperative pain can be drastically reduced [15].

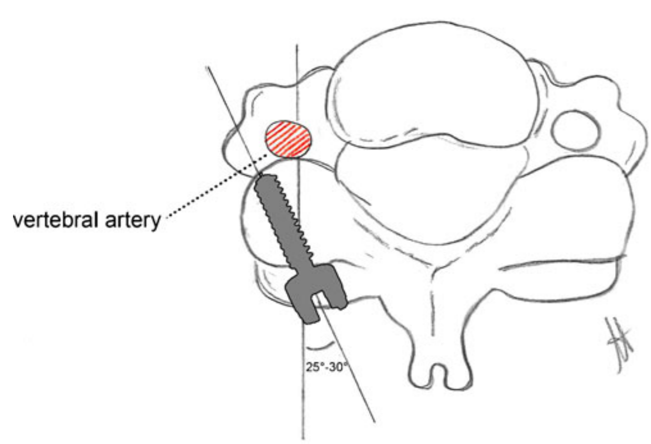

Fig. 2 Artist's drawing: axial view; the divergent direction of the screw is shown. The VA is more medial and anterior

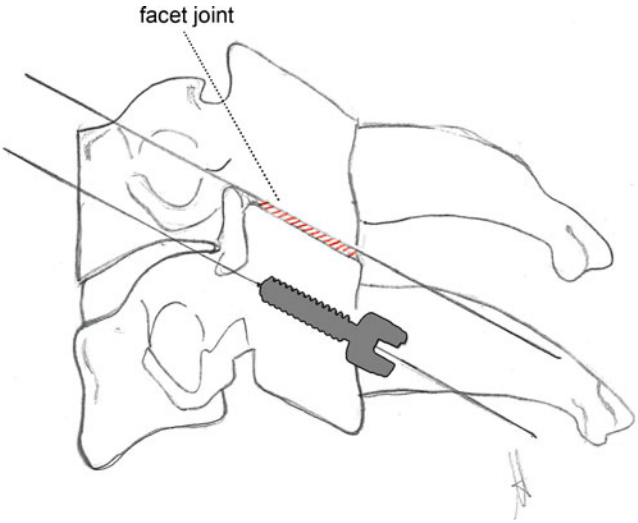

Fig. 3 Artist's drawing: lateral view; the screw trajectory is parallel to the superior facet joint

The C7 lateral mass is often too small and thin to accommodate a screw [1]. In those cases, the authors perform a pedicle screw technique. If the lateral mass is large enough, due to the obliquity of the screwing process, a skin incision should be carried out much lower than C7.

Indications

Lateral mass screw fixation is indicated for the treatment of cervical subaxial C3-C7 pathologies associated with instability. Main indications are:

1. Cervical stenosis with loss of lordosis or focal kyphosis
2. Cervical instability due to trauma, tumors or infections involving the posterior tension band
3. Cervical chronic instability due to degenerative lesions
4. Cervical deformity

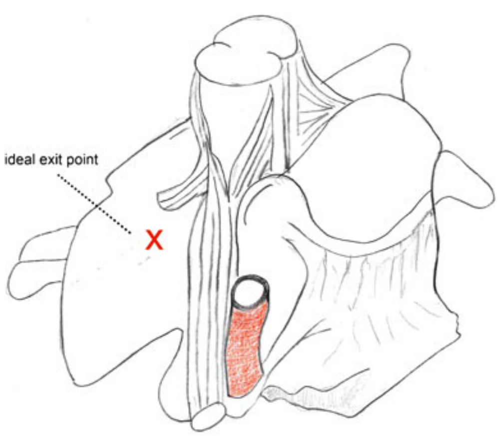

Fig. 4 Artist's drawing: oblique anterior view; the relationship among the screw exit point, the vertebral artery and the nerve root is shown

Limitations

This technique cannot be used in the following situations:

1. Fracture of the lateral mass.

   The presence of a lateral mass fracture is a contraindication to using this technique. In this case the surgeon should plan for an alternative cervical fixation technique (laminar hooks, laminar or pedicle screws). Cervical pedicle screw insertion is by far the stiffest technique for cervical fixation. This technique is considered difficult because of the pedicles' size and the proximity between the screw and the vertebral artery in its transverse foramen. This is why the use of neuronavigation systems is highly recommended [7]. The laminar hooks technique is dependent on the integrity of posterior elements and is not stiff enough in flexion and rotation. The laminar screws can be used as a rescue technique if the laminar thickness is large enough.
2. Relevant anterior column deficiency.

   Lateral mass screw fixation cannot be used alone for those cases in which the instability is mainly related to an anterior column deficiency. In this case an anterior complementary approach (cage/graft plus plating) should be added (Fig. 5a, b, c).
3. Previous posterior surgery affecting normal lateral mass integrity.

   Previous laminectomy with partial lateral mass resection can preclude the use of a lateral mass fixation. In such cases, the anatomical landmarks are distorted, and the bony surface may not be sufficient to accommodate a screw.

Furthermore, lateral mass screw fixation has been shown to be less stiff than the pedicle screw technique, with moderate resistance to withdrawal forces [9]. As a consequence, screwing a significant number of lateral masses is usually necessary to have good purchase.

How to avoid complications

1. Distorted anatomy:

   In elderly patients, the identification of the lateral mass anatomy and "safe quadrant" can be difficult because of the degenerative changes. Osteophytic spurs often cover the facet joints. In this case the surgeon should "create" the anatomy by resecting the spurs and by flattening the lateral mass with a high-speed drill.
2. Vertebral artery:

   If the screw is too long or the trajectory wrong, the vertebral artery can be damaged at its V2 segment. In order to avoid the artery, a good divergent direction

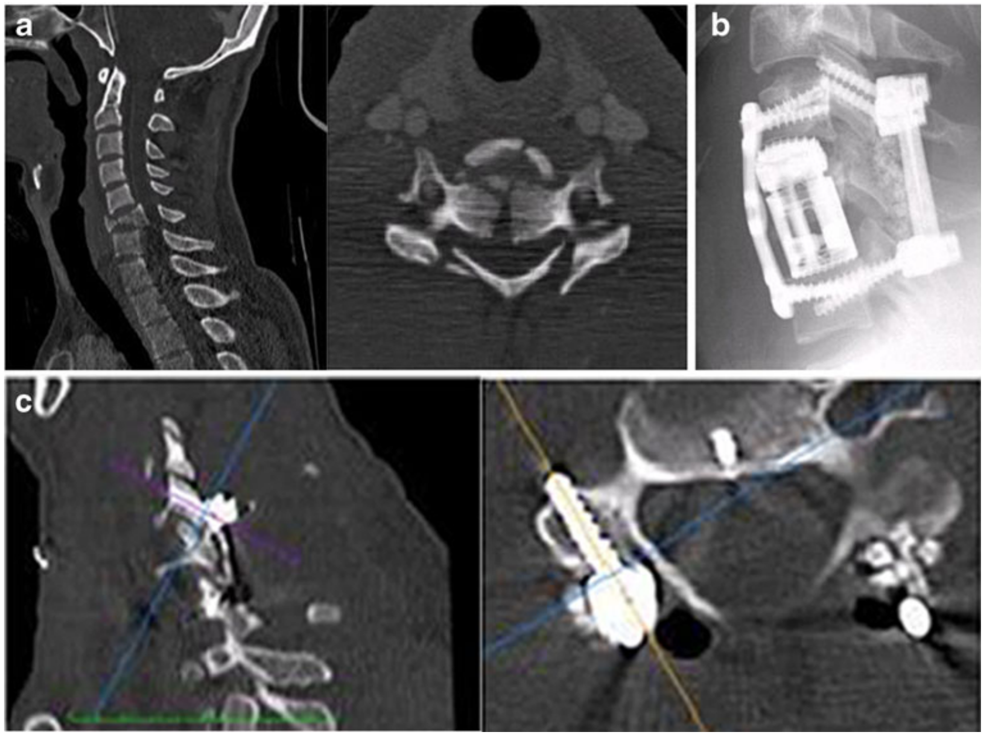

Fig. 5 Illustrative case (see video). **a** Preoperative CT scan showing a C6 burst fracture. **b** Postoperative x-ray showing screw placement and anterior stabilization. The inferior screws are C7 pedicle screws. **c** Postoperative CT on lateral and axial view showing screw placement

should be kept (about 25°) and the correct screw length chosen. If strong suspicion of VA damage exists, the surgeon should quickly insert the screw to stop bleeding, abandon the procedure and send the patient for an angiogram. If the damaged VA is the non-dominant one or is hypoplasic, the procedure can be continued, but the surgeon should change the strategy for the controlateral side (hooks or laminar screws).

3. Nerve root:

   The nerve root cannot be visualized during the screw insertion, so respecting the safe quadrant and choosing the right screw size are mandatory.

4. Facet joint:

   Respecting the facet joint is mandatory for keeping good segmental motion. The inserted screw should not enter into the articular rim; otherwise, the movement will be compromised. The surgeon should keep in mind the oblique direction of the facet joints. The right oblique direction can be checked by fluoroscopy.

Specific perioperative considerations

An appropriate radiological workup is necessary. Standard films are easily performed in any emergency center and available for a first evaluation of the cervical alignment. CT scans offer more accurate evaluation of bone integrity and can also detect some indirect signs of instability (disc rupture, increased interspinous distance, etc.). MRI is mandatory in the presence of a neurological deficit and in case of suspected disco-ligamentous injuries. If MRI results are equivocal or MRI contraindicated, a CT myelogram can be used.

During anesthesia induction, extension maneuvers should be avoided. Fiber optic intubation should always be implemented in case of cervical instability or severe stenosis. Motor-evoked potentials and/or sensory-evoked potentials can be an additional resource to avoid neurological impairment during induction and surgery. Neuronavigation can also be added as a useful tool to reduce the rate of screw misplacement.

In postoperative care, antibiotics are continued for 24 h. Patients are placed in a rigid Minerva collar to wear for 6 weeks after surgery. A postoperative CT scan is performed the day after surgery to check the screw's positioning. Patients usually stay in the hospital for up to 1 week. A physical therapist schedules daily sessions to help patients learn safe ways to move, dress and carry out activities without putting extra strain on the neck. Patients are able to return home when their medical condition is stable. However, they are usually required to keep their activities to a minimum. Outpatient physical therapy is usually started 4 to 6 weeks after the date of surgery. Upright AP and LL x-rays are used for the follow-up.

Specific information to give to the patient about surgery and potential risks

Patients should be informed and give their consent to surgery. The surgical procedure should be anticipated by the patient. The risks of the prone position (pressure points, shoulder stretching, etc.) should be mentioned. General risks of surgery are detailed (problem with anesthesia, infections, hematoma, thrombophlebitis, etc.). Specific potential risks associated with lateral mass screw fixation are: vascular injury (vertebral artery), spinal cord and nerve root injury, screw misplacement or failure, facet joint injury, and CSF leak.

Key points

- Lateral mass screw placement is a safe and effective fixation technique for cervical subaxial lesions associated with instability.
- The nerve root, vertebral artery and facet joints are in danger during this procedure.
- The Magerl technique, with the divergent and oblique trajectory of the screw, may reduce the risk for VA and nerve root injury.
- The “safe quadrant” should always be identified.
- Screw insertion should be performed under fluoroscopic guidance.
- Bicortical screw purchase is recommended.
- If distorted, anatomical landmarks should be restored.
- In case of VA injury, the procedure should be abandoned or an alternative technique chosen.
- Postoperative immobilization in a Minerva collar for 6 weeks is recommended.
- Upright AP and LL x-rays are used for the radiological follow-up.

Conflicts of interest None.

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